SPECIAL PUBLICATION 13

resource lignite analyses production sub-bituminous bituminous anthracite reserves geology

1979 Summary of COAL RESOURCES in Colorado

by D. Keith Murray

Colorado Geological Survey
Department of Natural Resources
Denver, Colorado / 1980

SELECTED COAL PUBLICATIONS OF THE COLORADO GEOLOGICAL SURVEY

BULLETINS

34-A--BIBLIOGRAPHY, COAL RESOURCES IN COLORADO, R.D. Holt, 1972, 32 p. Compilation of published and open-file reports through 1971. Includes subject and county-region indexes, $1.00.

41--BIBLIOGRAPHY AND INDEX OF PUBLICATIONS RELATED TO COAL IN COLORADO: 1972-77, H.B. Fender, D.C. Jones, and D.K. Murray, 1978, 54 p. Supplements but does not duplicate Bulletin 34-A. Contains 500 new references and Key Word Listing, $2.00.

INFORMATION SERIES

2--COAL MINES OF COLORADO, STATISTICAL DATA, D.C. Jones and D.K. Murray, 1976, 27 p., 4 tables. Mines, bed characteristics, production; chemical analyses, $3.00.

7--COLORADO COAL ANALYSES 1975. (ANALYSES OF 64 SAMPLES COLLECTED IN 1975), D.L. Boreck, D.C. Jones, D.K. Murray, J.E. Schultz, and D.C. Suek, 1977, 112 p., 23 figs., 11 tables. Tabulated whole-coal elemental compositions, oxide and trace-element analyses of ash, proximate and ultimate analyses, Btu values, forms of sulfur. Index maps, $3.00.

MAP SERIES

9--COAL RESOURCES AND DEVELOPMENT MAP OF COLORADO, D.C. Jones, J.E. Schultz, and D.K. Murray, 1978, (scale 1:500,000). Coal resources by depth and quality; estimates of original and remaining coal resources; Known Coal Resource Leasing Areas; active and abandoned mine locations; coal plants; railroad lines; proposed coal slurry routes, $4.00.

12--MAP OF LICENSED COAL MINES IN COLORADO, AS OF JUNE 1, 1978, S.M. Goolsby and N.B.S. Reade, 1978, (scale 1:1,000,000). Gives name, coal-bearing rock unit, coal bed name, thickness and rank, number of mine employees, 1977 production and cumulative production to 6/1/78, for all licensed mines as of June 1, 1978, $2.00.

RESOURCE SERIES

1--GEOLOGY OF ROCKY MOUNTAIN COAL--A SYMPOSIUM, 1976, D.K. Murray, ed., 1977, 175 p., 15 papers on stratigraphy, physical and chemical properties, analyses, petrology, resource evaluation, geophysics, $4.00.

3--COLORADO COAL DIRECTORY AND SOURCE BOOK, 1978, L.C. Dawson and D.K. Murray, 1978, 225 p. Status of coal mining and development in Colorado. Data on taxation, transportation, utilization, sales, and preparation. Lists coal companies and consultants, and all licensed and proposed coal mines, $6.00.

4--PROCEEDINGS OF THE SECOND SYMPOSIUM ON THE GEOLOGY OF ROCKY MOUNTAIN COAL - 1977, H.E. Hodgson, ed., 1978, 219 p. 14 papers on depositional environments, mine planning and development, geophysical and computer techniques, and coal petrography, $5.00.

5--COAL RESOURCES OF THE DENVER AND CHEYENNE BASINS, COLORADO, R.M. Kirkham and L.R. Ladwig, 1979, 70 p., 5 pl. Regional geology, structure and stratigraphy, mining history, mining areas, and details on the Laramie Formation coal and Denver Formation lignite beds, $7.00.

7--EVALUATION OF COKING COALS IN COLORADO, S.M. Goolsby, N.S. Reade, and D.K. Murray, 1979, 72 p., 3 pls. Coking-coal resources in Raton Mesa, San Juan, and Uinta regions, classifications, coal petrography, history, identified reserves, representative coal analyses, coal evaluation maps, references, $6.00.

OPEN FILE

78-8--LOCATION MAP OF DRILL HOLES USED FOR COAL EVALUATION IN THE DENVER AND CHEYENNE BASINS, COLORADO, R.M. Kirkham, 1978. Summary lithologic logs of the drill holes shown on this map are available on request. Map only, $3.00.

78-9--COAL MINES AND COAL ANALYSES OF THE DENVER AND CHEYENNE BASINS, COLORADO, R.M. Kirkham, 1978, $5.00.

79-1--COLORADO COAL RESERVE DEPLETION DATA AND COAL MINE SUMMARIES, D.L. Boreck and D.K. Murray, 1979, 65 p., appendix. Depletion of the reserve base by township, coal zone/coal bed, and thickness. Historical, geologic, and mining data compiled for 1667 recorded coal mines in Colorado. Report and index map, $4.00.

MISCELLANEOUS

BULLETIN 37--BIBLIOGRAPHY AND INDEX OF COLORADO GEOLOGY, 1875 TO 1975, American Geological Institute, 1976, 488 p., 3 figs. 12,000 citations of Colorado geology, cross-indexed by author, subject, county, and rock unit. Softbound 7.50; Hardbound 10.00

ENERGY RESOURCES MAP OF COLORADO--USGS and CGS, 1977, (scale 1:500,000). (USGS Misc. Geol. Inv. Map I-1039). Oil and gas fields, pipelines, thermal springs and Known Geothermal Resource Areas, oil shale, uranium districts and mines, coal resources and mines, power plants and transmission lines, $2.00.

GEOLOGIC MAP OF COLORADO--USGS, Ogden Tweto, 1979, (scale 1:500,000). This is the newly revised colored state geologic map, Over-the-counter or mailed folded, $4.00; Mailed rolled, $4.50.

MAKE CHECKS PAYABLE TO:

Colorado Geological Survey

MAIL TO:
Publications Department
Colorado Geological Survey
Room 715, 1313 Sherman Street
Denver, CO 80203
Telephone (303)-839-2611

MAILING CHARGES ON ALL ORDERS

up to $3.00	$ .50
$3.01 to $5.00	$1.00
$5.01 to $10.00	$1.50
$10.01 to $20.00	$2.00
$20.01 to $30.00	$2.50
$30.01 to $40.00	$3.00
$40.01 to $50.00	$3.50
$50.01 to $100.00	$5.00
over $100.00	5%

To order publications, specify series name and number, title, quantity desired, publication cost, and mailing charges. Order miscellaneous publications by title. Prepayment is required.

SPECIAL PUBLICATION NO. 13

1979 SUMMARY

OF

COAL RESOURCES IN COLORADO

BY

D. KEITH MURRAY

DOI: https://doi.org/10.58783/cgs.sp13.aeib1991

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

1980

PREFACE

This coal summary initially was prepared for the 1979 Keystone Coal Industry Manual, where it appears as the Colorado Chapter. It includes descriptive material concerning the geology of the coal fields and regions, together with analysis of the various coal seams or groups of coal seams.

This report precedes more detailed analysis of historical data, geology of coal fields and regions, and of the total coal resources of the state, currently under investigation and study by the Colorado Geological Survey and to be published at a later date. This summary report, therefore, should serve a present need in providing information on the coal resources of the state not otherwise available.

This 1979 summary, prepared by D. Keith Murray*, is an extensive revision and up-date of the Colorado Geological Survey Special Publication No. 9. Although the basic format of S.P. No. 9 has been followed, there have been numerous areas of expansion, i.e., coal rank, coking coal, production, and the inclusion of stratigraphic columns for each coal region and field. Other new items include sections on transportation, state coal lands, state and county taxation of coal, federal coal lands, and import export data.

ACKNOWLEDGEMENTS

Assisting D. Keith Murray in this revision were the staff of the Colorado Geological Survey, Colorado Division of Mines, and others.

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

L. R. Ladwig
Chief-Mineral Fuels Section

*Then employed by the Colorado Geological Survey

TABLE OF CONTENTS

FIGURES

PAGE

TABLES

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 million tons of the total 1978 state-wide coal production of 14.3 million tons. Projections for Colorado coal production through 1985 is in the order of 32.2 million tons per year.

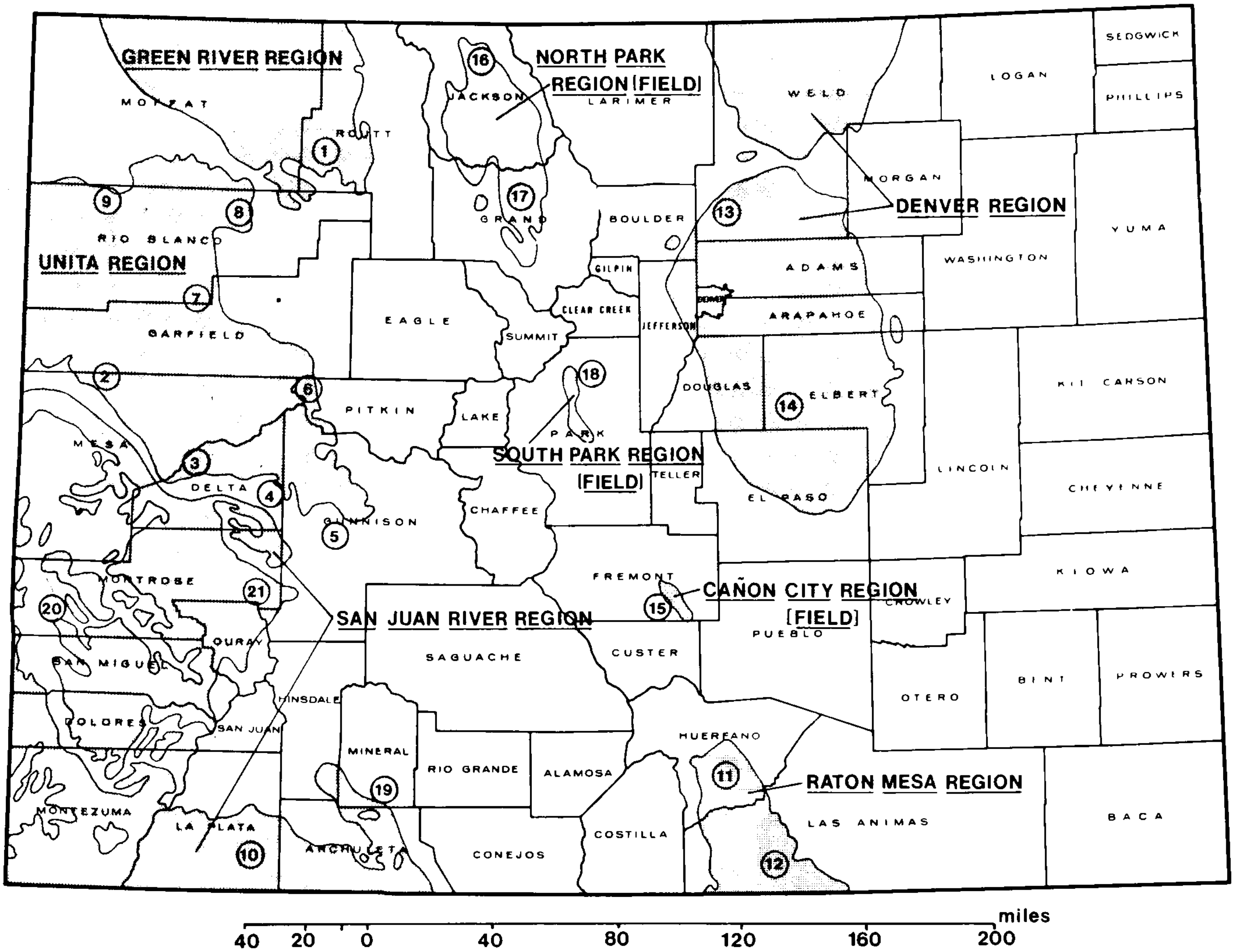

Figure 1. Coal-bearing regions and fields in Colorado.

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

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.

Prepared by D. Keith Murray, Chief, Mineral Fuels Section, Colorado Geological Survey, Denver, January 1979.

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

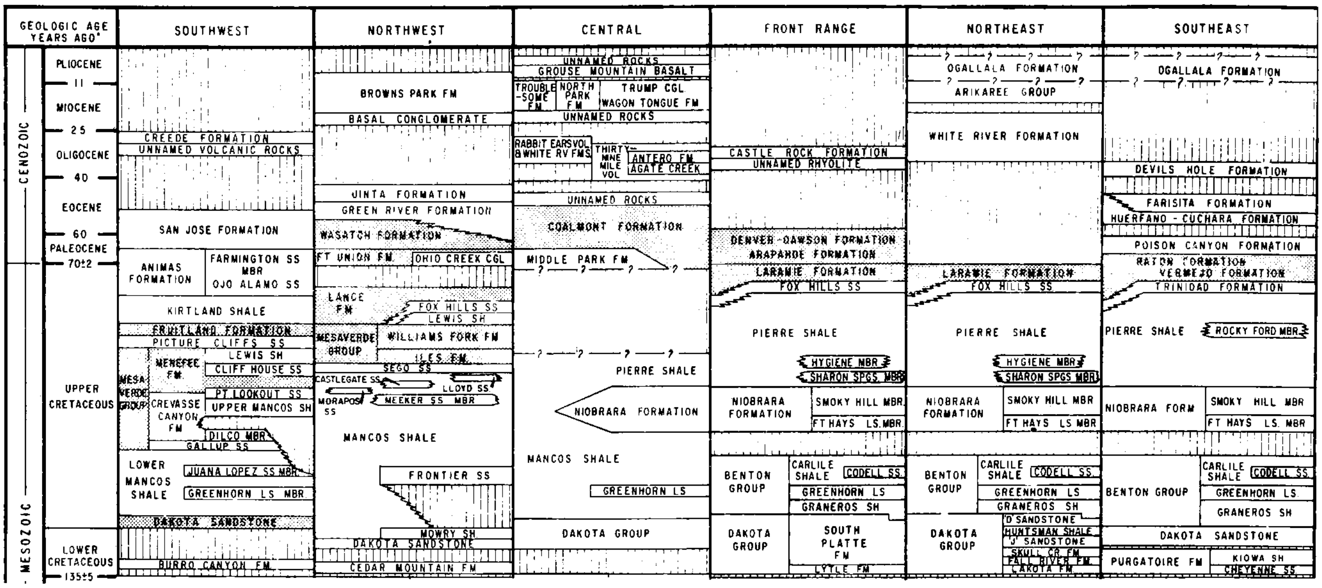

Figure 2. Colorado stratigraphic correlation chart, parts of Mesozoic and Cenozoic Periods. Coal-bearing units are shaded. (from Pearl, R.H., and Murray, D.K., 1974, Colorado Stratigraphic Correlation Chart: Colorado Geol. Survey, 1 plate).

curring in the Mesaverde Group (Upper Cretaceous). The marine-influenced (paralic) Cretaceous coals, related to 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.

Since 1864, over 632 million short tons of coal have been mined in Colorado, which is approximately one year's current output of the entire United States. Based on preliminary data, total coal production in Colorado during 1978 amounted to over 14 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. Colorado's 1978 production came from approximately 65 licensed coal mines (of which only 44 actually produced coal during the month of November). Nearly 70 percent of the coal mined in the State during 1978 came from surface mines. On the basis of plans announced by industry, and barring undue adverse impact of proposed EPA sulfur dioxide emissions regulations on Colorado's low-sulfur coal, the State's coal output should exceed 20 million tons per year by 1980.

The low sulfur, ash, and moisture content, together with generally high heating values, of the typical coals of this State are resulting in increasing demand for both steam-quality and metallurgical-grade coals. Bituminous coal comprised 94 percent of Colorado's 1978 production; the balance was subbituminous in rank (mainly subbituminous A). Approximately 20 percent of the coal presently mined in the State is used for metallurgical purposes. Two-thirds 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 our coal resources occur either on private or State-owned lands, assure a bright future for the coal industry in Colorado.

Coal-Bearing Regions

The coal resources of Colorado occur entirely within the Rocky Mountain coal province. The eight named coal-bearing regions and 20 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 trom 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. An overall average of about 12 percent moisture is considered reasonable for Colorado coals. Statewide, volatile matter content varies 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 precent 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 1978 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; Schultz, 1979) indicates that organic sulfur usually predominates, followed by pyritic sulfur and sulfate, at least insofar as the coal fields sampled to date are concerned. 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 combusion effluents.

Washability

During 1977, only 10.2 percent (or 1.2 million tons) of the coal mined in Colorado was washed; and only 0.1 percent (15,157 tons) was chemically treated or oiled (Table 6). 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 phrase of this program have been published (Boreck and others, 1977), and additional results will be published by the Colorado Geological Survey during 1979 (Schultz, 1979) and succeeding years. 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 (year 1975) of our coal sampling program (*from* Boreck and others, 1977, Table 10).

Although many of the analytical results of our sampling programs conducted during 1976, 1977, and 1978 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, and Heating Value Analyses for Fields (Boreck and Others, 1977, Table 10).

	Green River Region— Yampa Field	*North Park Field*	*Rocky Mountain Province*	*Interior Province*	*Northern Great Plains Province*
Moisture (%)	8.0	14.9	12.9	7.2	24.5
Volatile Matter (%)	37.4	35.0	36.0	32.2	31.7
Fixed Carbon (%)	45.9	41.5	42.0	48.0	35.4
Ash (%)	9.0	8.6	9.1	12.6	8.3
Hydrogen (%)	5.4	5.7	5.6	4.9	6.2
Carbon (%)	63.9	57.1	59.7	65.2	49.2
Nitrogen (%)	1.6	0.8	1.2	1.2	0.9
Oxygen (%)	19.8	27.3	23.8	12.2	34.2
Sulfur (%)	0.5	0.4	0.6	3.9	1.2
Heat Value (Btu/lb.)	11,203	9,930	10,480	11,580	8,480

Coking Coal

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 (Fig. 1).

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. Some of the coking coal produced in Colorado, New Mexico, and Utah is shipped eastward to be used in tempering coking-coal blends in some of the Eastern steel mills. 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

Table 2. Currently Producing Coking Coal Mines in Colorado (Jones and Murray, 1977).

Mine Name	*County*	*Production (short tons)* 1976	1977	*Overburden Thickness (feet)*
Bear	Gunnison	109,226	226,221	1200
Hawk's Nest East (#2)	Gunnison	26,787	190,350	1600
Hawk's Nest West (#3)	Gunnison	155,732	12,363	1600-2000
Somerset	Gunnison	950,156	914,552	200-2000
Allen	Las Animas	618,867	582,257	400-1100
Maxwell (New)	Las Animas	0	31,815	400-1400
Coal Basin	Pitkin	108,874	123,182	1000-3000
Bear Creek	Pitkin	115,547	58,352	1000-3000
Dutch Creek #1	Pitkin	132,408	232,481	1000-2500
Dutch Creek #2	Pitkin	268,902	208,142	1000-3000
L.S. Wood	Pitkin	263,109	298,405	1000-3000
Thompson Creek #1(New)	Pitkin	530	7,455	400-1300
Thompson Creek #3 (New)	Pitkin	150	8,413	400-1300
	Total	2,749,988	2,893,988	

Pueblo, Colorado steel mill. Likewise, U.S. Steel transports coal from its Somerset mine, in Gunnison County, to its 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 need to be considered. 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 tend to hinder 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).

According to Jones and Murray (1977), the total production represented by these mines, all of which presently are mining beneath more than 1,000 ft. of overburden, amounts to 29 percent of the State's total 1976 coal production of 9,461,513 tons. Over 32 percent of the deep-mined coking coal (or 888,840 tons), which represents approximately 9 percent of the total coal production of the State in 1976, came from mines working beneath from 2,000 to nearly 3,000 ft. of overburden. It should be noted that the 1977 production figure no doubt would have been somewhat higher had there not been a labor strike in some of the larger mines in late 1977-early 1978.

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 1976, railroads were used to ship 8 million tons of Colorado coal, 45.5 percent of which was shipped out-of-state. A large part of the tonnage that was shipped by rail —5.56 million short tons—was initially trucked to the railhead. Trucks were used exclusively for transporting approximately 1.5 million tons of coal, all of which was for in-State consumption by homes, businesses, institutions, and utilities (Dawson and Murray, 1978).

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 that railroads of Colorado and the routes and directions travelled by coal trains in the State.

Contracts for future coal production reveal that approximately 2 million tons will be transported by truck and as much as 13.9 million tons by rail in Colorado possibly as early as 1985. Based on these figures, the use of truck transportation will increase 33 percent, and rail use will increase 74 percent between 1976 and 1985 (Dawson and Murray, 1978).

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 1978, approximately 145-150 State coal leases were in force, totalling some 282,000 acres (224,187 acres in FL 1976-1977).

From 1908 to July 1, 1977, over 22.5 million short tons of coal were produced from State lands. During FY 1976-1977, 868,678 short tons of coal were produced from State lands (Colorado State Board of Land Commissioners, 1978, p. 14); and both production and income received from State coal leases are expected to be significantly higher when the FY 1977-1978 statistics are compiled. From 1908 to July 1, 1977, more than $4.6 million in royalties, rentals, and bonuses has been paid to the

State Land Board by coal lessees.

During FY 1976-1977, $320,009 in cash receipts was received by the State Land Board—$145,570 from annual rentals of coal leases and $175,439 in royalties from coal production (no lease bonus money was received that year). Of the rentals, $142,238 was allocated to the Public School Income Fund, and $3,332 to the Colorado State University Income Fund; all of the coal royalties went to the Public School Permanent Fund (Colorado State Board of Land Commissioners, 1978).

Table 3 shows that income to the School Permanent Fund increased approximately 650 percent during the 1977-78 period. Coal rentals received during the same period are nearly twice the amount collected in the previous year. These coal rental receipts are allocated to the School Income Fund.

Table 3. Colorado State Board of Land Commissioners' Receipts From Coal Leases, May 1978.

	July 1, 1976 to May 31, 1977	*July 1, 1977 to May 31, 1978*
SCHOOL PERMANENT FUND		
Coal Production Royalties	$114,460.24	$755,533.03
SCHOOL INCOME FUND		
Coal Lease Rentals	128,011.50	231,234.79

State and County Taxation of Coal

"The Severance Tax will be levied against mining operations . . . (including coal) to Colorado effective January 1, 1978."

The 1977 Severance Tax Act, H. B. 1076, was enacted by the Colorado General Assembly to serve two purposes: (1) to recover a portion of the State's mineral wealth lost by the removal of non-renewable natural resources, and (2) to provide a potential source of revenues necessary to assist State and local governments in mitigating the impact of resource development.

An incentive for underground coal mining is built into the new severance tax by crediting underground mines for 50 percent of the tax. In essence, therefore, underground production is taxed at a rate of only $0.30 per ton, while surface mined coal is taxed at a rate of $0.60 per ton. No tax is levied on the first 8,000 tons produced per quarter.

The revenues from the coal severance tax will be divided among three separate State collections: The General Fund, the Local Government Fund, and the State Trust Fund. Through 1981, 45 percent of the revenue is designated for the Local Government Fund; the initial 45 percent designated for the General Fund will *decrease* to 20 percent by 1981, while the initial 15 percent designated to the State Trust Fund will *increase to* 35 percent by 1981.

It is estimated that Colorado will receive between $5 and $6 million from severance taxes imposed upon coal production during calendar year 1978.

Ad valorem taxes, a Colorado property tax that each county directly collects, is based by statute on assessed valuations. These valuations generally amount to 30 percent of the *actual market value* of real and personal property remaining in possession at the conclusion of the business year; in other words, valuations for 1976 coal production and coal company property or improvements are based upon the remaining resources or property as of January 1, 1977. If actual value is not determinable, the base is supposed to be what the property will bring at a fair voluntary sale.

Proceeds from ad valorem taxes are used to cover the costs of city, town, and county governments and the costs of school districts (fire, water, sanitation, etc.).

The Statewide coal-related valuation total of $32,161,770 for 1977 represents more than a 60 percent increase over the total 1976 valuation of $19,508,390.

The 1976 Statewide assessed valuation of coal land and real property, taxed at a representative levy for a rural county of 66 mills, indicates a total income from ad valorem taxes of nearly $1.29 million. The 1977 assessed valuation of $32.16 million, taxed at the same mill levy, would have resulted in ad valorem tax revenues paid by the coal industry to 15 coal-producing counties of over $2.12 million (Dawson and Murray, 1978).

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.

Twenty-two mines licensed in 1977, with planned recovery of over 500 million short tons, are either partially or entirely on Federal lands. Three test sites involving large leasholds are totally on Federal lands; however, no production or reserve estimates are available for these tracts.

State of Colorado's Share of Federal Coal Lease Revenues

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 to date has received the revenues shown on Table 4 (Dawson and Murray, 1978, p. 44).

Table 4. Colorado's Share of Federal Coal Lease Revenues (Dawson and Murray, 1978, p. 44).

	FY 1975	*Calendar Year 1976*	*Calendar Year 1977*
Colorado Fed. tonnage	—	2,652,092 ST*	4,021,197 ST
(Surface)	—	(1,942,505 ST)	(2,761,978 ST
(Underground)	—	(709,587 ST)	(1,259,219 ST)
Colorado revenues[1]	$158,957	$387,770	$422,542
(Surface)	—	($318,387)	($281,574)
(Underground)	—	($ 69,382)	($140,968)

* Short tons. [1] Federal royalties allocated to the State.

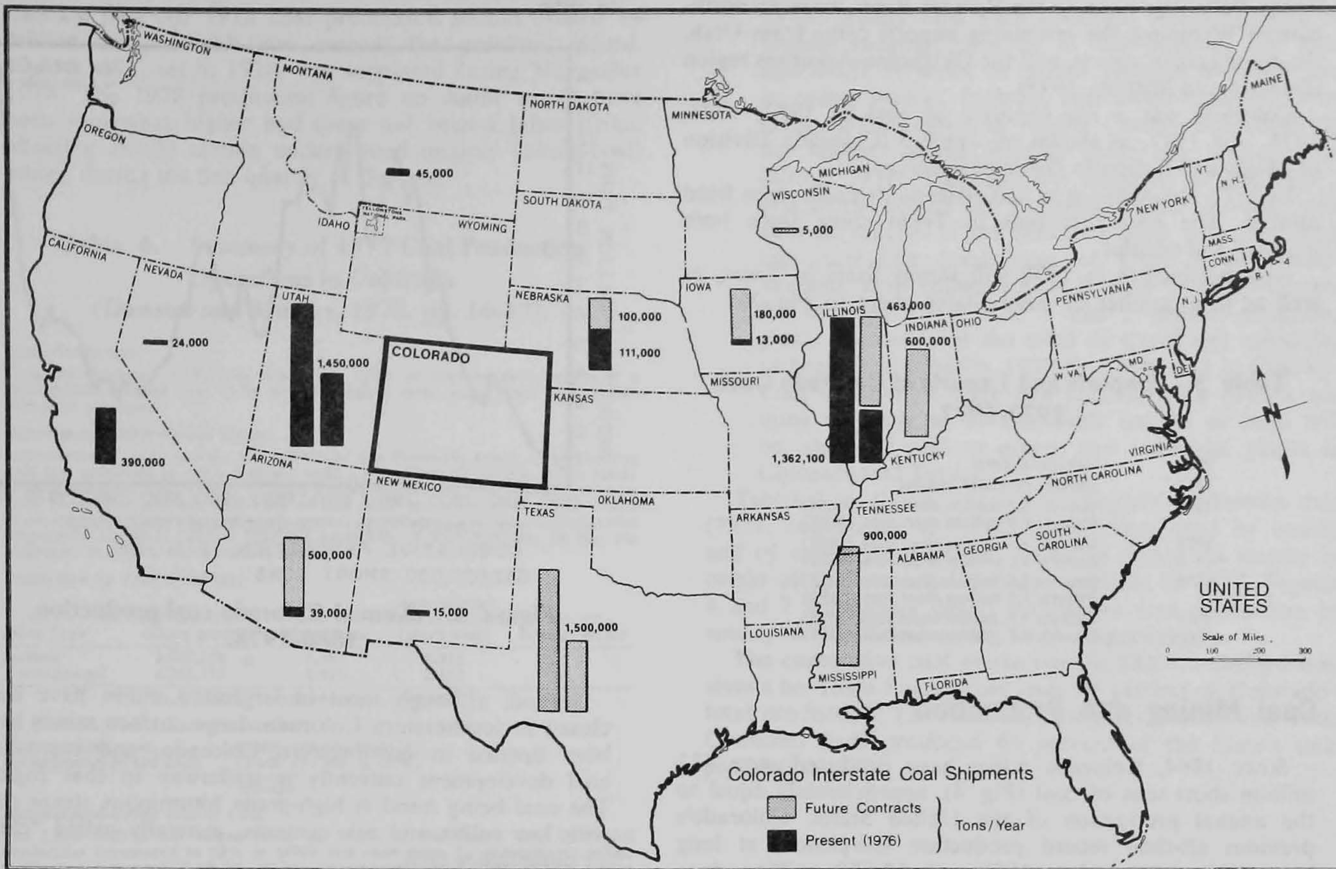

Figure. 3. Colorado interstate coal shipments, present (1976) and future contracts (Dawson and Murray, 1978, p. 77).

Royalty rates applied to coal production have increased over the years. According to the U.S. Geological Survey (1977), the 1976 Federal revenue was collected at an average rate of 22 cents/ton, or 3.2 percent of the nationally averaged F.O.B. mine price of $6.82 per ton. Coal produced from Federal land in Colorado, however, was assessed at an average of 15-17.5 cents per ton, based on an average F.O.B. mine price of $15.26 per ton. The Federal government collected a total of $1,034,053 in 1976, from which Colorado was allocated 37.5 percent, or $387,770. The State's revenue was then allocated to public schools (25%), conservation (10%), the socioeconomic impact fund (15%), and the counties from which the coal had been mined (50%), as mandated by legislation.

The Federal Coal Leasing Amendment Act of 1975, Rev. 1976 (FCLAA of 1975, Rev. 1976) changes the rate for royalties, allowing a very significant increase in revenues on any leases issued thereafter. Effective January 1, 1977, royalties are collectable at the minimum rate of 8 percent of the value of underground-mined coal and 12.5 percent of the value of surface-mined coal; the value of the coal is to be determined for each mine. The States' share of these revenues was also changed; instead of receiving 37.5 percent of the revenues, the States now receive 50 percent. The additional 12.5 percent turned over to the States has been designated by law to be placed in facilities and services planning, construction, and maintenance as needed by growth-impacted communities. The revenues shown above for Colorado in 1977 reflect only the increase in the State's share and not the increase in royalty rates, because no new Federal leases were issued in 1977.

Coal Prices

According to the U.S. Bureau of Mines (1977b), the coal produced in Colorado during 1976 was valued at over $144 million, assuming an F.O.B. mine price of $15.26/ton (the assumed price for 1977 was $16.22). However, 1976 price estimates that are more specific to the type of coal mined are as follows:

steam/stoker—$12-$18/ton

lump —$15-$25/ton

metallurgical—$20-$40/ton (or more)

Metallurgical coal has specific qualities that render it vital to the steel processing industry. Its coking qualities, together with the fact that it is mined underground, boost the price of such coal to as much as $40 (or more) per ton. According to reliable sources, the cost of mining coking coal in Colorado can be $20/ton or higher.

Imports and Exports of Colorado Coal

The 4.7 million tons of coal that were shipped out-of-State in 1977 represent an increase of 31 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 3.5 million tons. The imported coal was used by eastern Colorado electric power generating plants (e.g., in

Pueblo). About 89 percent of the imports came from the Amax Belle Ayr mine in the Powder River basin of northeastern Wyoming; the remaining imports came from Utah, the Appalachian region, and the Oklahoma-Arkansas region (Dawson and Murray, 1978).

Colorado was a net exporter of coal in 1973, 1974, 1975, and 1977, as shown on Table 5 (Colorado Division of Mines and Colorado Geological Survey).

In 1977, the Mississippi and Arizona demand came from utilities. The large demands in Texas came from both industry and utilities.

New production in 1978 will supply users in Texas, as well as in a number of other States (refer to Fig. 3).

Table 5. Imports and Exports of Colorado Coal, 1973-1977.

Year	*Imports/Exports*
1973	Imports exceeded exports
1974	Imports 2.7 million short tons (MST) Exports 2.9 million short tons (MST)
1975	Imports 2.5 million short tons (MST) Exports 2.6 million short tons (MST)
1976	Imports 3.6 million short tons (MST) Exports 3.6 million short tons (MST)
1977	Imports 3.5 million short tons (MST) Exports 4.7 million short tons (MST)

Coal Mining and Production

Since 1864, Colorado mines have produced over 632 million short tons of coal (Fig. 4), approximately equal to the annual production of the United States. Colorado's previous all-time record production (surpassed, at long last, 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.

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 250 percent—since 1971, as shown by the following tabulation (Colorado Division of Mines, 1978):

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	14.3 MST	(19.5% increase) (preliminary)

The Statewide increase in production since the 1960's has been due to several factors: First, since U.S. Steel's purchase of the Somerset Mine, in Gunnison County, and their contracts with other coking coal mines (e.g., those in Pitkin County), underground mining of coking coal in Colorado has increased significantly. The Dutch Creek coking coal mines in Pitkin County re-opened in 1956; and the L.S. Wood mine, also in Pitkin County, opened in 1966.

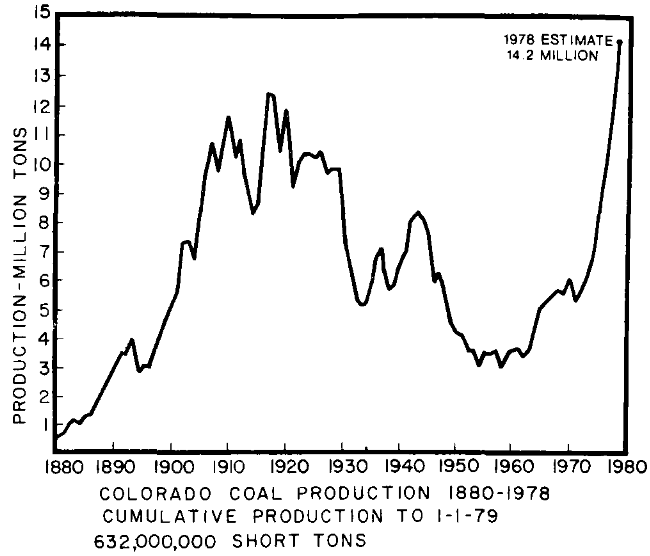

Figure 4. Annual Colorado coal production, 1880-1978.

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 mind 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 the Orchard Valley mine, located in Delta County, by Colorado Westmoreland, as well as of other mines in the Uinta region. This coal region (located in Delta, Garfield, Gunnison, Mesa, Pitkin, and Rio Blanco Counties) is projected to produce over 3.2 million tons in 1978, and to reach 6.5 million tons sometime between 1980 and 1982.

The Green River region produced over 9 million tons of coal during 1978 and is projected to produce nearly 11.5 million tons per year by 1980. Most of this coal is used to generate steam for electric-generation plants. 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 nearly 12 million tons of coal produced in Colorado in 1977 was worth an estimated $194.2 million dollars, assuming an average price of $16.22/short ton (U.S. Bureau of Mines, 1978). This value represents over 14 percent of the value of the State's total mineral production during 1977, which set an all-time record of more than $1.3 billion.

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 23 surface mines have been licensed to operate in Colorado. To date, over 56 million tons of coal have been produced by surface-mining methods in Colorado, which is approximately 9 percent of the State's cumulative production.

Colorado's 1977 coal production amounted to 11.971 million short tons (MST), an increase over 1976 of 27 percent and the highest since 1920, when 12.515 MST were produced. Table 6 summarizes Colorado coal industry operations during 1977.

Preliminary data from the Colorado Division of Mines indicate that our 1978 coal production should exceed 14 million tons, an all-time record; the previous record, 12.658 MST, set in 1918, was surpassed during November 1978. The 1978 production figure no doubt would have been somewhat higher had there not been a labor strike, affecting chiefly certain underground (mainly coking-coal) mines, during the first quarter of the year.

Table 6. Summary of 1977 Coal Production Operations in Colorado (Dawson and Murray, 1978, pp. 16-17).

Total Production

Colorado produced 11,971,143 short tons (ST) of coal in 1977, which is a 26.5 percent increase over 1976, and the highest since 1920, when 12.5 million tons were produced.

Bituminous/Subbituminous Output

Approximately 10.82 million ST (90.4% of the Statewide total) of bituminous coal was produced in 1977, together with 1.15 million ST (9.6% of the total) of subbituminous coal (about 52% of the subbituminous coal production came from mines that produce coal only of this rank; the balance was from mines in northwestern Colorado that produce coal of both ranks in some undesignated proportion; we have assumed that this proportion is approximately 50:50). No anthracite or lignite was produced during 1977.

Production by Type of Mining

Mine Type	*1977 Prod'n. (short tons)*	*No. of Employees*	*Ave. Annual Prod'n./Miner. (short tons)*	*No. of Prod'g. Mines*
Surface	7,727,768	1,307	5,912	21
Underground	4,243,375	1,637	2,592	34
	11,971,143	2,944	4,066	55

As Percent of Total State Production

Surface-mined coal: 64.6% (64.4% in 1976)
Underground-mined coal: 35.4% (35.6% in 1976)
100.0%

Metallurgical-Grade Coking Coal

The 2.894 million S.T. mined made up 24.2% of the State's total 1977 coal production (compared to 29% in 1976) and came from 13 underground mines. Coking coal comprised 68.2% of all underground-mined coal in 1977, down from 82% in 1976; however, production of this grade of coal in 1977 increased 5% over that produced in 1976.

Geographic Distribution of Coal Mines

Western Colorado: 11,033,056 ST (92.2% of total)
Eastern Colorado: 938,087 ST (7.8% of total)

Total Mines Licensed During 1977

Underground: 47 (34 produced coal)
Surface: 21 (21 produced coal)
Total 68 (55 produced coal)

Average Number of Days Worked Per Mine: 169

Average Daily Production
By mine: 70,835 S.T.
Per miner: 24 S.T.

Loading Methods: 97.7% of the coal produced in 1977 was mechanically loaded, using 27 loading machines.

Mining Machinery: 65 continuous miners and 8 electrical cutting machines were employed.

Rail Connections: 21 mines (38% of those that produced coal during 1977) had direct rail connections.

Coal Treated

Washed: 1,221,555 S.T. (10.2% of total produced)

Chemically treated or oiled: 15,157 S.T. (0.1% of total produced).

As of December 1, 1978, the following satistics are available for Colorado's coal operations:

Number of employees—3,910 (vs. 3,290 during November 1977)

Number of mines—65 lincensed (vs. 69 in 1977); 42 underground and 23 surface (of which a total of 44 currently are producing)

Surface-mined coal—9.62 million short tons (MST), estimated, or approximately 67 percent of the total 1975 Statewide production.

Coking coal—2.69 MST, estimated (a decrease of approximately 12% from 1977, primarily due to a labor strike early in 1978 that affected mainly the coking-coal mines); this comprises about 19 percent of all coal produced in the State.

Rank by county: Gunnison 45%, Pitkin 34%, Las Animas 21%.

Rank by coal region: Uinta, 79%; Raton Mesa, 21%.

Counties with significant production increases during 1978: among nine such counties, which showed increases ranging from 34 to 700 percent, the most significant in terms of actual tonnage increases are, in order, Moffat, Jackson, and Delta Counties. New large surface mines in Moffat County accounted for the largest volume increase (over one million tons) during 1978. This country currently is the No. 2 producing county in Colorado (after Routt), with over 22 percent of the Statewide total, primarily from the increasing production of Utah International's Trapper strip mine (which is now stockpiling coal for the new Craig Nos. 1 and 2 electric-generating plants, located near the town of Craig and scheduled to begin operations in 1979 or 1980), and at Colowyo Coal Company's large new surface mine (which will mine as many as 10 coal beds and is, or soon will be, shipping coal to power and industrial plants in Colorado and Texas).

Tables 7, 8, 9, 10, 11, and 12 display production data (1977, cumulative to 1-1-78, projections, etc.) by county and by coal-bearing region. Table 13 shows the county of origin of coal exported outside Colorado in 1977. Figures 6 and 7 graphically depict cumulative coal production by county to 1-1-78 and during 1977, respectively.

The cumulative coal production of 568.051 million tons shown on Table 8 comprises over 93 percent of Colorado's total production. Las Animas, Huerfano, Routt, and Weld Countries have produced 65 percent of the State's total production.

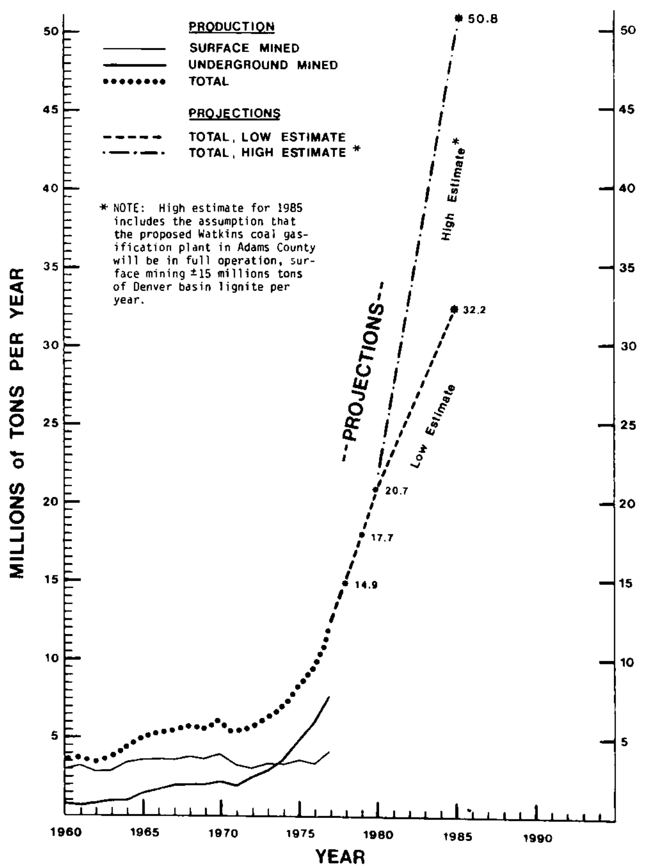

Figure 5. Production history and projections for Colorado coal production, 1960-1985 (Dawson and Murray, 1978, p. 12).

Table 7. 1977 Coal Production in Colorado by County (Dawson and Murray, 1978, p. 19).

County	*Production (S.T.)*	*% of Total*	*No. of Employees*	*No. Mines Prod'g. (Surface/ Underground)*
Routt	6,309,173	52.70	471	8(6/2)
Gunnison	1,347,182	11.25	454	5(0/5)
Moffat	1,113,015	9.30	450	5(3/2)
Pitkin	936,430	7.82	456	7(0/7)
Las Animas	742,315	6.20	530	5(3/2)
Jackson	495,956	4.14	97	2(2/0)
Delta	327,352	2.73	136	4(1/3)
Mesa	300,199	2.51	116	1(0/1)
Weld	105,103	0.88	62	1(0/1)
Montrose	94,402	0.79	24	1(1/0)
Fremont	90,669	0.76	44	6(4/2)
Garfield	70,793	0.59	66	5(0/5)
La Plata	25,648	0.21	23	3(0/3)
Rio Blanco	8,836	0.07	10	1(0/1)
Archuleta	4,070	0.03	5	1(1/0)
	11,971,143	99.98	2,944	55(21/34)

(1976 production: 9,461,513 S.T.)

Table 8. Cumulative Coal Production, Top 10 Counties, January 1, 1978 (Dawson and Murray, 1978, p. 19). (Millions of Tons)

1.	Las Animas	173.348
2.	Routt	77.961
3.	Huerfano	75.525
4.	Weld	66.956
5.	Gunnison	48.255
6.	Boulder	43.321
7.	Fremont	40.387
8.	Pitkin	18.839
9.	El Paso	15.209
10.	Moffat	8.250
	TOTAL	568.051

Table 9. Cumulative Coal Production (Short Tons) by County, 1864 to January 1, 1978 (Dawson and Murray, 1978, p. 18)

County	*1976 Prod.*	*1977 Prod.*	*Cum. to 1-1-78*
Adams			37,112
Arapahoe			36,259
Archuleta		4,070	40,620
Boulder			43,321,306
Delta	14,023	327,352	4,972,927
Dolores			62,631
Douglas			27,367
Elbert			108,948
El Paso			15,208,890
Fremont	90,956	90,669	40,386,525
Garfield	1,425	70,793	7,049,672
Gunnison	1,246,723	1,347,192	48,255,414
Huerfano			75,525,388
Jackson	270,085	495,956	2,975,121
Jefferson			6,697,939
La Plata	16,870	25,648	6,509,871
Larimer			54,284
Las Animas	649,468	742,315	173,348,315
Mesa	57,134	300,199	7,549,626
Moffat	507,010	1,113,015	8,250,293
Montezuma			174,515
Montrose	97,939	94,402	1,975,103
Ouray			14,216
Park			724,658
Pitkin	889,520	936,430	18,838,755
Rio Blanco		8,836	632,235
Routt	5,553,486	6,309,173	77,960,812
San Miguel			26,429
Weld	66,874	105,103	66,956,394
TOTAL	9,461,513	11,971,143	607,721,625

Table 10. Cumulative Colorado Coal Production by Coal Region to January 1, 1978 (Dawson and Murray, 1978, p. 8). (Millions of Tons)

Rank	*Coal Region (County) Production (% of State Total)*
1	RATON MESA (Huerfano & Las Animas Cos.): 248.873 (40.9%)
2	DENVER (Adams, Arapahoe, Boulder, Douglas, Elbert, El Paso, Jefferson, Larimer and Weld Cos.): 132.447 (21.8%)
3	UINTA (Delta, Garfield, Gunnison, Mesa, Pitkin, and Rio Blanco Cos.): 87.299 (14.4%)
4	GREEN RIVER (Moffat and Routt Cos.): 86.211 (14.2%)
5	CANON CITY (Fremont Co.): 40.387 (6.6%)
6	SAN JUAN RIVER (Archuleta, Dolores, La Plata, Montezuma, Montrose, Ouray, and San Miguel Cos.): 8.804 (1.4%)
7	NORTH PARK (Jackson Co.): 2.975 (0.5%)
8	SOUTH PARK (Park Co.): 0.725 (0.1%)
	TOTAL = 607.721 (100%)

Colorado Division of Mines county records show a total as of 1-1-78 of 618.035 MST, a difference of 10.314 MST).

Table 11. 1977 Colorado Coal Production (Short Tons) by Coal Region (Dawson and Murray, 1978, p. 8).

Coal Region	*Production*	*% of Total*	*No. of Employees*	*No. of Mines*	*No. Surface/ No. Under-ground*
Green River	7,422,188	62.0	921	13	9/4
Uinta	2,990,792	25.0	1,238	23	1/22
Raton Mesa	742,315	6.2	530	5	3/2
North Park	495,956	4.1	97	2	2/0
San Juan River	124,120	1.0	52	5	2/3
Canon City	90,669	0.8	44	6	4/2
Denver	105,103	0.9	62	1	0/1
South Park	0	0.0	0	0	0

Table 12. Colorado Coal Production History and Projections (Short Tons) by Coal Region 1970-1980 (Colorado Geological Survey).

Canon City Field		*North Park Region*	
1970	288,510	1970	None
1971	247,443	1971	None
1972	214,948	1972	None
1973	247,172	1973	None
1974	152,681	1974	7,899
1975	147,318	1975	320,677
1976	90,956	1976	270,085
1977	90,669	1977	495,956
1978*	119,000	1978	715,500
1979**	148,000	1979**	650,000
1980**	166,000	1980**	300,000
Denver Region		*Raton Mesa Region*	
1970	581,183	1970	625,468
1971	474,119	1971	520,936
1972	574,707	1972	621,570
1973	509,951	1973	624,045
1974	300,295	1974	539,845
1975	162,732	1975	632,207
1976	66,874	1976	649,468
1977	105,103	1977	742,315
1978*	69,300	1978*	635,000
1979**	90,000	1979**	829,500
1980**	400,000	1980**	1,045,000
Green River Region		*San Juan River Region*	
1970	2,459,023	1970	92,195
1971	2,159,368	1971	67,100
1972	2,526,958	1972	104,068
1973	2,895,585	1973	116,286
1974	3,698,650	1974	116,636
1975	4,674,213	1975	120,770
1976	6,060,496	1976	114,809
1977	7,422,188	1977	124,120
1978*	9,277,000	1978*	79,500
1979**	10,329,500	1979**	169,000
1980**	11,455,000	1980**	185,000
Uinta Region		*South Park Field*	
1970	1,974,683	No production since 1932.	
1971	1,838,305		
1972	1,487,928		
1973	1,839,406		
1974	2,144,680		
1975	2,306,409		
1976	2,208,825		
1977	2,990,792		
1978*	3,176,000		
1979**	5,526,000		
1980**	6,722,000		

* Preliminary.
** Projected.

Table 13. 1977 Colorado Out-of-State Coal Exports, by County (Colorado Geological Survey).

County	*Short Tons*	*% of Total County Prod'n Exported*
Archuleta	300	7.4
Delta	268,075	81.9
Fremont	7,547	8.3
Garfield	29,715	42.0
Gunnison	1,073,175	79.7
Jackson	478,746	96.5
La Plata	11,135	43.4
Las Animas	324	0.04
Mesa	266,732	88.9
Moffat	274,490	24.7
Pitkin	920,562	98.3 (est.)
Routt	1,395,365	22.1
Total	4,726,166 (39.5% of total State production)	

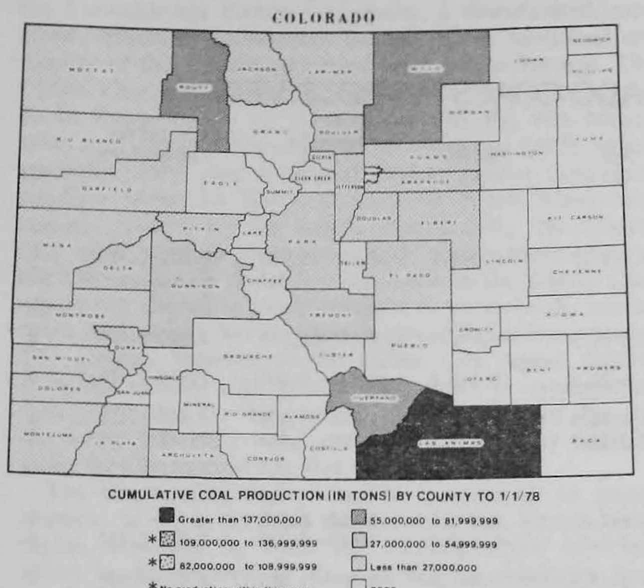

Figure 6. Cumulative coal production (in short tons) in Colorado by county, to January 1, 1978 (Dawson and Murray, 1978, p. 21).

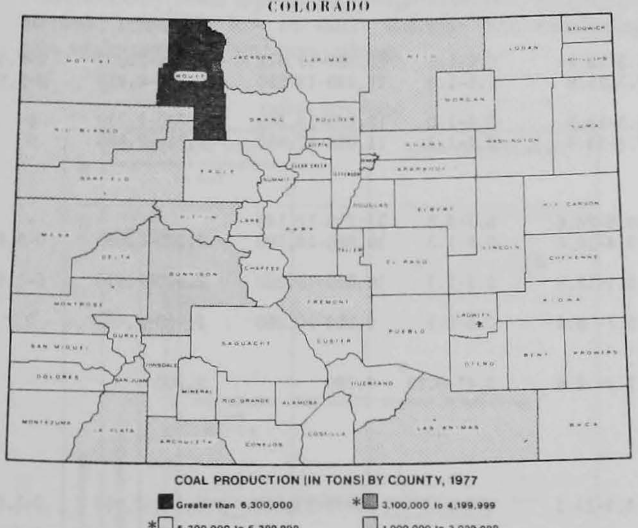

Figure 7. Cumulative coal production (in short tons) in Colorado by county, year 1977 (Dawson and Murray, 1978, p. 22).

Coal Utilization

During 1976, Colorado coal was utilized as follows (Dawson and Murray, 1978, p. 37):

Consumed by out-of-state utilities and industry (steel mills, etc.): 3.64 million short tons (MST), or approximately 39% of total 1976 production.

Consumed within Colorado: 5.82 MST
- Utilities (power generation)—65%
- Steel mills (coke)—28%
- Other industrial use (plant heating, processing)—6%
- Domestic (space heating, etc.)—1%

In 1976, the major public utilities in Colorado burned approximately 5.726 MST of coal in their steam-electric generating plants. This total can be broken down as follows (revised from Dawson and Murray, 1978, p. 79, and Table 19):

- Public Service Company of Colorado, 6.003 MST
- Colorado Ute Electric Association, 0.715 MST
- Colorado Springs Public Utilities, 0.422 MST
- Central Telephone Utilities, Southern Colorado Power Division, 0.111 MST
- Walsenburg Utilities, 0.015 MST

In total, 7.286 MST of coal was burned by the major utilities in Colorado to generate electricity, of which approximately 3.8 MST came tfrom mines in Colorado, chiefly from the Green River and Uinta regions on the Western Slope. The balance about 3.5 MST, was imported into the State, primarily from the Powder River basin of northeastern Wyoming.

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, which recently was revised by Janet E. Schultz of the Colorado Geological Survey.

New to this year's *Keystone* article on Colorado coal is a series of stratigraphic columns constructed for most of the coal regions and areas. These columns 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 a mile or so (if that much). 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, which were prepared by Donna L. Boreck of our office (*see* Boreck and Murray, 1979), represents only preminary 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. The Colorado Geological Survey welcomes any suggestions or corrections in this regard.

Additional details on the coal fields of Colorado may be found in our *Keystone* article for 1978, as well as in the references listed at the end of the present paper.

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

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; therefore, 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.

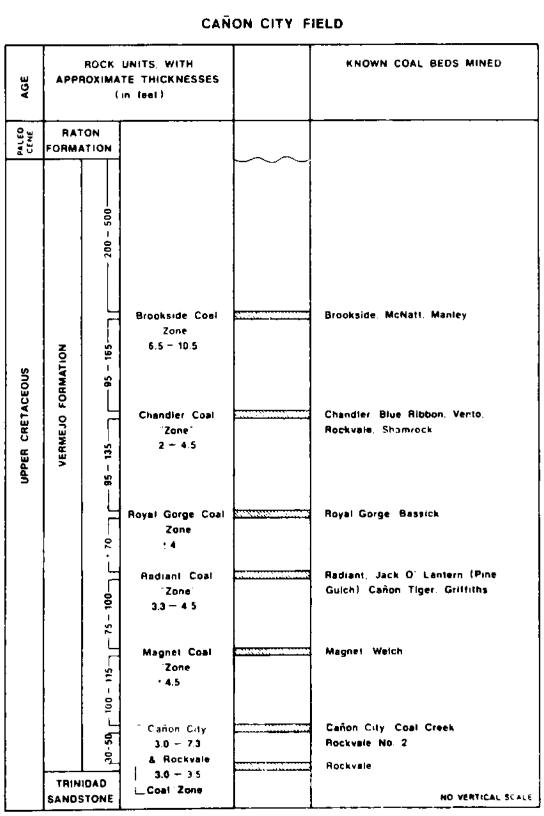

Figure 8. Stratigraphic column, coal-bearing sequence, Canon City coal field (no vertical scale).

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 miles have operated in this region. In 1977, only four underground and two surface mines, employing a total of 44 persons, were in operation (Table 11).

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

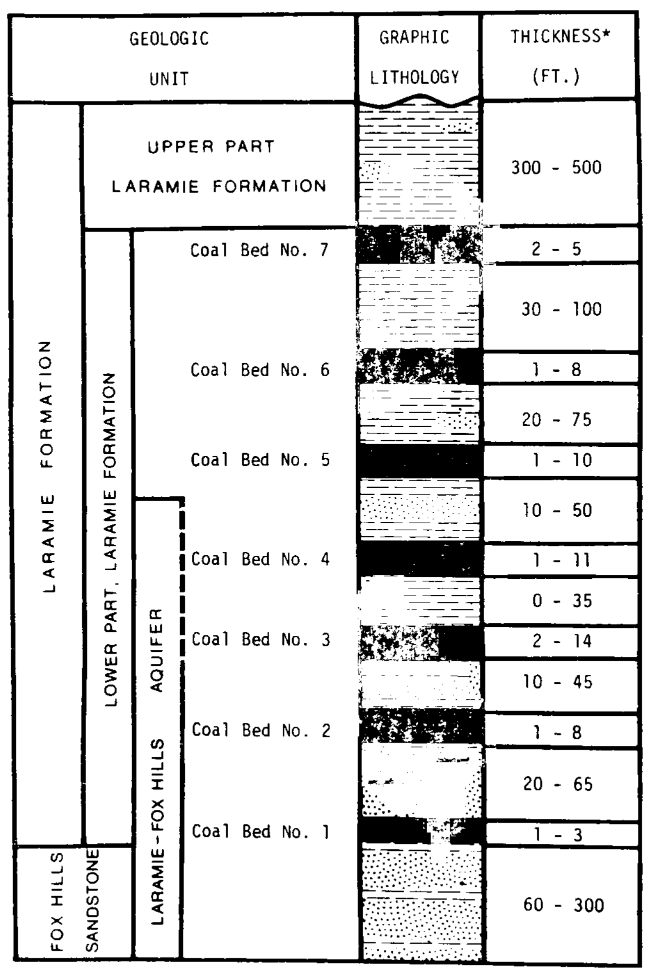

Figure 9. Stratigraphic column, coal-bearing part of Laramie Formation, Boulder-Weld coal field, Denver region (no vertical scale) (after Kirkham and Ladwig, 1979, Fig. 12).

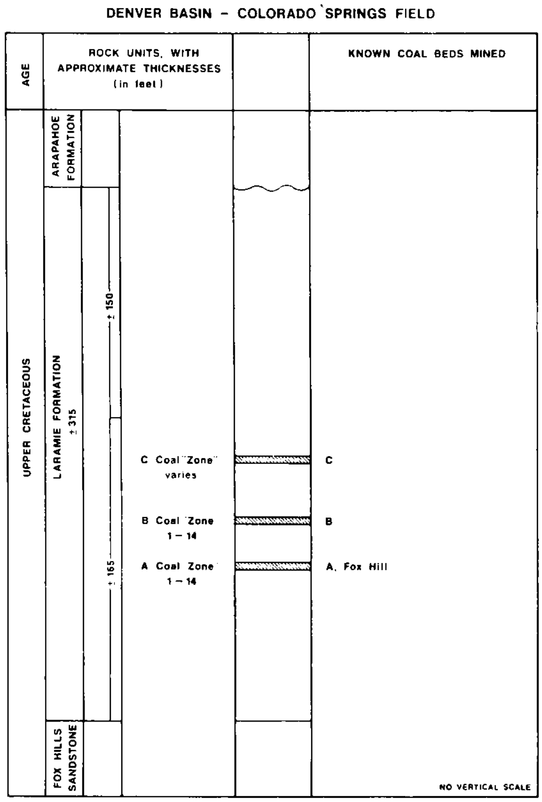

Figure 10. Stratigraphic column, coal-bearing part of Laramie Formation, Colorado Springs coal field, Denver region (no vertical scale).

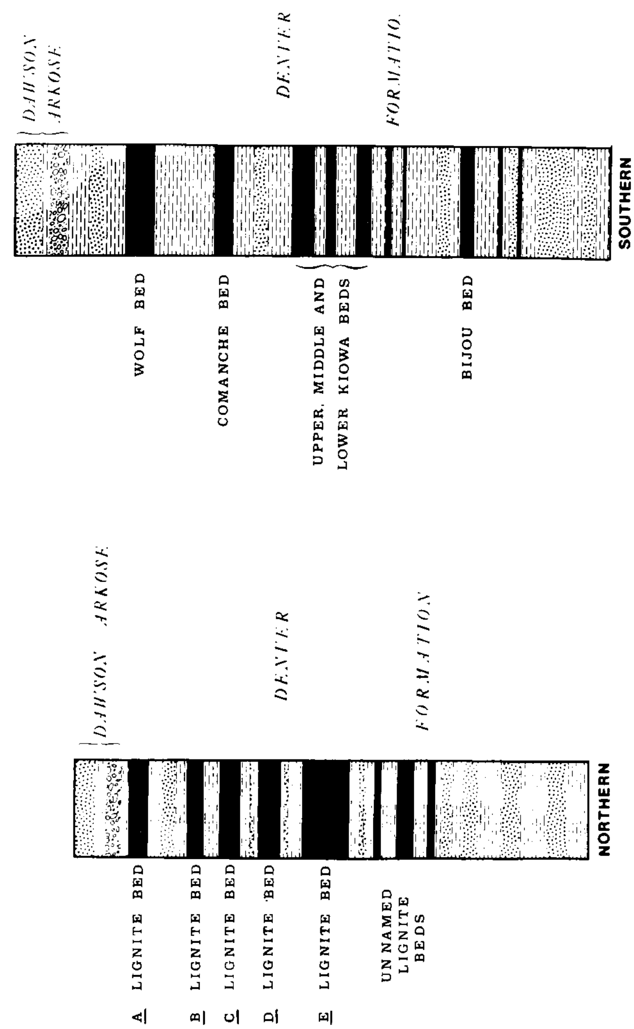

Figure 11. Generalized stratigraphic columns of Denver Formation lignites in the northern and southern lignite areas, Denver sub-basin, Denver region, (no vertical scale) (Kirkham and Ladwig, 1979, Fig. 17).

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 ar underlain by coals of the Laramie Formation, although coals may be thin or absent in a few areas. Laramie coal beds occur in a 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 side 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 of 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).

PERIOD	DENVER BASIN	CHEYENNE BASIN
QUATERNARY	UNDIFFERENTIATED	
PLIOCENE		? ? ?
MIOCENE		OGALLALA FORMATION
		ARIKAREE FORMATION
OLIGOCENE	CASTLE ROCK CONGLOMERATE	WHITE RIVER GROUP
EOCENE	DAWSON ARKOSE	
PALEOCENE	DENVER FORMATION	
UPPER CRETACEOUS	ARAPAHOE FORMATION	
	LARAMIE FORMATION	
	FOX HILLS SANDSTONE	
	PIERRE SHALE	
PRECAMBRIAN, PALEOZOIC AND MESOZOIC FORMATIONS, UNDIFFERENTIATED		

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

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. The Colorado Springs field has produced no coal since 1957. 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 1978, the lone mine operating in the entire region (the Lincoln, in Weld County) produced an estimated 71,500 tons of subbituminous steam coal; overburden thickness in this mine is approximately 425 ft.

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. The sum of these two figures (30-40 billion tons) is less than the 42.47 billion tons estimated by Hornbaker and others (1976, p. 14).

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 Fields,** the only 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 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).

As described earlier in this paper, the Mesaverde coals in the Green River region, for the most part, are high-volatile C bituminous in rank and vary in thickness from

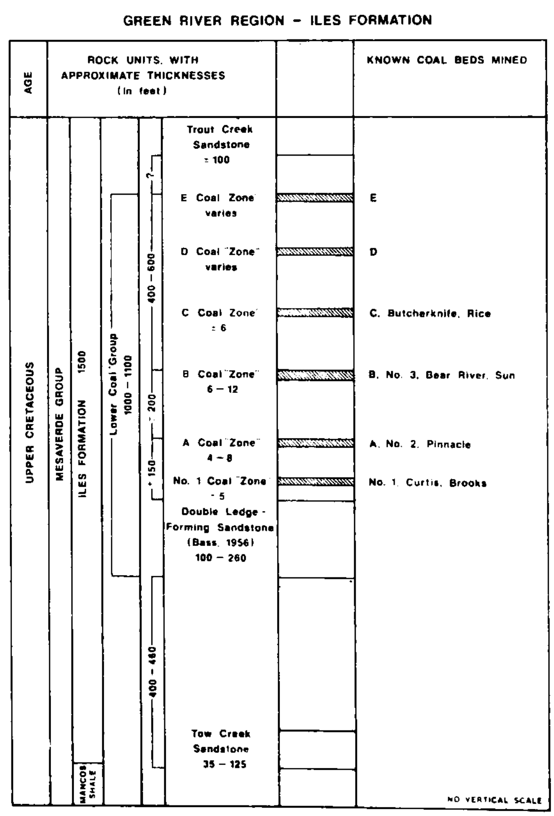

Figure 13. Stratigraphic column, coal-bearing Iles Formation, lower Mesaverde Group, Green River region (no vertical scale).

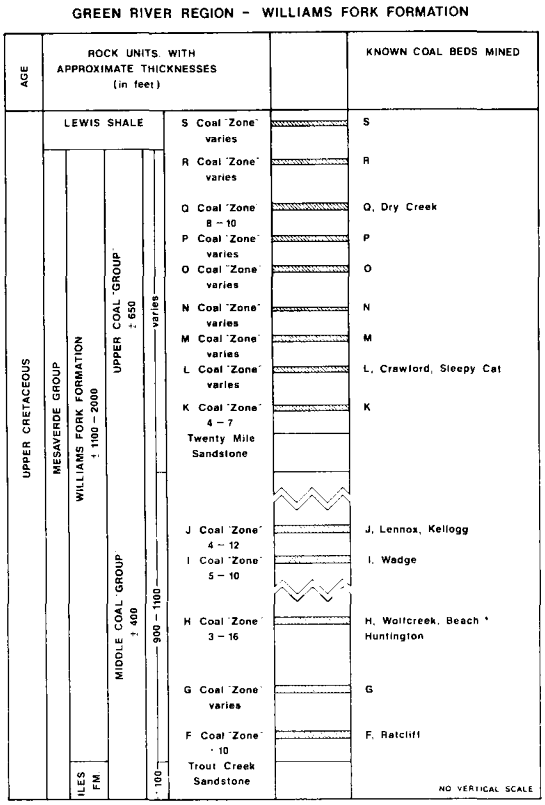

Figure 14. Stratigraphic column, coal-bearing Williams Fork Formation, upper Mesaverde Group, Green River region (no vertical scale).

approximately 3-20 ft. The younger Lance Formation coals, which have been only locally mined in the past (but are not mined at present), appear to be subbituminous B or C and range up to about 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 locally at several ranches on both sides of the Colorado-Wyoming State line. Like the older Fort Union and Lance coals, those in the Wasatch Formation probably are subbituminous B or C in rank, range from a few feet to 20 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 95 million short tons of coal (or approximately 15% of the State's coal) from nearly 200 mines. During 1978, preliminary reports indicate that about 9.3 million tons of coal were produced in the Green River region, Colorado, which is two-thirds of all of the coal produced in the State (*see* Tables 10, 11, and 12). Present production is from 11 surface and three underground mines; surface-mining also predominates in actual volume.

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 either within the region, at Craig and Hayden; or elsewhere in Colorado, mostly in the Denver area. Some of the coal is 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

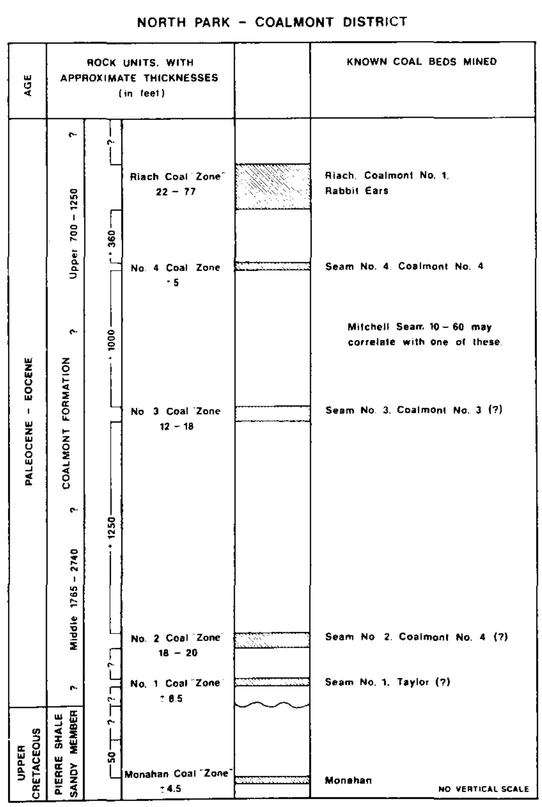

Figure 15. Stratigraphic column, coal-bearing part of Coalmont Formation, Coalmont district, North Park region (no vertical scale).

(4) somewhat upgraded in rank due to the relatively high geothermal gradient inparts 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).

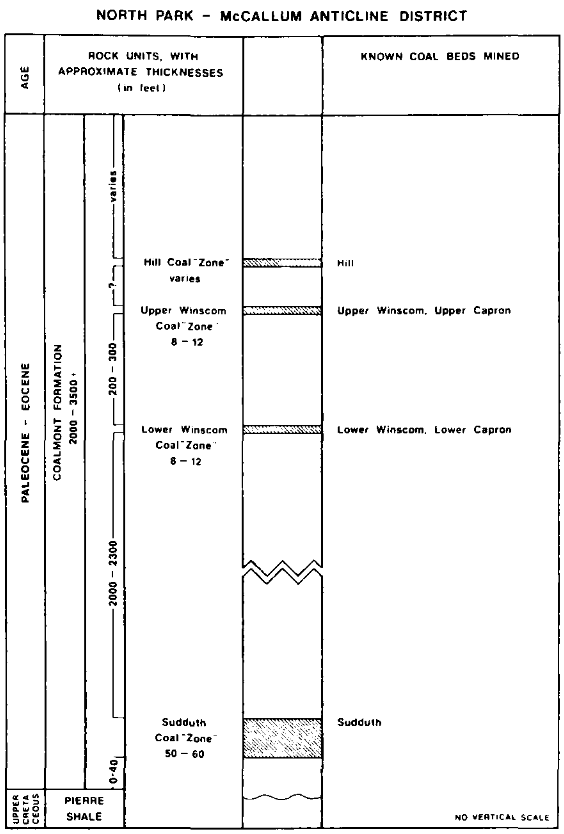

Figure 16. Stratigraphic column, coal-bearing part of Coalmont Formation, McCallum Anticline district, North Park region (no vertical scale).

The North Park region has produced nearly 3.7 million tons of coal from 35 mines since the early 1900's. Most of the coal produced during the last few years has been shipped via a light-duty railroad, operated by Union Pacific, which extends from just south of Walden (the Jackson County seat) to the UPRR main line at Laramie, Wyoming (*see* map by Jones and others, 1978).

During 1978, the North Park region produced approximately 715,000 short tons of steam coal from two surface, or open-pit, mines, Canadian and Kerr, located on the east flank of McCallum anticline (which produces oil and gas from Lower Cretaceous sandstones). This production represents a 44 percent increase over 1977 (Tables 9, 10, 11) and is about five 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 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).

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—

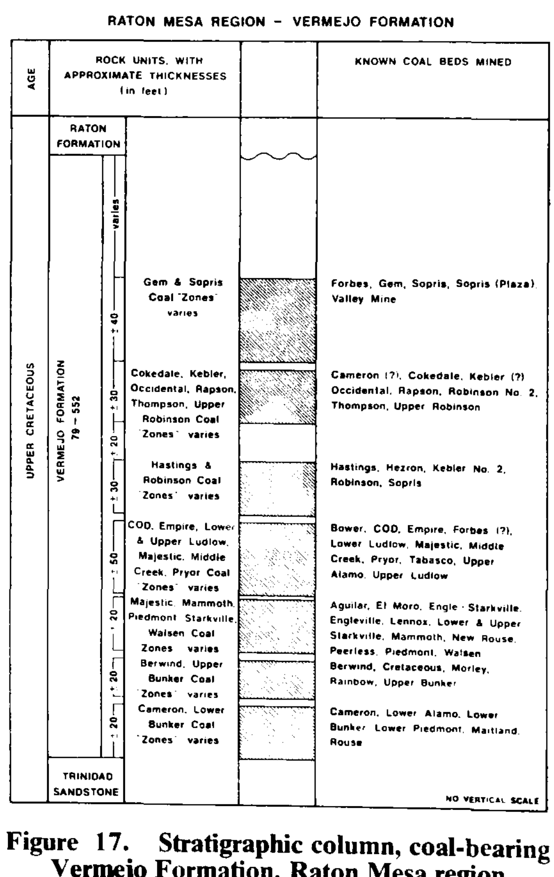

Figure 17. Stratigraphic column, coal-bearing Vermejo Formation, Raton Mesa region (no vertical scale).

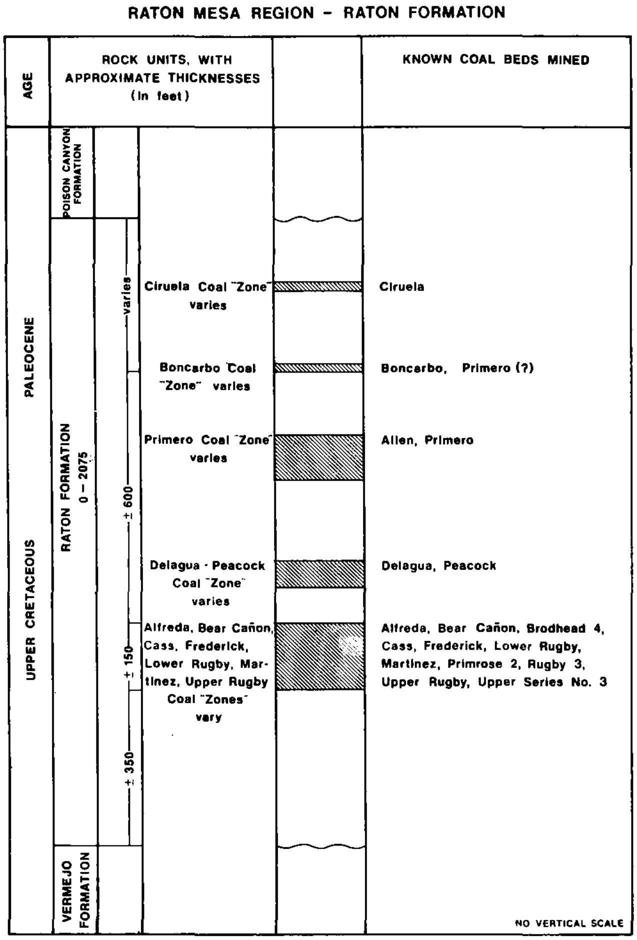

Figure 18. Stratigraphic column, coal-bearing Raton Formation, Raton Mesa region (no vertical scale).

approximately 174 million tons through 1978, or more than 27 percent of the total for the entire State, from more than 150 mines, most of them underground. Clearly, 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 1978 production from the Trinidad field came from CF&I Steel's two captive coking coal mines, the Allen and the new Maxwell, which together accounted for approximately 588,000 tons of coal, or 90 percent of the field's total production for the year. Five small surface mines produced the balance. Coal from the CF&I mines is shipped by rail to the company's steel mill in Pueblo, 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 coal was mined in this field for a number of years until October 1978, when a small surface mine was opened; this mine has produced several thousand tons to date.

The Raton Mesa region (Colorado portion) has produced more than 247 million tons of coal to date from approximately 370 miles; 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 .

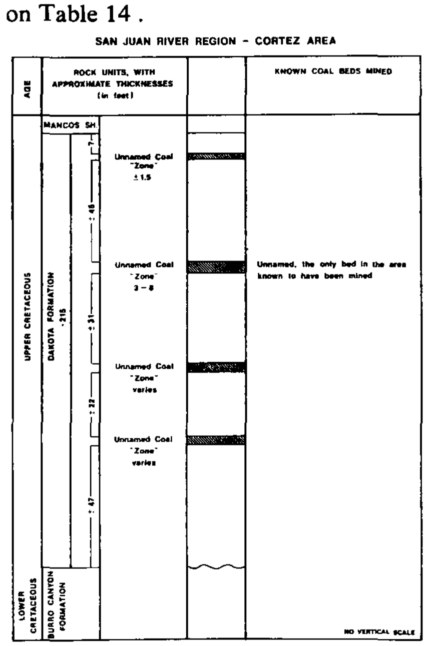

Figure 19. Stratigraphic column, coal-bearing member of Dakota Sandstone, Cortez area, Durango field, San Juan River region (no vertical scale).

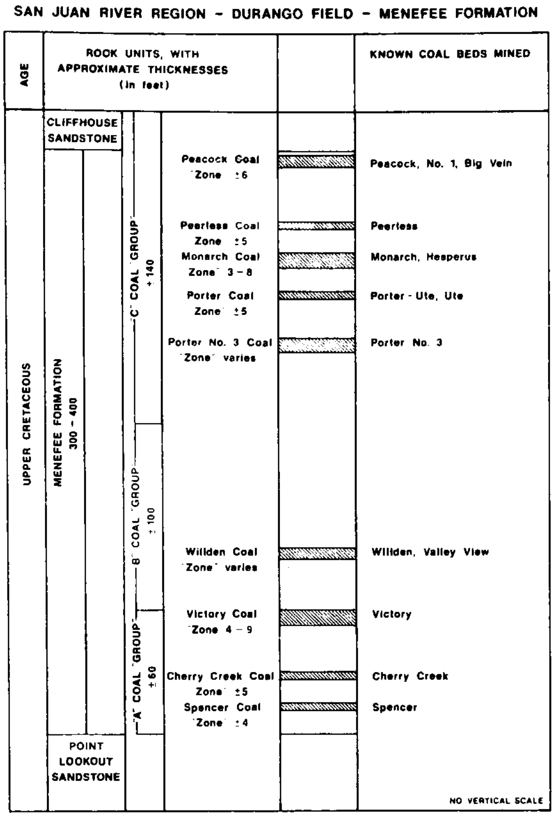

Figure 20. Stratigraphic column, coal-bearing Menefee Formation, Durango field, San Juan River region (no vertical scale).

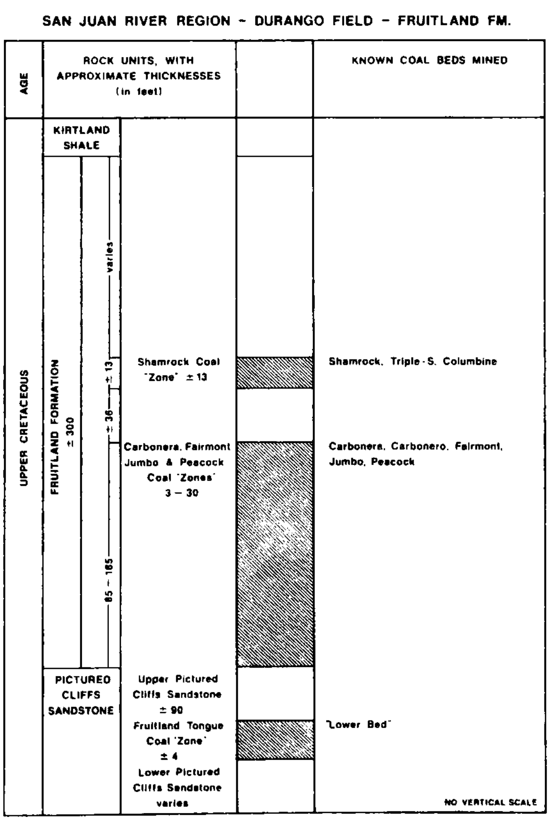

Figure 21. Stratigraphic column, coal-bearing Fruitland Formation, Durango field, San Juan River region (no vertical scale).

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 1978 from two small underground mines in La Plata County totalled less than 80,000 tons; most of this coal is used locally for domestic and industrial purposes, and a few spot sales were trucked to eastern Colorado and eastern Utah.

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 single currently producing mine in this field, Peabody Coal's Nucla multiple-bench surface mine, furnishes approximately 100,000 tons of coal per 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 2.1 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 a total of only 75,000 tons of bituminous coal over the years. The lone operating mine in the field, the Martinez, which opened in 1977, surface-mined an estimated 36,000 tons of coal during 1978.

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

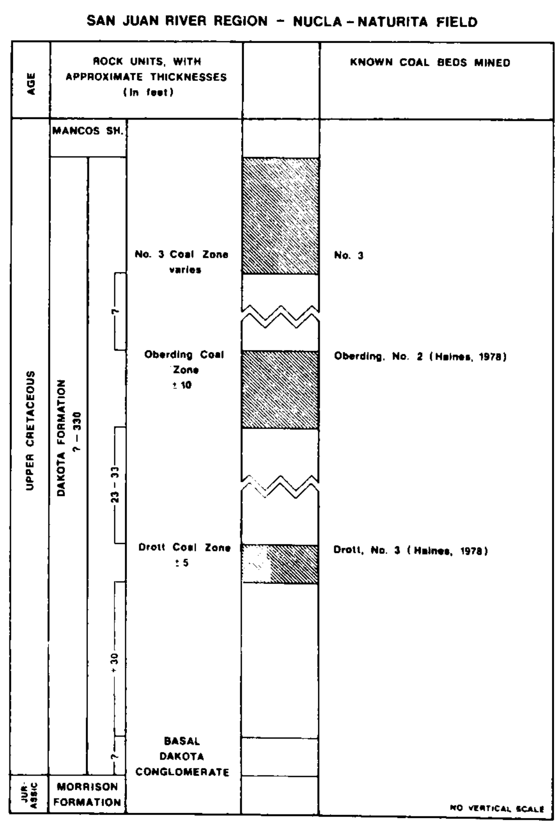

Figure 22. Stratigraphic column, coal-bearing part of Dakota Formation, Nucla-Naturita field, San Juan River region (no vertical scale).

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 1978, the region produced approximately 219,000 tons of bituminous coal from two underground and two surface mines; this is approximately 1.5 percent of the total State 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.

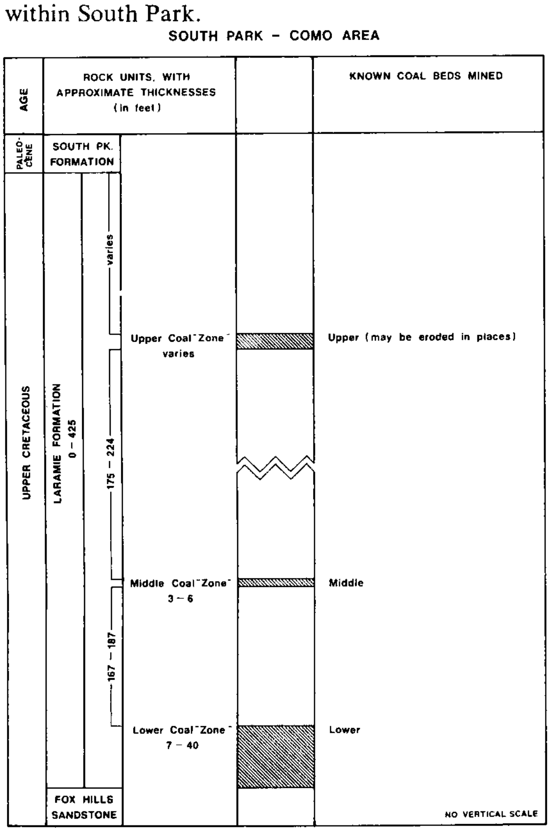

Figure 23. Stratigraphic column, coal-bearing Laramie Formation, Como area, South Park region (no vertical scale).

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).

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 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 alphabetical 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 are 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 1978, approximately 537,000 tons of coal were produced from the Book Cliffs field, all from underground mines—two in Garfield County and one in Mesa County.

Carbondale Field, located at the eastern edge of the region, in Garfield and Pitkin Counties, produces high-

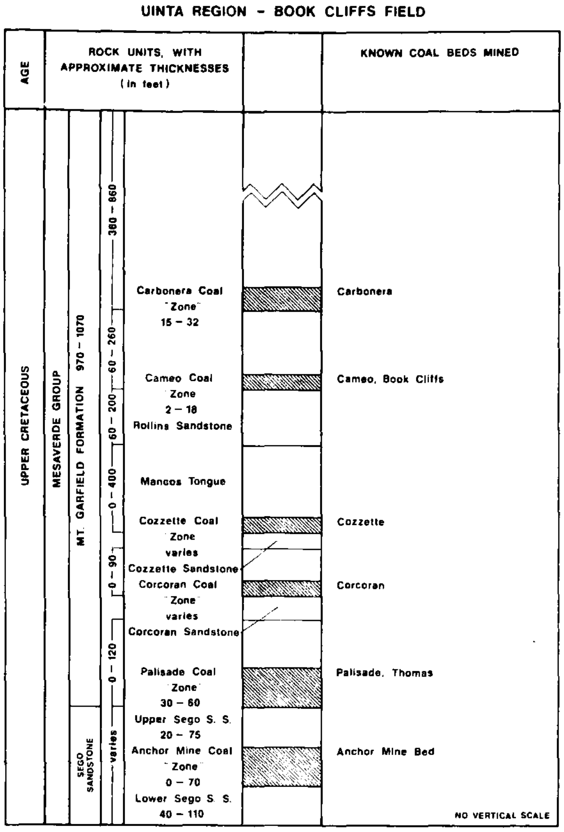

Figure 24. Stratigraphic column, coal-bearing Mesaverde Group, Book Cliffs field, Uinta region (no vertical scale).

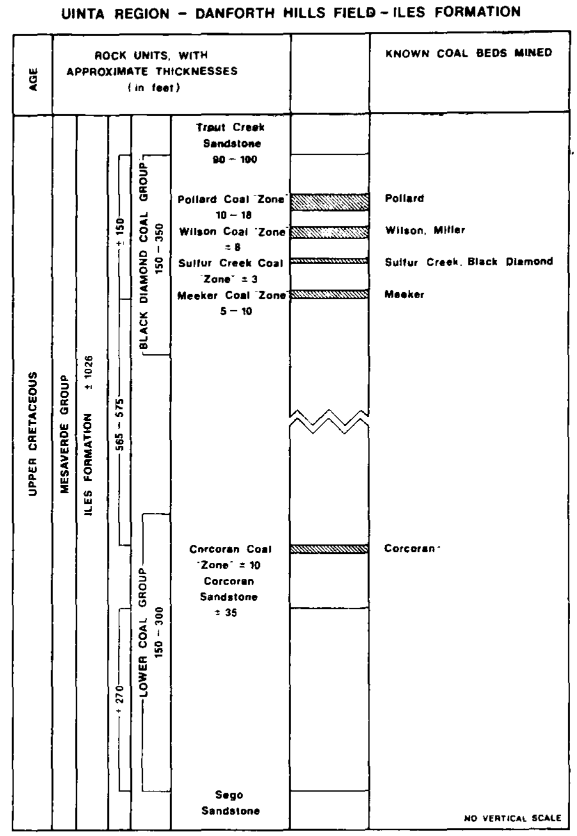

Figure 25. Stratigraphic column, coal-bearing Iles Formation, lower Mesaverde Group, Danforth Hills field, Uinta region (no vertical scale).

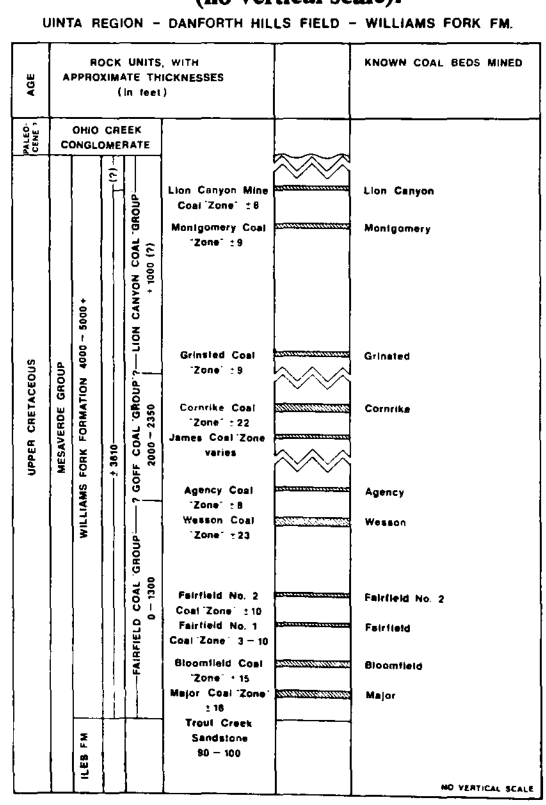

Figure 26. Stratigraphic column, coal-bearing Williams Fork Formation, upper Mesaverde Group, Danforth Hills field, Uinta region (no vertical scale).

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. Last year, the Carbondale field produced approximately 909,000 tons of coal, all but 500 tons from 7 underground coking coal mines in Pitkin County.

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 1978.

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 1.07 million tons were produced from the Danforth Hills field in 1978, a significant increase over the 0.3 million tons produced during 1977. The old Rienau No. 2 underground mine, in Rio Blanco County was reopened by Northern Coal Co. late in 1977 produced nearly 35,000 tons in 1978.

Grand Hogback Fields 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 in-place 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). Two small "one-man" underground mines produced slightly more than 500 tons of coal from steeply dipping Mesaverde beds during 1978.

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 approximately 36,500 tons of bituminous steam coal in 1978.

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 ofthe 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 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

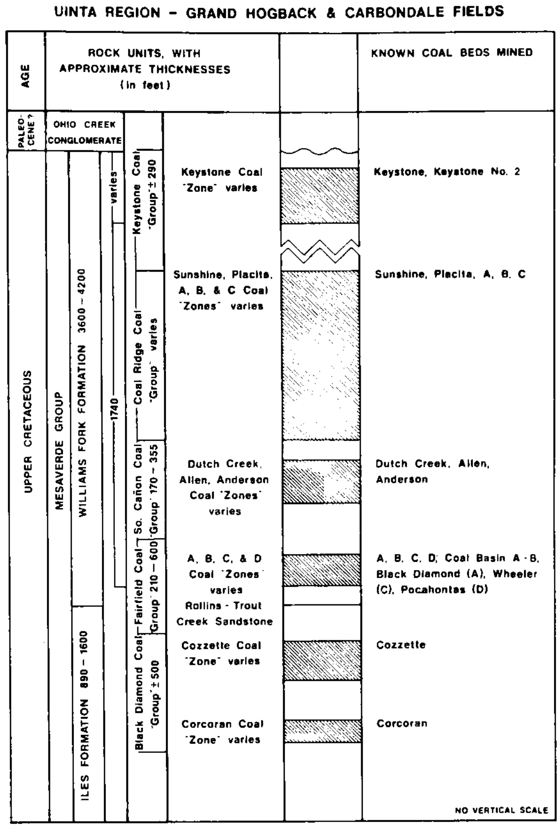

Figure 27. Stratigraphic column, coal-bearing part of Mesaverde Group, Grand Hogback and Carbondale fields, Uinta region (no vertical scale).

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, although new mining activity reportedly is being planned by at least one company.

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). More than 1.2 million tons of coking coal were produced from three mines in the field during 1978, based on preliminary data. 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); 1978 production in the region is estimated to be more than 4.2 million tons, most of it (77%) from underground mines. Since the late 1880's, this important region has produced more than 91.5 million tons of 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, Danforth Hills, and Lower White River. A spur line more than 20 mi in length is being constructed 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 1980 or 1981 from 10 beds in the William Fork Formation that total about 60 ft in thickness (Dawson and Murray, 1978, p. 178).

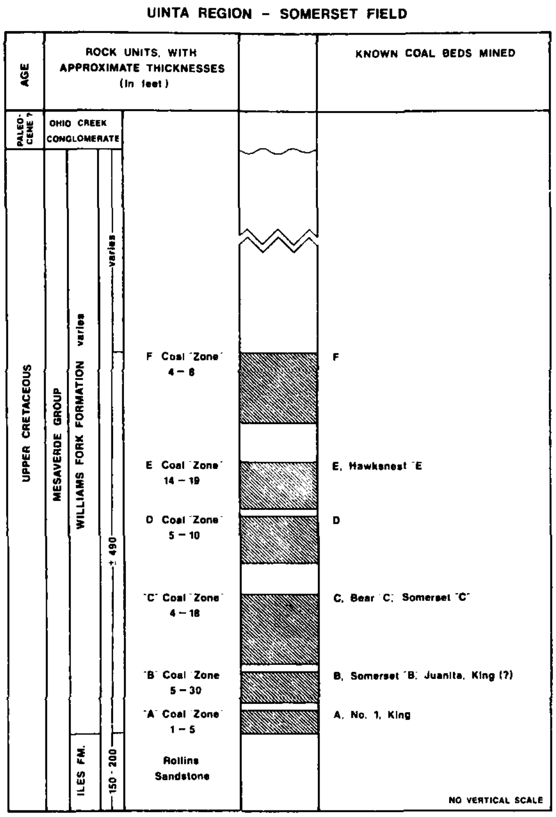

Figure 28. Stratigraphic column, coal-bearing Williams Fork Formation, Upper Mesaverde Group, Somerset field, Uinta region (no vertical scale).

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 (Jones and Murray, 1978).

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 area 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.

References

Amuedo and Ivey (consultants), 1975, Coal mine subsidence and land use in the Boulder-Weld coalfield, Boulder and Weld Counties, Colorado: Colorado Geol. Survey Environmental Geol. 9, text, 6 pls.

Averitt, Paul, 1966, Coking coal deposits of the western United States: U.S. Geol. Survey Bull. 1222-G, p. G1-G48 (Colorado, p. G27-G33).

———, 1972, Coal. *in* Geologic atlas of the Rocky Mountain region: Rocky Mtn. Assoc. Geologists, p. 297-299, Fig. 3 (map).

———, 1975, Coal resources of the United States, January 1, 1974: U.S. Geol. Survey Bull. 1412, 131 p.

Boreck, D. L., Jones, D. C., Murray, D. K., Schultz, J. E., and Suek, D. C., 1977, Colorado coal analyses, 1975 (Analyses of 64 samples collected in 1975): Colorado Geol. Survey Inf. Ser. 7, 112 p.

———, and Murray, D. K., 1979, Colorado coal reserves depletion data, and coal mine summaries: Colorado Geol. Survey Open-file Rept. 79-1 *in preparation*).

Cattany, R. W., 1977, The impact of energy on the Colorado economy. Colorado School Mines Quart., v. 72, no. 4, 139 p.

Collins, B. A., 1976, Coal deposits of the Carbondale, Grand Hogback, and southern Danforth Hills coal fields, eastern Piceance basin, Colorado: Colorado School Mines Quart., v. 71, no. 1, January, 138 p.

———, 1977, Geology of the Coal Basin area, Pitkin County, Colorado, *in* Exploration frontiers of the Central and Southern Rockies: Rocky Mtn. Assoc. Geologists Field Conf. Guidebook, p. 363-377.

Colorado Division of Mines, 1978, A summary of mineral industry activities in Colorado—Part 1: Coal: Dept. Natural Resources, 45 p.

Colorado State Board of Land Commissioners, 1978, Summary of transactions—July 1, 1976 through June 30, 1977: Dept. Natural Resources, 27 p.

Crump, L. H., 1976, Historical fuels and energy consumption data, 1960-1972, United States by States and census districts west of the Mississippi: U.S. Bur. Mine Inf. Circ. 8705, pp. 54-63.

Dawson, L. C., and Murray, D. K., 1978, Colorado coal directory and source book: Colorado Geol. Survey Resource Ser. 3, 225 p.

Fender, H. B., and Murray, D. K., 1978, Data accumulation on the methane potential of the coal beds of Colorado, final report: Colorado Geol. Survey Open-file Rept. 78-2, 25 p., 1 fig., 4 tables, 5 pl., 7 forms.

———, Jones, D. C., and Murray, D. K., 1978, Bibliography and index of publications related to coal in Colorado, 1972-1977: Colorado Geol. Survey Bull. 41, 54 p.

Goolsby, S. M., and Reade, N. B. S., 1978, Map of licensed coal mines in Colorado as of June 1, 1978: Colorado Geol. Survey Map Ser. 12, 1 pl., scale 1:1,000,000.

Hodgson, H. E. (ed.), 1978, Proceedings of the Second Symposium on the Geology of Rocky Mountain Coal: Colorado Geol. Survey Resource Ser. 3, 219 p.

Holt, R. D., 1972, Bibliography, coal resources in Colorado: Colorado Geol. Survey Bull. 34-A, 32 p.

Hornbaker, A. L., Holt, R. D., and Murray, D. K., 1976, Summary of coal resources in Colorado, 1975: Colorado Geol. Survey Spec. Pub. 9, 17 p.

Jones, D. C., and Murray, D. K., 1976, Coal mines of Colorado, statistical data: Colorado Geol. Survey Inf. Ser. 2, 27 p.

———, and ———, 1978, First annual report, evaluation of coking-coal deposits in Colorado: Colorado Geol. Survey Open-file Rept. 78-1, 18 p., 1 fig., 5 pl., 10 tables.

———, Schultz, J. E., and Murray, D. K., 1978, Coal resources and development map of Colorado: Colorado Geol. Survey Map Ser. 9, 1 pl., scale: 1:500,000.

Kirkham, R. M., 1978a, Isopach map of the Watkins lignite seam, Adams and Arapahoe Counties, Colorado; and a map showing extent of alluvial valley floors and overburden thickness above the Watkins lignite seam, Adams and Arapahoe Counties, Colorado: Colorado Geol. Survey Open-file Rept. 78-6, 2 pls.

———, 1978b, Location map of drill holes used for coal evaluation in the Denver and Cheyenne Basins, Colorado: Colorado Geol. Survey Open-file Rept. 78-8, 1 pl., scale 1:250,000.
———, 1978c, Coal mines and coal analyses of the Denver and Cheyenne Basins, Colorado: Colorado Geol. Survey Open-file Rept. 78-9, 104 p., 1 pl. (map, scale 1:250,000).
———, and Ladwig, L. R., 1977, Preliminary investigation and feasibility study of environmental impact of energy resources development in the Denver Basin (Colorado): Colorado Geol. Survey Open-file Rept. 77-1, 30 p., 1 pl.
———, and ———, 1979, Coal resources of the Denver and Cheyenne Basins, Colorado: Colorado Geol. Survey Resource Ser. 5 (*in preparation*).
Landis, E. R., 1959, Coal resources of Colorado: U.S. Geol. Survey Bull. 1071-C, p. 131-232.
Lowrie, R. L., 1977, Western coal in the U.S. energy picture, *in* Mining Yearbook, 1977: Denver, Colorado Mining Association, p. 114-131.
Murray, D. K., 1975, Colorado coal—outlook for future (abs.): Am. Assoc. Petroleum Geologists Bull., v. 59, no. 5, May, p. 917-918.
———, 1976, New frontiers in Colorado coal research (abs.): Am. Assoc. Petroleum Geologists Bull., v. 60, no. 8, August, p. 1404-1405.
———, 1977a, Colorado coal, a versatile resource (abs.): Geol. Soc. America Abs. with Programs, v. 9, no. 1, January, p. 65.
——— (ed.), 1977b, Geology of Rocky Mountain coal, Proceedings of the 1976 Symposium: Colorado Geol. Survey Resource Ser. 1, 175 p.
———, Fender, H. B., and Jones, D. C., 1977, Coal and methane gas in the southeastern part of the Piceance Creek basin, Colorado, *in* Exploration frontiers of the Central and Southern Rockies: Rocky Mtn. Assoc. Geologists Field Conf. Guidebook, p. 379-405.
Miller, A. E., 1975, Geologic, energy, and mineral resource maps of Routt County, Colorado: Colorado Geol. Survey Map Ser. 1, 2 pls., scale 1:126,720.
———, 1977, Geology of Moffat County, Colorado: Colorado Geol. Survey Map Ser. 3, 1 pl., scale 1:126,720.
Morse, J. G., and Hebb, D. H., 1976, Colorado energy resources handbook, Volume 1, Coal: Golden, Colorado Energy Research Institute, 52 p.
Pederson, J. A., and Rudawsky, Oded, 1974, The role of minerals and energy in the Colorado economy: Golden, Dept. Mineral Economics, Colorado School Mines, 357 p.
Rich, C. H., Jr., 1978, Projects to expand energy sources in the Western States—an update of Information Circular 8719: U.S. Bur. Mines Inf. Circ. 8772, 199 p. (Colorado, p. 40-59).
Rocky Mountain Association of Geologists Research Committee, C. Dennis Irwin, Chmn., 1977, Subsurface cross sections of Colorado: Rocky Mtn. Assoc. Geologists Spec. Pub. 2, 39 p., 24 figs. (incl. index map, correlation chart, 22 cross sections).
Schultz, J. E., 1979, Coal analyses, Green River and Uinta regions, Colorado: Colorado Geol. Survey Inf. Ser. 10 (*in preparation*).
Soister, P. E., 1974, A preliminary report on a zone containing thick lignite beds, Denver basin, Colorado: U.S. Geol. Survey Open-file Rept. 74-27, 64 p.
———, 1978, Geologic setting of coal in Denver basin (Colorado), *in* Energy resources of the Denver basin: Rocky Mtn. Assoc. Geologists Field Conf. Guidebook, p. 183-185.
Speltz, C. N., 1976, Strippable coal resources of Colorado—location, tonnage, and characteristics of coal and overburden: U.S. Bur. Mines Inf. Circ. 8713, 70 p.
U.S. Bureau of Mines, 1977a, Demonstrated coal reserve base of the United States on January 1, 1976: U.S. Bur. Mines Mineral Industry Surveys, Washington, D.C., 8 p.
———, 1977b, The mineral industry of Colorado in 1976: U.S. Bur. Mines Mineral Industry Surveys, State Liaison Office—Colorado, 2 p.
———, 1978, The mineral industry of Colorado in 1977: U.S. Bur. Mines Mineral Industry Surveys, State Liaison Office—Colorado, 3 p.
U.S. Geological Survey, Conservation Division, 1977, Federal and Indian lands, coal, phosphate, potash, sodium, and other mineral production, royalty income, and related statistics, 1920 through 1976 (calendar year): compiled by W. M. Harris, S. K. Piper, and B. S. McFarlane, June, 312 p.
U.S. Geological Survey and Colorado Geological Survey, 1977, Energy resources map of Colorado: U.S. Geol. Survey Misc. Inf. Map I-1039, 1 pl., scale: 1:500,000.