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COAL RESOURCES OF COLORADO

A Progress Report, January 1, 1953

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INTRODUCTION

This report is preliminary to a more detailed reappraisal of the coal resources of Colorado now in progress. It is based, for the most part, on studies of published and unpublished reports in the files of the United States Geological Survey. Although the most comprehensive that can be prepared with the data immediately available, the coal reserve estimates included in this report should be considered provisional because information on the extent and thickness of coal in many parts of the State is meager or lacking. At the present time, however, the Geological Survey is investigating several coal-bearing areas in Colorado, and the results of these investigations will aid in providing more accurate data on which to base the planned revision of the present estimate.

SUMMARY

The gross value of the coal produced annually in Colorado ranks second among the many valuable mineral products of the State, exceeded only by petroleum and petroleum products. Although coal production in the State has decreased in recent years, interest in coal reserves has increased because of the potential future needs for coking coal and for coal of lower ranks suitable for the manufacture of synthetic liquid fuels.

The original coal reserves of Colorado are estimated to be 100,408 million tons, of which 9,437 million tons is subbituminous coal, 90,258 million tons is bituminous coal, and 713 million tons is semianthracite or anthracite. (See tables 1 and 2.) Although coal-bearing rocks underlie about 25,400 square miles or 24 percent of the total area of the State, most of these rocks occur in intermontane structural basins, and little is known about the occurrence of coal in the central parts of these basins. Large areas in the State such as the Denver, Green River, Unita, and San Juan River regions, are believed to be underlain by coal throughout their entire area, but only the marginal areas were included in preparing the present estimate.

The data used to compile the present estimate were restricted for the most part to mapped and explored areas within six miles, or less, of the coal outcrops. Thus restricted, the area of coal-bearing rocks considered in preparing this report totaled only 5,277 square miles, or 20 percent of the total probable coal-bearing area in the State. (See pl. 1.) This smaller area, however, includes all coal that is immediately accessible.

Although most of the coal is in thicker beds, the minimum thickness of beds included in the estimate is 14 inches for bituminous coal and anthracite, and 30 inches for subbituminous coal. The maximum overburden on the coal included in the estimate is 3,000 feet, although most of the reserves lie at depths much less than 3,000 feet.

CLASSIFICATION OF RESERVES

The estimates given in tables 1 and 2 are for original reserves in the ground before mining began. They include coal formerly present in mined-out areas; coal in the narrow weathered zone at the outcrop; and coal underlying railways, roads, and towns. The calculation of original reserves is both desirable and practicable for it gives a relatively stable figure on which to base estimates of remaining and recoverable reserves, which change with production and with changes in mining methods. Remaining and recoverable reserves as of any given time can be ascertained more readily if the records of original reserves and the amount of coal mined and lost in mining are kept separately.

The total recorded production of coal in Colorado from the beginning of mining to January 1, 1952, is 479 million tons. In addition to the coal produced, an equal amount, more or less, is left underground, or otherwise lost in mining. On this basis an amount equal to twice that of the coal production shown in table 6 (958 million tons), has been mined and lost in mining in the State. This figure, subtracted from the total original reserves of 100,408 million tons, leaves remaining reserves on January 1, 1952, of 99,450 million tons.

Assuming that mining losses in the future will remain about equal to actual production, the recoverable reserves as of January 1, 1952, are estimated as half the remaining reserves, or approximately 50,000 million tons.

Rank of coal

Coal is classified by rank according to the percentage of fixed carbon and the Btu content. The rank is determined according to the standard specifications of the American Society for Testing Materials, which are reproduced as table 3.

The greatest part of the reserves in Colorado, 90,258 million tons, or 90 percent of the total remaining reserves, is of bituminous rank. Most of this coal is of high-volatile C bituminous rank; the remainder ranges from high-volatile B to low-volatile bituminous rank. It is present in the Yampa, South Park, and Canon City fields and the Uinta, San Juan River, and Raton Mesa regions. The next larger part, 9,437 million tons, or 9 percent of the total reserves, is of subbituminous rank. The subbituminous coal ranges from subbituminous C to A. It is present in the coal fields of the Denver region and in the North Park, Yampa, and Tongue Mesa fields. The smallest part, 713 million tons, or 1 percent of the total reserve is semianthracite or anthracite in rank. It is present in the Crested Butte field of the Uinta region. A relatively small tonnage of semianthracite and anthracite in the Routt County part of the Yampa field is included in the tables with the bituminous coal.

Although coking coal was not segregated in the tables, it is present in five areas in Colorado: the Trinidad, Durango, Crested Butte, Somerset, and Carbondale fields. The Crested Butte field, together with the adjacent Somerset and Carbondale fields in Gunnison, Delta, and Pitkin Counties, and the Trinidad field in Las Animas and Huerfano Counties constitute the second and third largest coke-producing areas in the West,

Table 1.--Original coal reserves of Colorado, by fields, under less than 3,000 feet overburden

(In millions of short tons)

Region or field	Square miles	Rank of coal			Region or field total
		Sub-bituminous	Bituminous	Semianthracite or anthracite	
Denver	535	3,662	---	---	3,662
Canon City	35	---	466	---	466
Raton Mesa	1,023	---	12,167	---	12,167
North Park	60	2,074	---	---	2,074
Yampa	793	3,136	22,405	---	25,541
Uinta	2,510	---	51,797	713	52,510
South Park	3	---	20	---	20
Tongue Mesa	32	537	---	---	537
San Juan	286	28	3,403	---	3,431
Total	5,277	9,437	90,258	713	100,408

Table 2.--Original coal reserves of Colorado, by counties, under less than 3,000 feet overburden

(In millions of short tons)

County	Square miles	Rank of coal			County total
		Sub-bituminous	Bituminous	Semianthracite or anthracite	
Adams	24	238	---	---	238
Arapahoe	4	28	---	---	28
Archuleta	114	28	412	---	440
Boulder	63	425	---	---	425
Delta	225	---	4,315	---	4,315
Douglas	3	40	---	---	40
Elbert	28	205	---	---	205
El Paso	67	396	---	---	396
Fremont	35	---	466	---	466
Garfield	325	---	8,059	---	8,059
Gunnison	419	144	[1] 10,194	713	11,051
Huerfano	273	---	1,270	---	1,270
Jackson	60	2,074	---	---	2,074
Jefferson	113	1,040	---	---	1,040
La Plata	139	---	[1] 2,855	---	2,855
Larimer	18	98	---	---	98
Las Animas	750	---	[1] 10,897	---	10,897
Mesa	395	---	4,470	---	4,470
Moffat	640	1,711	22,014	---	23,725
Montezuma	7	---	15	---	15
Montrose	40	287	121	---	408
Ouray	7	106	---	---	106
Park	3	---	20	---	20
Pitkin	32	---	[1] 830	---	830
Rio Blanco	865	---	17,223	---	17,223
Routt	413	1,425	7,097	---	8,522
Weld	215	1,192	---	---	1,192
Total	5,277	9,437	90,258	713	100,408

[1] Includes some coking coal.

Legend: F.C. = Fixed Carbon. V.M. = Volatile Matter. Btu. = British thermal units.

Class	Group	Limits of Fixed Carbon or Btu. Mineral-Matter-Free Basis	Requisite Physical Properties
I. Anthracitic	1. Meta-anthracite	Dry F.C., 98 per cent or more (Dry V.M., 2 per cent or less)	Nonagglomerating[b]
	2. Anthracite	Dry F.C., 92 per cent or more and less than 98 per cent (Dry V.M., 8 per cent or less and more than 2 per cent)	
	3. Semianthracite	Dry F.C., 86 per cent or more and less than 92 per cent (Dry V.M., 14 per cent or less and more than 8 per cent)	
II. Bituminous[d]	1. Low volatile bituminous coal	Dry F.C., 78 per cent or more and less than 86 per cent (Dry V.M., 22 per cent or less and more than 14 per cent)	Either agglomerating or nonweathering[f]
	2. Medium volatile bituminous coal	Dry F.C., 69 per cent or more and less than 78 per cent (Dry V.M., 31 per cent or less and more than 22 per cent)	
	3. High volatile *A* bituminous coal	Dry F.C., less than 69 per cent (Dry V.M., more than 31 per cent); and moist[c] Btu., 14,000[e] or more	
	4. High volatile *B* bituminous coal	Moist[c] Btu., 13,000 or more and less than 14,000[e]	
	5. High volatile *C* bituminous coal	Moist Btu., 11,000 or more and less than 13,000[e]	
III. Subbituminous	1. Subbituminous *A* coal	Moist Btu., 11,000 or more and less than 13,000[e]	Both weathering and nonagglomerating
	2. Subbituminous *B* coal	Moist Btu., 9500 or more and less than 11,000[e]	
	3. Subbituminous *C* coal	Moist Btu., 8300 or more and less than 9500[e]	
IV. Lignitic	1. Lignite	Moist Btu., less than 8300	Consolidated
	2. Brown coal	Moist Btu., less than 8300	Unconsolidated

a This classification does not include a few coals which have unusual physical and chemical properties and which come within the limits of fixed carbon or Btu. of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

b If agglomerating, classify in low-volatile group of the bituminous class.

c Moist Btu. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

d It is recognized that there may be noncaking varieties in each group of the bituminous class.

e Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

f There are three varieties of coal in the high-volatile C bituminous coal group, namely, Variety 1, agglomerating and nonweathering; Variety 2, agglomerating and weathering; Variety 3, nonagglomerating and nonweathering.

Table 3. CLASSIFICATION OF COALS BY RANK

exceeded only by the Sunnyside-Castlegate field in Utah (Berryhill, 1951, p. 13).

METHODS OF PREPARING RESERVE ESTIMATES

The reserves shown in this report represent for the most part a compilation of estimates made by many authors at various times in the past. Some authors estimated reserves by individual coal beds; others used an average total thickness of several beds; some used a depth figure of 3,000 feet as the basis for the boundary of the reserve areas, and others used stipulated distances behind the outcrop of the coal beds. Few authors classified the individual beds according to thickness or overburden, and none separated the reserves into measured, indicated, and inferred categories according to present practice.

Because of the preliminary nature of this report, and because sufficient data are lacking in some of the fields, reserve tonnages were not broken down into the accepted categories of measured, indicated, and inferred reserves, nor the accepted categories of thickness and overburden. In a few of the coal fields the estimates used herein are those calculated by the earlier authors. In most fields, however, the earlier estimates were modified to accord with the plan of presentation selected for this preliminary report.

The minimum thickness of coal included in the estimates of reserves was 14 inches for anthracite, semianthracite, and bituminous coal, and 30 inches for subbituminous coal. Partings more than three-eighths of an inch thick were excluded from the thickness of the bed and no tonnages were included in the estimate for coal more than 3,000 feet below the surface.

The following weights of coal per acre-foot were used in calculating reserves: anthracite and semianthracite, 2,000 short tons; bituminous coal, 1,800 short tons; and subbituminous coal, 1,770 short tons.

A more detailed description of the methods used in preparing the reserve estimates for each individual field is included in the section Coal fields of Colorado.

COMPARISON OF PAST AND PRESENT ESTIMATES

Previous estimates of the coal resources of Colorado were made by Campbell (1913, p. 537) and Vanderwilt (1947, pp. 266-276). (See table 4.) In 1913, Campbell estimated the original reserves of coal in the State to be 317,996 million tons, contained in an area of 14,341 square miles. A revision of this estimate, made in 1947 by Vanderwilt, decreased the tonnage of original reserves to 174,208 million tons, or approximately one-half of Campbell's estimate. The area contained in Vanderwilt's report is 20,295 square miles. Although entire basin areas, such as the Denver and Uinta regions, and the South Park field were considered in the Vanderwilt estimate, the reserves presumably were calculated for a much smaller area.

In this provisional report the original reserves are estimated to be 100,408 million tons, contained in an area of 5,277 square miles (tables 1, 2, and 4). As compared with the two previous estimates, the areal extent as well as the reserve tonnages were cut down considerably in areas such as the Denver and San Juan River regions, and the Yampa field.

In the Denver region, Campbell calculated coal reserves for an area of 5,380 square miles; in the present report reserves are calculated for an area of only 535 square miles. Although the probable coal-bearing land of this region comprises about 7,600 square miles, mining operations and data pertaining to coal outcrops in the larger area indicate that the beds lack persistency in thickness and continuity.

Both the reserve tonnage and coal acreage for the San Juan River region are much smaller than those given by Campbell (table 4), because recent field work in parts of this region indicates that not only are the coal beds lenticular, but the areal extent of the coal lying at depths of less than 3,000 feet is much smaller than had been supposed.

Campbell (1913) calculated reserves for an area of 3,130 square miles in the Yampa field, as compared to 793 square miles in the present report. Recent field investigations, however, have proven that in a very large area in the northern part of the field in Routt County, the coal of the lower and middle coal groups of the Mesaverde group occurs at depths of more than 3,000 feet and the coals of the Lance and Fort Union formations are sporadic. Because of this, reserves were estimated for only short distances from points of observation.

In many of the fields and regions throughout the State, the greater tonnages and areas shown in the earlier reports are due to the inclusion by Campbell and Vanderwilt of large areas of coal-bearing rock for which data as to the thickness and extent of beds are not available. No estimates of reserves in such areas are included in this report, although a large part of them may contain coal, which subsequent explorations may discover.

Table 4.--Comparison of past and present estimates of Colorado coal reserves, in millions of short tons

Region or field	Adapted from Campbell (1913)		Adapted from Vanderwilt (1947)		This report (1952)	
	Square miles	Tons	Square miles	Tons	Square miles	Tons
Denver	5,380	40,018	[1] 7,600	14,000	535	3,662
Canon City	40	1,028	40	900	35	466
Raton Mesa	1,035	24,473	1,035	22,000	1,023	12,167
North Park	57	2,854	500	[2] 450	60	2,074
Yampa	3,130	135,607	3,100	40,000	793	25,541
Uinta	2,780	84,101	[1] 6,000	75,000	2,510	52,510
South Park	3	20	[1] 80	18	3	20
Tongue Mesa	40	929	40	840	32	537
San Juan	1,876	28,965	1,900	21,000	286	3,431
Total	14,341	317,995	20,295	174,208	5,277	100,408

[1] Includes whole basin area; reserves presumably calculated for smaller area.
[2] Includes coal under more than 3,000 feet overburden.

COAL FIELDS OF COLORADO

As a result of the structural disturbances and the igneous activity that accompanied and followed the uplift of the Rocky Mountains, coal beds occur in almost every conceivable attitude and physiographic environment in Colorado. The coals also differ widely in rank, ranging from subbituminous and bituminous coal to semianthracite and anthracite. The distribution of the numerous coal fields in Colorado, classified according to the rank of the coal, is shown in plate 1.

The coal-bearing rocks in these fields underlie about 25,400 square miles, or 24 percent of the total area of the State. Of this area, only 5,277 square miles, or about 5 percent of the total area of the State is immediately accessible. This results from the fact that most of the coal fields are in intermontane structural basins in which the coal-bearing rocks crop out around the edges and dip towards the centers of the basins. The coal-bearing rocks are thus more readily accessible only in narrow bands around the edges of the basins, and most exploration and development has taken place in these bands. Coal probably occurs at depth in the centers of the structural basins, but the thickness and distribution of the beds can only be surmised. The restriction of reserve studies to the more accessible edges of the basins, where mining will be concentrated in the immediate future and where information as to the thickness and extent of the beds has been, or can be ascertained, is, therefore, both desirable and practicable.

The coal-bearing formations in the State are of Late Cretaceous and early Tertiary age. These formations beginning with the oldest, are as follows: the Dakota sandstone, Mesaverde group, Fruitland, Lance, Laramie, Vermejo, Animas, Raton, Fort Union, Denver, and Coalmont formations. Except for the Coalmont formation, which is of Eocene age, the stratigraphic position of these formations is shown in figure 1.

Yampa field

The Yampa field is in northwestern Colorado and includes parts of Moffat, Routt, and Rio Blanco Counties. The field lies in a broad syncline that trends southeastward from Wyoming through this part of Colorado. The coal-bearing rocks in the east-central part of the field are strongly folded and faulted, and locally are cut by igneous intrusives, which have helped to develop high-rank coals.

Anthracite, semianthracite, bituminous coal and subbituminous coal are found in the field. Although the largest part of the reserves occur in the Mesaverde group of the Late Cretaceous age, most of the lower rank coals occur in the Lance and Fort Union formations of the Late Cretaceous and Paleocene age.

In the eastern part of the field, small tonnages of anthracite are included with the reserves of bituminous coal (tables 1 and 2) because it is present only locally near sills of basalt that have intruded the coal-bearing rocks, and geologic information is not sufficient to permit an accurate delineation of these small areas.

The reserves in the eastern part of the field were obtained from a recent report on the field by Bass (in preparation). The coal reserves given in his report were estimated, by Spencer, separately for each bed and were divided into the three thickness categories; three depths of overburden zones, based on maximum cover of 1,000, 2,000, and 3,000 feet; and into measured, indicated, and inferred reserves.

The reserves in the western part of the field were obtained from a report by Hancock (1925, p. 53), who based his estimate on an average total thickness of coal in each group of coal beds in the Iles and Williams Fork formations of the Mesaverde group. Hancock drew outcrop lines "at a horizon representing the center or weight" of each coal group and calculated reserves by townships to a depth of 3,000 feet. His tonnage figures are included in the tables of this report, but the reserves for the upper beds are transferred from bituminous to subbituminous rank in order to conform with the more recent classification of coal used by the American Society for Testing Materials.

Uinta region

The Uinta region occupies the Colorado portion of the Uinta Basin which is a broad structural depression, extending from the middle of Gunnison County, Colorado, northwestward into central Utah. The coal-bearing rocks form a band nearly encircling the region. The band is extremely narrow along much of the eastern margin of the region because there the rocks dip steeply southwestward. The data available, however, suggest (1) that the steep dips prevail only a very short distance southwest of the outcrop, and (2) that, except for the rim area, gentle dips probably prevail throughout most of the Uinta region. Deep wells, out in the basin, suggest that in large areas the depth to the coals of the Mesaverde group exceeds two miles. Large folds in the northeastern and northwestern parts of the region cause the outcrop band of coal-bearing rocks here to be relatively broad. The band is of medium width on the southwestern margin of the region, for here the rocks dip gently northeastward.

The coal of the Uinta region occurs in several zones in the Mesaverde formation of Late Cretaceous age. Individual beds range from less than 3 to more than 20 feet in thickness. The region is divided into eight coal fields: the Danforth Hills, Lower White River, Book Cliffs, Grand Mesa, Somerset, Crested Butte, Carbondale, and Grand Hogback fields.

Igneous intrusions and extrusions have greatly disturbed the southeastern end of the region and have markedly affected the rank of the coal. The Crested Butte field in this area contains large reserves of anthracite and semianthracite. This field together with the adjacent Somerset and Carbondale fields constitute the second largest coke-producing area in the West.

Danforth Hills field.—The Danforth Hills field in the northern part of the region includes parts of Moffat and Rio Blanco Counties. The coal is of bituminous rank and occurs in the Williams Fork formation of the Mesaverde group. The field contains 3 to 10 workable coal beds ranging from 3 to 18 feet in thickness.

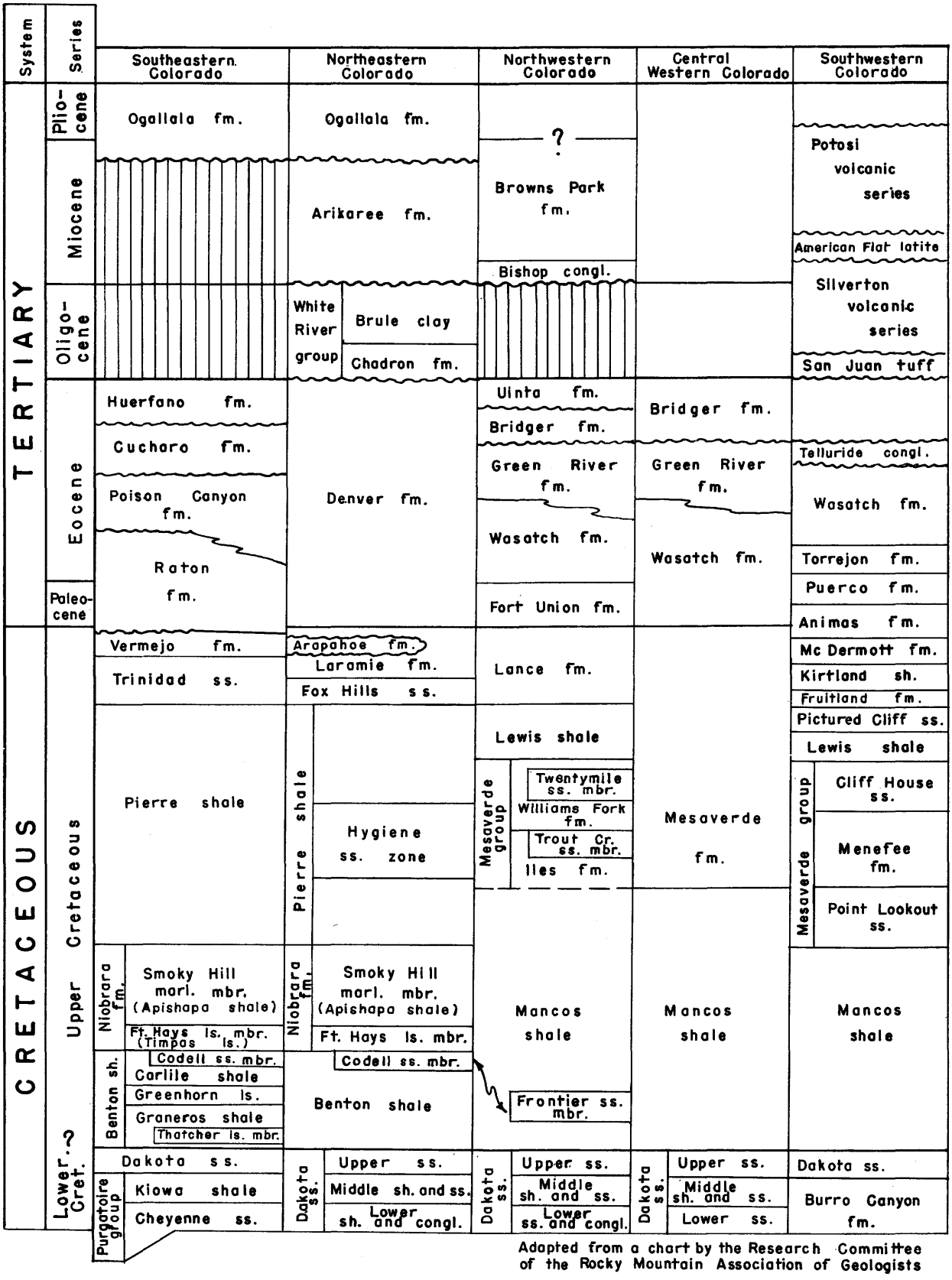

Figure 1.--Chart showing tentative correlations of Cretaceous and Tertiary rocks in Colorado.

Reserves for the field east of the 108th meridian were obtained from two reports by Hancock (1925 and 1929), in which the reserves were estimated by the same method employed in the western part of the Yampa field. Reserves for the field west of the 108th meridian were calculated from acreages of coal land shown by Gale (1910) and the average total thickness of coal in several beds shown in his stratigraphic sections.

Lower White River field.—The Lower White River field is in Rio Blanco and Garfield Counties. The coal is of bituminous rank and occurs in the Williams Fork formation of the Mesaverde group. Reserves in this field were calculated from average total thicknesses of coal in several beds as described by Gale (1910). The areal extent and thickness of overburden were estimated from his geologic maps and from recent field work by Geological Survey field parties.

Book Cliffs field.—The Book Cliffs field includes parts of Garfield and Mesa Counties. In this field, 2 to 5 workable bituminous coal beds are present in the Mesaverde formation. Each bed ranges from 3 to 21 feet in thickness.

The reserves for the field were taken from a report by Erdmann (1934, pp. 92-99), in which he drew thickness lines on each coal bed and calculated "immediate" reserves by coal beds within a strip of land extending 3,000 feet back from the outcrop, and "future" reserves for an area extending a distance back from the outcrop equal to one-half the length of the outcrop.

Grand Mesa field.—The Grand Mesa field includes parts of Mesa and Delta Counties. The coal occurs in strata equivalent to the Paonia and Bowie members of the Mesaverde formation and is of bituminous rank.

Reserves for the field were calculated from data contained in a report by Lee (1907, p. 332). The estimates were based on an average total thickness of several coal beds and an assumed limit of available coal 6 miles back from the outcrop.

Somerset field.—The Somerset field includes parts of Delta and Gunnison Counties. Eight to 10 workable beds of bituminous coal occurring in the Mesaverde formation are present in the field. Several of the coal beds each average from 6 to 7 feet in thickness; however, small areas of lenticular coal from 20 to 42 feet in thickness are present. There is some coking coal in the field.

Data used in calculating the reserves of the Somerset field were derived from reports by Lee (1907) and Johnson (1948). Johnson calculated reserves by estimating the thickness of individual beds and calculating the reserves under less than 3,000 feet of overburden. His information included data derived from mines, core drilling, and field mapping. In the area adjacent to that mapped by Lee (1907) and Johnson (1948) reserves were computed by using average thicknesses of coal shown by Lee and Johnson and estimating the areal extent of the coal lying at a depth of less than 3,000 feet.

Crested Butte field.—The anthracite, semianthracite, and bituminous coal reserves of the Crested Butte field in Gunnison County are in strata equivalent to the Bowie shale and overlying Paonia shale members of the Mesaverde. Several coal beds of minable thickness occur in each of the two members, and a total of eight beds have been observed in one locality. Accurate determinations of thickness are difficult because of the deformation in the area, but, in general, the thicker beds range between 4 to 22 feet in thickness. Comparatively large reserves of coking coal are present in the field.

Reserves for a large part of the field were obtained from reserve figures in geologic reports by Emmons (1894), Lee (1912), and Johnson (1948). The reserves for most of the area, however, are taken from Lee's report. Lee obtained an average total thickness of coal in each district, estimated the areal extent of the beds, and computed the reserves from these data. In portions of the field not mapped by Lee, Johnson, or Emmons, reserves were calculated from data in the adjacent mapped areas.

Carbondale field.—The Carbondale field includes parts of Pitkin, Gunnison, and Garfield Counties. The coal in this field occurs in the Mesaverde formation and is of bituminous rank. The coal present in Pitkin and Gunnison Counties will coke. The reserves were calculated by using the average total thickness in several beds shown in a report by Gale (1910), and by estimating the area under which the coal lies at depths of less than 3,000 feet.

Grand Hogback field.—The Grand Hogback field, in Garfield and Rio Blanco Counties, contains coal of bituminous rank. The coal occurs in several zones in the Mesaverde formation. The reserves for the field were calculated by using Gale's estimated area of coal lands (1910, p. 112) and an average total thickness of the coal in several beds shown in his stratigraphic section.

Tongue Mesa field

The relatively small Tongue Mesa field, south of the Uinta region, includes parts of Montrose, Gunnison, and Ouray Counties. The field contains subbituminous coal in Mesaverde strata. The reserves were calculated from data on thickness of the coal and the measured areal extent of the coal-bearing rocks contained in a report by Storr (1901, p. 439).

San Juan River region

The San Juan River region is in southwestern Colorado and includes parts of Montezuma, La Plata, and Archuleta Counties. It occupies part of the San Juan Basin, a broad structural depression approximately 125 miles long, lying in southwestern Colorado and northwestern New Mexico.

The coal is of bituminous rank. It occurs in the Dakota sandstone, the Menefee formation of the Mesaverde group, and in the Fruitland formation. The largest part of the reserves is contained in the Menefee and Fruitland formation.

The Pagosa field in Archuleta County and the small coal-bearing areas in Montrose and Montezuma Counties

northwest of the Durango field are not a part of the San Juan River region as shown on plate 1, but for convenience the reserves for these areas are included with the reserves of the region.

Durango and adjacent fields.—The reserves for the Durango coal field were obtained from a report by Zapp (1949), which gives estimates for reserves in individual coal beds divided into thickness categories; overburden categories; and measured, indicated, and inferred categories. The coal occurs in the Menefee formation of the Mesaverde group and the Fruitland formation of Late Cretaceous age. The reserves for the large area southwest of the Durango field, chiefly in Montezuma County, were obtained from a report by Barnes (in preparation). Barnes calculated reserves partly by individual coal beds and partly by total thickness of the coal in zones containing several beds. He also calculated reserves for the western part of Archuleta County lying west of the Piedra River. The reserves for the area lying east of the Piedra River in Archuleta County were calculated from data on thicknesses of coal beds supplied by Wood (1952). The coal in this area occurs in the Fruitland formation of Late Cretaceous age.

Coal-bearing areas in Montrose and Montezuma Counties.—The coal reserves in Montrose and Montezuma Counties, located north of the Durango field, were calculated from data in unpublished geologic reports in the Geological Survey's files of field investigations of widely separated tracts of land. The coal found here is generally thin and very lenticular. It occurs in the Dakota sandstone.

Pagosa field.—Reserves for the Pagosa field in Archuleta County were calculated from the information contained in a report by Cross (1935, p. 132). The coal is of subbituminous rank and occurs in the Animas formation of Late Cretaceous and Paleocene age.

Raton Mesa region

The Raton Mesa region is located in southern Colorado in Las Animas and Huerfano Counties. Structurally the area is a northward trending syncline with steep dips on the west side and gentle dips on the east side.

In the northwestern part of the region, igneous intrusives have developed many local variations in the character of the coal and have aided in converting large quantities of lower rank coal into higher rank bituminous coal. The southern part of this region is the third largest producer of coking-coal in the West.

The coal occurs in three zones, the lower in the Vermejo formation of Late Cretaceous age, and the middle and upper in the Raton formation of Paleocene and Eocene ages. The beds in the lower zone are most persistent and contain the highest rank bituminous coal in the field.

As many as eight workable beds are present in parts of the field. They are generally discontinuous, however, and only a few are persistent over wide areas. The beds range from 2 to 14 feet in thickness.

The reserves for a part of the region were obtained from a report by Wood and others (1951) and in part from unpublished reports by Wood and others which include the results of recent field investigations. These calculations were made by the same methods as described for the eastern part of the Yampa coal field.

Canon City field

The Canon City field is in central Colorado in Fremont County. Structurally the field is a syncline with steep overturned dips on the west and gentle dips on the east. The coal is bituminous in rank and occurs in the Vermejo formation of Late Cretaceous age. The computations for the reserves in the field were made by individual beds, based on data in reports by Washburne (1908).

South Park field

South Park field in Park County occupies a faulted synclinal area about 20 miles long and 5 miles wide. The coal found in the field is bituminous in rank and occurs in three main beds separated by barren strata of considerable thickness. Although locally very thick, the beds are irregular in thickness and in many areas contain little workable coal. The age of the coal-bearing rocks in the field have not been determined precisely; however, they are believed to be correlative with the Laramie formation.

An average total thickness of coal was used in calculating the reserves, based on data in reports by Washburne (1908).

Denver region

The Denver region is in northeastern Colorado and includes all of Denver County and parts of Adams, Arapahoe, Boulder, Douglas, Elbert, El Paso, Jefferson, Larimer, Morgan, and Weld Counties. Structurally the region is a broad basin extending southward from Wyoming past the middle of El Paso County in central Colorado.

The coal in the Denver region is of subbituminous rank and occurs in the Laramie formation of Late Cretaceous age and in the Denver formation of Paleocene and Late Cretaceous age.

Calculation of the reserves for the several small coal fields in the region were made from data obtained from several sources. The tonnages were estimated from the weighted average total thickness of coal in each coal-bearing zone and from the areal extent of the zones. The coal zones were assumed to extend 4 miles basinward from outcrops and for a radius of 2 miles from drill holes or small isolated mining areas. The data for the Northern coal field were derived from Eldridge (Emmons and others, 1896) and from a current investigation of the field by Spencer (in preparation). Data for the Scranton field and the fields west, southwest, and southeast of Denver were obtained from reports by Eldridge (Emmons and others, 1896), Dane

and Pierce (1936), Brown (1943), and Allen (1951). Data for the field on the Larimer-Weld County boundary, just south of the Colorado-Wyoming line, were obtained from reports by Eldridge (Emmons and others, 1896), Allen (1939), and the Colorado State Planning Commission (1940); that on the Colorado Springs field from a report by Goldman (1908).

North Park field

The North Park field is in Jackson County in northwestern Colorado. The coal is of subbituminous rank and occurs in the Coalmont formation of Eocene age. Although the extent and thickness of the workable coal in many parts of the field have not been determined, it is not uncommon to find lenticular coal in beds 50 feet or more in thickness.

The reserve estimate for the field was obtained from a report by Beekly (1915, p. 115). His calculations were based entirely on one thick coal bed in one district and the area was limited to a tract where the coal lies at minable depth. The reserve figure, therefore, appears to be conservative.

HISTORY OF COAL PRODUCTION

The presence of coal in Colorado has been described by many early writers. In 1820, coal was noted in the Canon City area by an exploration party headed by S. H. Long (James, 1823, p. 267). Later in 1848, General Emory found coal in the Raton Mesa region (Hayden, 1868, p. 199). Coal was mined commercially in the State in the Denver region as early as 1860 on Coal (Upper Sand) Creek, T. 4 S., R. 65 W. The earliest production records of the Colorado State Mine Inspector show that 43,600 tons of coal was produced in Colorado during the years 1864-69, all of which was from the Denver region. (See table 5.) The highest annual production of coal was reached in 1917, when a total of 12½ million tons was mined. (See table 6.) The record of past coal production in Colorado has been maintained largely through the office of the Colorado State Mine Inspector, and most of the figures presented in tables 5 and 6 were obtained originally from this source.

The demand for coking-coal for use in the various industries of Colorado has increased considerably in the last few years. Approximately 1 million tons of coking-coal is used annually in the State in the manufacture of coke. About 25 percent of this amount is imported from Arkansas, New Mexico, and Oklahoma to be used as a blend with the Colorado coals. Over a ten year period, 1939-49, the production of coke in the State increased markedly. The total production of coke in 1939 was approximately 398,000 tons, as compared to the total production in 1949 of 739,000 tons. Although exact figures are not available, the reserves of coking-coal in the State are believed adequate to supply the demand for coke far into the future.

Most coal in the State is mined by underground methods. Of the 4.1 million tons of coal mined in 1951, more than 3.7 million tons, or 91 percent, was produced from underground mines. Strip-mining has been carried on in the State since as early as 1931, although the amount of coal mined by this method did not exceed 1 percent of the total State production until 1946. In 1951, however, 363,000 tons, or 9 percent of the total State production, was from strip mines.

CONCLUSIONS

With remaining reserves of 99,450 million tons as currently estimated, Colorado contains larger reserves of coal than many coal-bearing states, particularly reserves of higher rank coal and coal suitable for making coke. Its present production of 4 to 5 million tons annually is exceeded in the West only by that of Utah and Wyoming. With large reserves of high rank and high quality coal, and demonstrated productive capacity, Colorado stands as a storehouse of energy ready to be tapped as future needs dictate.

Table 5.--Coal produced in Colorado from 1864-86[1]
(In short tons)

Year	Tons	Year	Tons	Year	Tons
1864	500	1872	68,540	1880	437,005
1865	1,200	1873	69,977	1881	706,744
1866	6,400	1874	77,372	1882	1,061,479
1867	17,000	1875	98,838	1883	1,229,593
1868	10,500	1876	117,666	1884	1,130,024
1869	8,000	1877	160,000	1885	1,356,062
1870	13,500	1878	200,630	1886	1,368,338
1871	15,600	1879	322,732	Total	8,477,700

[1]U. S. Geol. Survey Mineral Resources of the United States, 1886.

Table 6.--Coal produced in Colorado from 1887 to Jan. 1, 1952 by counties[1]
(In short tons)

Year	Boulder	Delta	El Paso	Fremont	Garfield	Gunnison	Huerfano	Jefferson	La Plata	Las Animas
1887	288,218	---	47,517	417,326	30,000	243,122	131,810	12,000	22,880	506,540
1888	315,155	---	44,114	438,789	115,0000	258,374	159,610	9,000	33,625	706,455
1889	323,096	1,357	54,212	274,029	239,292	252,442	333,717	10,790	34,971	993,534
1890	425,704	775	25,617	397,418	183,884	229,212	427,832	10,984	43,193	1,154,668
1891	498,494	---	34,364	545,789	191,994	261,350	494,466	17,910	72,471	1,219,224
1892	545,563	200	23,014	538,887	277,794	225,260	541,733	21,219	81,500	1,171,069
1893	663,220	2,580	19,415	536,787	212,918	258,539	521,205	1,895	104,992	1,587,338
1894	419,734	3,697	30,268	245,616	75,663	200,325	408,045	34,108	53,571	1,153,863
1895	377,395	4,514	51,840	315,344	274,271	239,182	386,696	---	106,099	1,253,149
1896	448,706	[10] 3,856	([11])	294,822	165,797	260,596	353,338	---	104,661	1,261,555
1897	477,790	5,765	[8] 12,849	304,589	182,884	297,417	367,894	[13] 15,445	76,788	1,427,526
1898	451,539	5,052	([11])	426,553	222,480	323,321	1,075,881	12,366	100,650	1,211,340
1899	540,475	6,100	27,668	620,609	134,354	319,434	632,577	9,900	116,500	2,125,143
1900	574,334	5,417	94,334	619,413	141,159	432,555	854,944	([11])	123,524	2,123,411
1901	482,975	5,844	175,979	536,313	173,707	397,043	918,609	([11])	144,892	2,476,138
1902	806,371	9,350	218,549	695,999	207,262	364,874	1,189,313	---	155,029	3,245,271
1903	803,924	13,029	207,797	633,858	176,354	436,604	1,319,666	---	143,637	3,213,743
1904	736,824	21,683	248,013	256,200	198,545	494,545	1,187,905	([11])	146,080	2,808,953
1905	839,804	9,497	188,775	512,002	172,563	513,317	1,426,640	([11])	168,669	4,297,599
1906	1,022,096	6,812	210,793	666,034	193,063	583,175	1,803,791	([11])	173,720	4,768,882
1907	1,296,729	22,087	269,795	772,949	220,040	588,859	1,797,790	([11])	184,018	4,885,105
1908	1,067,948	37,689	317,763	669,274	220,099	503,140	1,644,068	([11])	166,090	4,190,801
1909	1,332,322	55,031	312,233	611,980	257,796	598,463	1,915,910	([11])	139,858	4,592,964
1910	802,769	63,590	336,780	722,142	189,755	640,982	2,387,090	([11])	147,755	5,548,085
1911	954,752	71,399	332,155	661,240	165,908	575,648	1,786,654	([11])	96,749	4,458,753
1912	1,054,925	75,043	334,904	738,833	185,452	557,685	1,899,538	([11])	132,487	4,708,698
1913	902,918	86,464	326,899	535,778	158,662	472,753	1,705,240	([11])	140,055	3,739,357
1914	1,000,590	86,861	280,577	169,271	112,842	402,045	1,724,265	([11])	132,317	2,693,288
1915	946,888	69,053	299,883	473,284	139,393	439,403	1,682,335	[29] 152,498	117,502	2,853,847
1916	1,057,539	70,696	312,670	605,108	133,771	512,265	1,884,943	[29] 185,704	108,603	4,042,937
1917	1,277,663	94,569	371,166	871,846	104,463	655,584	2,411,440	[29] 217,486	139,478	4,359,844
1918	1,360,261	89,476	301,647	871,326	92,655	652,770	2,586,911	126,330	138,963	4,250,291
1919	1,122,485	90,301	306,039	823,743	20,539	477,674	1,858,661	([11])	111,333	3,303,970
1920	1,218,504	120,899	383,977	871,532	28,376	618,894	2,395,261	[29] 228,821	127,732	4,219,086
[35] 1921	851,686	89,935	288,531	590,821	16,795	479,007	1,755,750	[36] 181,027	99,653	2,727,713
1922	728,943	105,203	389,403	478,202	19,778	437,522	2,069,350	180,547	79,086	3,370,064
1923	628,002	107,600	355,583	613,463	22,340	542,992	1,965,417	[36] 214,047	110,757	3,189,502
1924	683,544	87,325	363,941	698,300	26,420	469,021	1,990,741	127,382	92,136	3,118,572
1925	619,985	70,120	296,640	634,788	30,263	513,880	2,102,470	[41] 104,087	103,041	2,986,277
1926	619,550	74,629	352,596	570,345	31,305	574,641	1,965,912	[41] 105,296	106,004	3,299,599
1927	441,991	91,793	356,510	447,485	30,279	559,116	1,815,930	60,332	89,823	3,183,945
1928	428,195	70,519	349,746	472,501	35,773	462,844	1,781,394	100,409	86,568	2,910,631
1929	480,126	74,360	359,146	531,670	44,906	518,786	1,772,558	98,826	74,121	2,543,895
1930	429,197	70,356	344,989	402,978	36,275	499,627	1,375,456	123,471	56,876	1,945,290
1931	498,088	60,529	345,761	345,882	31,585	402,117	978,268	140,314	30,068	1,336,253
1932	578,921	52,637	313,209	351,707	33,649	403,653	674,845	132,551	22,541	859,107

1933	459,880	43,972	299,354	346,815	28,162	404,573	572,833	141,592	21,918	855,569
1934	461,796	36,609	299,293	352,736	28,072	443,073	608,445	135,635	18,849	864,130
1935	498,773	52,676	302,086	417,029	40,315	491,254	668,748	137,533	28,660	953,791
1936	503,274	69,049	291,802	492,542	45,978	627,652	766,914	169,131	34,947	1,225,846
1937	528,540	68,111	293,053	503,170	52,394	659,163	787,683	179,096	40,180	1,425,197
1938	590,351	54,984	264,308	471,012	44,912	522,071	591,667	160,215	32,533	803,648
1939	608,433	61,614	[53] 428,380	510,007	37,978	530,425	615,167	([11])	28,195	1,067,136
1940	622,556	65,707	250,434	515,756	34,925	619,249	753,133	147,501	29,146	1,252,332
1941	654,334	73,244	237,552	516,161	37,344	708,037	815,632	([11])	31,443	1,352,119
1942	711,320	94,662	248,491	540,191	53,768	774,358	982,815	147,057	43,534	1,457,318
1943	605,266	113,523	249,436	567,648	58,958	751,274	1,088,838	[41] 157,915	55,238	1,695,153
1944	604,039	120,216	232,251	621,277	56,178	749,982	1,003,802	[29] 156,435	69,680	1,583,232
1945	477,099	131,505	215,206	552,199	58,037	775,803	882,897	[29] 150,662	68,342	1,432,208
1946	377,639	98,899	191,186	349,507	49,342	609,203	613,846	[29] 160,940	56,147	1,070,392
1947	326,198	102,415	214,494	429,600	51,956	623,110	585,181	[29] 164,097	48,977	1,289,582
1948	235,074	97,554	192,788	394,873	46,906	588,006	551,379	[29] 138,620	48,923	1,142,004
1949	165,250	84,516	126,992	339,651	49,667	491,485	439,130	[29] 97,096	45,091	889,306
1950	109,565	71,560	112,986	274,273	49,401	401,990	304,730	[36] 30,225	46,685	965,904
1951	113,012	75,267	89,622	281,937	39,649	338,071	311,812	[36] 10,315	41,936	998,445
Total production 1889-1951	42,078,337	3,609,775	14,857,375	33,289,209	6,822,045	31,258,837	75,408,521	4,918,810	5,631,490	150,346,597

Year	Mesa	Moffat	Montezuma	Pitkin	Rio Blanco	Routt	Weld	Other counties	Small mines	Total
1887	---	---	---	---	---	---	48,401	[2] 43,921		1,791,735
1888	300	---	---	28,113	---	---	28,054	[2] 48,888		2,185,477
1889	1,100	---	816	---	2,900	1,491	28,628	[3] 44,806		2,597,181
1890	1,000	---	238	74,362	200	705	46,417	[4] 54,794		3,077,003
1891	5,000	---	---	91,642	---	---	22,554	[5] 57,374		3,512,632
1892	5,050	---	30	---	100	330	2,205	[6] 76,876		3,510,830
1893	18,100	---	90	99,211	---	816	35,355	[7] 39,928		4,102,389
1894	31,750	---	235	97,724	1,680	2,710	42,818	[8] 29,602		2,831,409
1895	41,150	---	190	---	1,761	2,767	27,934	[9] 690		3,082,982
1896	28,979	---	203	168,413	1,400	1,832	4,300	[12] 13,942		3,112,400
1897	[14] 10,508	---	([11])	171,111	1,882	945	8,310	---		3,361,703
1898	[14] 10,690	---	([11])	195,496	1,341	1,339	24,085	[12] 14,214		4,076,347
1899	[14] 17,572	---	([11])	[15] 174,172	([11])	1,211	47,573	[16] 2,936		4,776,224
1900	[14] 8,990	---	([11])	175,942	[17] 3,911	1,375	80,015	[16] 5,040		5,244,364
1901	[18] 27,103	---	([11])	325,872	([11])	1,558	33,374	[16] 608		5,700,015
1902	[19] 432,464	---	---	---	([11])	3,180	73,681	---		7,401,343
1903	28,452	---	---	[20] 346,774	([11])	2,775	94,492	---	2,497	7,423,602
1904	26,450	---	---	[21] 405,297	---	5,568	118,862	---	3,430	6,658,355
1905	49,500	---	---	[21] 539,752	---	3,643	101,812	---	2,856	8,826,429
1906	37,696	---	([11])	[22] 542,519	([11])	5,297	95,420	---	1,920	10,111,218
1907	44,530	---	([11])	[22] 564,380	([11])	5,690	136,074	---	2,190	10,790,236
1908	59,250	---	([11])	[23] 399,452	([11])	13,005	343,414	---	2,980	9,634,973
1909	98,241	---	([11])	[24] 364,114	([11])	92,439	327,545	---	18,040	10,716,936
1910	129,530	---	---	[25] 419,212	([11])	258,452	322,896	---	4,698	11,973,736

Table 6.--Coal produced in Colorado from 1887 to Jan. 1, 1952 by counties[1]--Continued

Year	Mesa	Moffat	Montezuma	Pitkin	Rio Blanco	Routt	Weld	Other counties	Small mines	Total
1911	92,881	---	(11)	[26] 111,662	(11)	317,791	520,396	---	11,395	10,157,383
1912	114,493	---	(11)	[27] 222,286	---	448,261	491,037	---	14,182	10,977,824
1913	134,438	---	---	[25] 277,505	(11)	334,961	409,131	---	8,349	9,232,510
1914	163,894	---	(11)	[28] 256,959	(11)	666,384	475,734	---	5,532	8,170,559
1915	101,327	---	[30] 2,375	[15] 52,143	(11)	852,315	432,501	---	10,233	8,624,980
1916	132,111	---	---	[15] 42,861	(11)	915,028	464,959	---	15,042	10,484,237
1917	179,222	---	---	[15] 26,693	(11)	1,074,103	654,977	---	[31] 44,802	12,483,336
1918	191,043	---	---	[32] 98,078	(11)	941,355	687,609	---	[31] 18,856	12,407,571
1919	116,321	---	---	[33] 225,136	(11)	1,181,332	659,660	---	26,226	10,323,420
1920	170,256	(11)	---	---	[34] 6,472	964,342	920,073	---	4,000	12,278,225
[35] 1921	113,761	(11)	(11)	[37] 10,992	(11)	889,015	1,028,074	---	14,869	9,137,629
1922	151,937	4,875	[38] 4,002	[36] 66,092	3,349	432,198	1,473,911	---	25,135	10,019,597
1923	180,574	(11)	(11)	[39] 12,130	3,706	803,455	1,577,430	---	19,220	10,346,218
1924	135,489	6,963	5,484	[40] 72,844	3,188	911,643	1,648,646	[41] 2,459	---	10,444,098
1925	126,011	7,188	5,192	[40] 70,520	6,264	1,009,703	1,624,122	---	---	10,310,551
1926	125,632	4,950	5,659	[42] 66,606	(11)	920,569	1,813,932	---		10,637,225
1927	113,823	3,913	4,804	[36] 74,965	4,598	925,633	1,509,573	[43] 9,562		9,724,075
1928	160,048	4,896	6,086	[44] 83,274	5,165	929,190	1,947,386	[45] 13,082		9,847,707
1929	113,151	5,853	5,163	[29] 75,025	5,977	1,006,157	2,196,258	[45] 14,763		9,920,741
1930	91,183	7,637	4,969	[36] 64,615	5,599	838,828	1,891,099	[46] 8,465		8,196,910
1931	90,398	5,147	6,678	[47] 12,038	6,931	570,886	1,696,878	[48] 46,548		6,604,369
1932	65,452	3,798	3,677	[49] 49,247	5,323	572,458	1,472,519	[13] 3,427		5,598,721
1933	68,919	2,606	3,304	[29] 29,745	4,264	467,551	1,470,413	[50] 8,297		5,229,767
1934	54,218	2,945	5,056	[29] 25,672	3,937	485,311	1,375,783	[50] 9,373		5,210,933
1935	65,755	6,804	7,298	[51] 3,741	4,518	789,905	1,408,375	[52] 33,250		5,910,511
1936	64,762	6,871	4,510	[51] 3,601	5,206	987,338	1,480,260	[52] 32,119		6,811,802
1937	78,268	18,229	(11)	[14] 15,891	4,320	1,024,621	1,477,673	[52] 31,622		7,187,211
1938	65,116	35,205	(11)	[14] 30,159	4,254	741,431	1,231,371	[52] 19,907		5,663,144
1939	77,464	55,900	(11)	[54] 32,418	(11)	727,440	1,134,630	[41] 8,023		5,923,210
1940	69,664	48,162	[10] 43,218	[55] 7,694	(11)	909,942	1,197,585	[52] 21,738		6,588,742
1941	106,254	49,459	(11)	[56] 5,916	[10] 57,358	878,952	1,276,231	[57] 148,496		6,948,532
1942	118,629	65,817	---	(11)	[56] 15,064	[10] 1,231,608	1,585,159	[36] 15,889		8,085,680
1943	100,188	[29] 100,689	---	---	[10] 50,869	1,194,483	1,534,714	---		8,324,192
1944	103,785	138,394	---	---	[10] 54,497	1,187,237	1,484,263	[41] 2,445		8,167,713
1945	106,732	128,595	---	---	[10] 40,796	1,093,294	1,505,904	[41] 1,733		7,621,021
1946	91,846	142,923	1,251	---	[10] 11,927	896,303	1,145,968	[41] 1,189		5,868,508
1947	103,790	146,494	---	---	[10] 23,572	1,016,823	1,230,683	[41] 1,132		6,358,104
1948	97,651	144,288	---	---	[10] 35,142	939,875	976,532	[41] 1,171		5,630,786
1949	92,775	130,404	1,295	4,327	[10] 48,050	807,289	823,013	[41] 1,095		4,636,432
1950	88,437	125,743	1,598	6,873	[58] 73,611	832,928	778,378	---		4,274,887
1951	93,749	110,275	1,222	8,468	[58] 40,190	678,698	879,267	---		4,111,945
Total production 1887-1951	5,624,852	1,515,023	124,643	7,329,734	549,322	34,803,764	51,686,326	869,404	256,452	470,980,516

[1] 1864-92, 1900-32, U. S. Geol. Survey: Mineral Resources of the United States. 1893-99, U. S. Geol. Survey Annual Reports 16-21. 1932-49, U. S. Bureau of Mines: Minerals Yearbook. 1950-51, Colorado State Mine Inspector Record.

[2] Includes Arapahoe, Douglas, Dolores, and Park Counties.

[3] Includes Arapahoe, Douglas, Larimer, Park, and San Miguel Counties.

[4] Includes Arapahoe, Douglas, Dolores, Larimer, Park, and San Miguel Counties.

[5] Includes Arapahoe, Dolores, and Park Counties.

[6] Includes Arapahoe, Douglas, and Park Counties.

[7] Includes Arapahoe, Douglas, Montrose, and Park Counties.

[8] Includes Arapahoe County.

[9] Includes Arapahoe and Montrose Counties.

[10] Includes Montrose County.

[11] Production included elsewhere.

[12] Includes Arapahoe, El Paso, and Larimer Counties.

[13] Includes Larimer.

[14] Includes Montrose and Montezuma Counties.

[15] Includes Rio Blanco County.

[16] Includes Arapahoe and Larimer Counties.

[17] Includes Jefferson County.

[18] Includes Jefferson, Rio Blanco, Montezuma, and Montrose Counties.

[19] Includes Arapahoe, Larimer, Montezuma, Ouray, Pitkin, and Rio Blanco Counties.

[20] Includes Arapahoe, Larimer, and Rio Blanco Counties.

[21] Includes Adams, Jefferson, and Larimer Counties.

[22] Includes Adams, Archuleta, Jefferson, Larimer, Montezuma, and Rio Blanco Counties.

[23] Includes Archuleta, Douglas, Jefferson, Larimer, Montezuma, and Rio Blanco Counties.

[24] Includes Archuleta, Jefferson, Montezuma, and Rio Blanco Counties.

[25] Includes Archuleta, Jackson, Jefferson, and Rio Blanco Counties.

[26] Includes Archuleta, Jefferson, Larimer, Montezuma, and Rio Blanco Counties.

[27] Includes Archuleta, Jackson, Jefferson, and Montezuma Counties.

[28] Includes Archuleta, Jackson, Jefferson, Montezuma, and Rio Blanco Counties

[29] Includes Jackson County.

[30] Includes Archuleta County.

[31] Includes Montrose and Ouray Counties.

[32] Includes Jackson and Rio Blanco Counties.

[33] Includes Jackson, Jefferson, Moffat, and Rio Blanco Counties.

[34] Includes Moffat County.

[35] Exclusive of Wagon Mines in 1921 and from 1924-52.

[36] Includes Jackson and Elbert Counties.

[37] Includes Moffat, Montezuma, Ouray, and Rio Blanco Counties.

[38] Includes Ouray County.

[39] Includes Archuleta, Moffat, Montezuma, and Montrose Counties.

[40] Includes Archuleta, Jackson, and Montrose Counties.

[41] Includes Elbert County.

[42] Includes Archuleta, Jackson, Montrose, and Rio Blanco Counties.

[43] Includes Dolores, Ouray, and San Miguel Counties.

[44] Includes Jackson and Montrose Counties.

[45] Includes Dolores, Elbert, and San Miguel Counties.

[46] Includes Dolores, Montrose, and Ouray Counties.

[47] Includes Montrose, Ouray, and Park Counties.

[48] Includes Archuleta, Elbert, Jackson, and Larimer Counties.

[49] Includes Arapahoe, Elbert, Jackson, Montrose, and Ouray Counties.

[50] Includes Elbert and Larimer Counties.

[51] Includes Montrose and San Miguel Counties.

[52] Includes Elbert, Jackson, and Larimer Counties.

[53] Includes Jackson, Jefferson, and Larimer Counties.

[54] Includes Archuleta, Montezuma, Montrose, and Rio Blanco Counties.

[55] Includes Archuleta and Rio Blanco Counties.

[56] Includes Montezuma County.

[57] Includes Elbert, Jackson, Jefferson, and Larimer Counties.

[58] Includes Archuleta, Montrose, and San Miguel Counties.

BIBLIOGRAPHY

Allen, Thomas, 1939-40, 27th and 28th Annual report of the (Colorado) State Inspector of coal mines.

_____ 1950-51, Annual report to the Governor by the Colorado State Coal Mine Inspection Department.

Amer. Soc. Testing Materials, 1939, Standard specifications for classification of coals by rank (A. S. T. M. Designation: D388-38): 1939 Book of A. S. T. M. Standards, pt. 3, pp. 1-6.

Beekly, A. L., 1915, Geology and coal resources of North Park, Colo.: U. S. Geol. Survey Bull. 596, 118 pp.

Berryhill, L. R., and Averitt, Paul, 1951, Coking-coal deposits of the western United States: U. S. Geol. Survey Circ. 90, 20 pp.

Bituminous Coal Annual, 1950, Nat. Coal Assoc.

Brown, R. W., 1943, Cretaceous-Tertiary boundary in the Denver Basin, Colorado: Geol. Soc. Am. Bull., vol. 54, pp. 65-86.

Campbell, M. R., 1913, Coal reserves of the United States: Coal resources of the World, vol. 2, Marang and Co. Ltd., Toronto, Canada, pp. 525-539.

_____ 1923, The Twentymile Park district of the Yampa coal field, Routt County, Colo.: U. S. Geol. Survey Bull. 748, 79 pp.

Collier, A. J., 1919, Coal south of Mancos, Montezuma County, Colo.: U. S. Geol. Survey Bull. 691, pp. 293-310.

Colorado State Planning Commission, 1940, Coal fields of northeastern Colorado (map).

Cross, W., and Larsen, E. S., 1935, A brief review of the geology of the San Juan region of southwestern Colorado: U. S. Geol. Survey Bull. 843, 138 pp.

Dane, C. H., and Pierce, W. G., 1936, Dawson and Laramie formations in southeastern part of Denver Basin: Am. Assoc. Petroleum Geologists, vol. 20, no. 10, pp. 1308-1328.

Emmons, S. F., 1894, Anthracite-Crested Butte, Colo.: U. S. Geol. Survey Geol. Atlas, folio 9.

Emmons, S. F., Cross, W., and Eldridge, G. H., 1896, Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, 556 pp.

Erdmann, C. E., 1934, The Book Cliffs coal field in Garfield and Mesa Counties, Colo.: U. S. Geol. Survey Bull. 851, 150 pp.

Fenneman, N. M., 1905, Geology of the Boulder district, Colorado: U. S. Geol. Survey Bull. 265, 101 pp.

Fenneman, N. M., and Gale, H. S., 1906, The Yampa coal field, Routt County, Colorado: U. S. Geol. Survey Bull. 297, 96 pp.

Finley, G. I., 1916, Colorado Springs, Colo.: U. S. Geol. Survey Geol. Atlas, folio 203.

Gale, H. S., 1907, Coal fields of the Danforth Hills and Grand Hogback in northwestern Colorado: U. S. Geol. Survey Bull. 316, pp. 264-301.

_____ 1910, Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, 265 pp.

Goldman, M. I., 1908, The Colorado Springs coal field, Colorado: U. S. Geol. Survey Bull. 381, pp. 317-340.

Hayden, F. V., 1868, Notes on the lignite deposits of the West: The Am. Jour. Science and Arts, vol. 45, no. 134, article 22, pp. 198-208.

Hancock, E. T., 1925, Geology and coal resources of the Axial and Monument Butte quadrangles, Moffat County, Colo.: U. S. Geol. Survey Bull. 757, 134 pp.

Hancock, E. T,, and Eby, J. B., 1929, Geology and coal resources of the Meeker quadrangle, Moffat and Rio Blanco Counties, Colo.: U. S. Geol. Survey Bull. 812-C, pp. 191-242.

Hills, R. C., 1899, Elmoro, Colo.: U. S. Geol. Survey Geol. Atlas, folio 58.

_____ 1900, Walsenburg, Colo.: U. S. Geol. Survey Geol. Atlas, folio 68.

_____ 1901, Spanish Peaks, Colo.: U. S. Geol. Survey Geol. Atlas, folio 71.

James, Edwin, 1823, Account of an expedition from Pittsburg to the Rocky Mountains performed in the years 1819-20: Philadelphia, H. C. Carey and I. Lea, Chestnut St., vol. 2, 442 pp.

Johnson, V. H., 1948, Geology of the Paonia coal field, Delta and Gunnison Counties, Colo.: U. S. Geol. Survey Prelim. Map.

Lee, W. T., 1907, The Grand Mesa coal field, Colorado: U. S. Geol. Survey Bull. 341, pp. 283-334.

_____ 1912, Coal fields of Grand Mesa and the West Elk Mountains, Colorado: U. S. Geol. Survey Bull. 510, 237 pp.

Lee, W. T., and Knowlton, F. H., 1917, Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, 450 pp.

Lee, W. T., and Knowlton, F. H., 1922, Raton-Brilliant-Koehler folio, N. Mex.-Colo.: U. S. Geol. Survey Geol. Atlas, folio 214.

Martin, G. C., 1908, Coal in the Denver Basin, Colorado: U. S. Geol. Survey Bull. 381, pp. 297-306.

Richardson, G. B., 1908, The Trinidad coal field, Colorado: U. S. Geol. Survey Bull. 381, pp. 379-446.

_____ 1909, Reconnaissance of the Book Cliffs coal field between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, 54 pp.

Shaler, M. K., 1905, The Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 285, pp. 241-258.

_____ 1907, A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 316, pp. 375-426.

Storrs, L. S., 1901, The Rocky Mountain coal fields: U. S. Geol. Survey 22d Ann. Rept., pt. 3, pp. 415-471.

Toenges, A. L., and others, 1952, Coal Deposit, Coal Creek district, Gunnison County, Colo.: U. S. Bur. Mines Bull. 501, 83 pp.

Tuff, J. A., 1907, The Durango coal district, Colorado: U. S. Geol. Survey Bull. 316, pp. 321-337.

Vanderwilt, J. W., 1947, Mineral resources of Colorado: State of Colorado Min. Res. Board, Denver, Colo., pp. 266-276.

Washburne, C. W., 1908, The Canon City coal field, Colorado: U. S. Geol. Survey Bull. 381, pp. 341-378.

_____ 1908, The South Park coal field, Colorado: U. S. Geol. Survey Bull. 381, pp. 307-316.

Wood, G. H., and others, 1951, Geology and coal resources of the Stonewall-Tercio area, Las Animas County, Colo.: U. S. Geol. Survey Oil and Gas Inv. Map C 4.

Woodruff, E. G., 1910, The coal resources of Gunnison Valley, Mesa and Delta Counties, Colo.: U. S. Geol. Survey Bull. 471, pp. 565-573.

Zapp, A. D., 1949, Geology and coal resources of the Durango area, La Plata and Montezuma Counties, Colo.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 109 (2 sheets).

U. S. Bureau of Mines, Minerals Yearbook, 1932-49.

U. S. Geol. Survey Annual Reports 16-21, 1893-99.

U. S. Geol. Survey, Mineral Resources of the United States, 1886-92, 1900-32.

UNPUBLISHED REPORTS

Barnes, Harley, Baltz, Elmer, Wanek, A. A., in preparation, Estimation of coal reserves of San Juan Basin region: U. S. Geol. Survey Bull.

Bass, N. W., in preparation, Geology and mineral fuels of the Mount Harris, Pilot Knob, Elkhead Creek, and Dayton Peak quadrangles, Routt and Moffat Counties, Colo.: U. S. Geol. Survey Bull.

Spencer, F. D., in preparation, Northern coal field of the Denver Basin: U. S. Geol. Survey Bull.

U. S. Geol. Survey, 1912-21, Unpublished minutes in files of U. S. Geol. Survey Conservation, Washington, D. C.

Wood, G. H., and others, Estimation of coal reserves of the Raton Mesa region: U. S. Geol. Survey.

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