Coal Resources of the Trinidad Coal Field in Huerfano and Las Animas Counties, Colorado

GEOLOGICAL SURVEY BULLETIN 1112-E

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By ROSS B. JOHNSON

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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A résumé of the coal resources in an area of 1,100 square miles in south-central Colorado

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COAL RESOURCES OF THE TRINIDAD COAL FIELD IN HUERFANO AND LAS ANIMAS COUNTIES, COLORADO

By Ross B. Johnson

ABSTRACT

The Trinidad coal field underlies an area of about 1,100 square miles in Huerfano and Las Animas Counties, south-central Colorado, and extends from the Colorado-New Mexico boundary northward almost to the Huerfano River. Its western margin is the eastern front of the Sangre de Cristo Mountains, and its eastern margin extends to longitude 104°30' West. The coal field is largely a highly dissected upland area in the westernmost part of the Great Plains province, and the coal occurs in rocks limited to the structural trough of the Raton basin.

Sedimentary rocks of Paleozoic, Mesozoic, and Cenozoic age crop out in or near the Trinidad coal field. Rocks of pre-Cretaceous age are exposed in the Sangre de Cristo Mountains and the Wet Mountains west and north of the coal field. Cretaceous and younger rocks crop out in and adjacent to the field. The sedimentary rocks in the coal field include the Trinidad sandstone and the coal-bearing Vermejo formation of Cretaceous age, the coal-bearing Raton formation of Cretaceous and Paleocene age, the Poison Canyon formation of Paleocene age, and the Cuchara and Huerfano(?) formations of Eocene age.

Igneous rocks have been intruded as stocks, laccoliths, sole injections, plugs, dikes, and sills into the sedimentary rocks in and adjacent to the Trinidad coal field. The igneous rocks vary in composition from mafic to silicic, and range in texture from very fine to coarse grained.

The effect of contact metamorphism on the sedimentary rocks that were invaded by magma generally was not great. However, shale has been altered to slate and phyllite at the White Peaks, the Black Hills, and other smaller intrusive masses. Contact metamorphic effects are very prominent next to the intrusive mass of West Spanish Peak. Conglomerate, sandstone, and shale beds have been altered to conglomeratic quartzite, quartzite, hornfels, and slate. In a faulted block that lies between West Spanish Peak and East Spanish Peak, shale and sandstone beds have been altered to slate and quartzite. At several localities sills have replaced coal beds or altered them to natural coke over several square miles.

The Raton basin is the principal structural feature of the coal field; it is a broad asymmetric trough whose axis trends generally northward through the field. Smaller folds of variable orientation and relief are scattered throughout

the coal field. The rocks in the Sangre de Cristo Mountains along the western margin of the Trinidad coal field have been thrust faulted, but involve the coal-bearing and younger formations only locally. Normal faults are not common in the coal field, but isolated groups of normal faults of small displacement occur throughout the area.

Beds of coal occur throughout the Vermejo and Raton formations, and thin beds of coal occur locally in the lowermost beds of the Poison Canyon formation. The beds of coal differ in thickness and in purity. Those in the Raton and Poison Canyon formations are, in general, more lenticular than those in the Vermejo formation. The coal is a nonagglomerating high-volatile C bituminous coal in the northern part of the coal field, and an agglomerating high volatile A and B bituminous coal in the southern part of the field. On an "as received" basis the heating value ranges from slightly more than 11,000 to slightly less than 14,000 Btu. The original reserves are estimated on a "bed-by-bed" basis and on a "coal-zone" basis to have been about 16,367 million short tons. The original recoverable reserves based on an average percentage of recovery in coal mines of the western United States are about 8,184 million short tons. At least 218 million tons of coal had been mined by 1957, or about 2.7 percent of the estimated total recoverable reserves.

INTRODUCTION

LOCATION AND EXTENT OF THE COAL FIELD

The Trinidad coal field underlies an area of about 1,100 square miles in Huerfano and Las Animas Counties (fig. 18) in the south-central part of Colorado. It is irregular in shape, the boundary extending from the Colorado-New Mexico boundary, northward along the front of the Sangre de Cristo Mountains almost to the Huerfano River; and thence southeastward to longitude 104°30′ West near the State line. The Trinidad coal field is that part of the Raton Mesa coal region (Richardson, 1910, p. 379) that lies in Colorado, whereas the Raton coal field is that part of the coal region in New Mexico. This report describes the coal resources of the Trinidad coal field west of longitude 104°30′ W.

PURPOSE AND SCOPE OF REPORT

The purpose of this report is to describe the coal deposits of the Trinidad coal field, to evaluate the total coal reserves of the field, and to synthesize information contained in recently published Geological Survey reports on coal resources of various parts of the coal field (see fig. 18.) Geologic work was directed principally toward describing, measuring, and tracing the coal beds and enclosing strata to determine the coal reserves of the field. Attention was also given to the sedimentary, metamorphic, and igneous rocks to determine the general geology, structure, and geologic history of the coal field and surrounding regions.

FIELDWORK AND ACKNOWLEDGMENTS

The fieldwork on which this report is based was done during the summers of 1948, 1949, 1950, 1951, 1952, and 1956. Workers in the field included G. H. Wood, Jr., R. B. Johnson, D. H. Eargle, R. T.

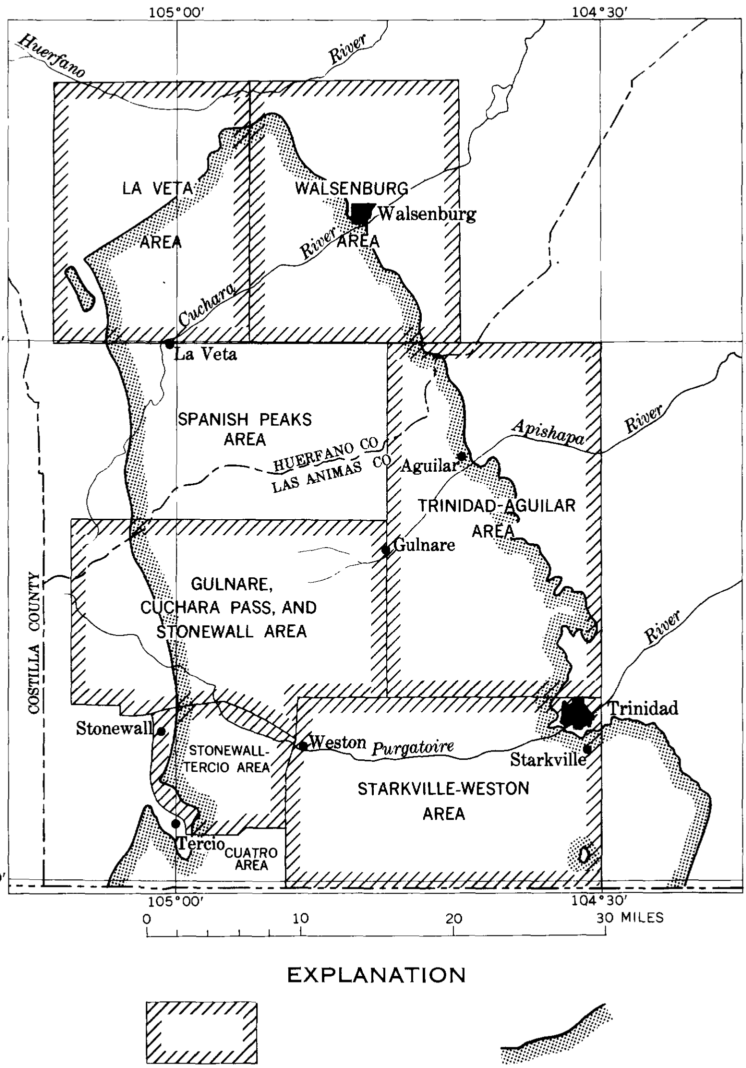

FIGURE 18.—Index map of the Trinidad coal field, Colorado, showing areas of recent coal reports by the Geological Survey: Stonewall-Tercio area (Wood, Johnson, Eargle, and others, 1951). La Veta area (Johnson and Stephens, 1954a, 1954b), Gulnare, Cuchara Pass, and Stonewall area (Wood, Johnson, and Dixon, 1956), Starkville-Weston area (Wood, Johnson, and Dixon, 1957), Walsenburg area (Johnson, 1958a), and Trinidad-Aguilar area (Harbour and Dixon, 1959).

Duffner, and Harald Major in 1948; G. H. Wood, Jr., R. B. Johnson, and G. H. Dixon, assisted by K. W. Brett, in 1949; G. H. Wood, Jr., R. B. Johnson, and G. H. Dixon, assisted by J. D. Hill, in 1950; R. L. Harbour with G. H. Dixon, and R. B. Johnson with J. G. Stephens, in 1951; R. L. Harbour assisted by R. L. Koogle in 1952; and R. B. Johnson assisted by J. E. Doty in 1956.

Fieldwork consisted of mapping sedimentary formations, coal beds, igneous and metamorphic rocks, and structural features on single-lens photographs. Individual beds of sandstone were traced laterally where exposed to facilitate correlation of coal beds. Coal beds were measured, described, and correlated in the field wherever outcrops were available for examination. The base for the small-scale regional geologic map (pl. 12) was prepared from planimetric quadrangle maps compiled in 1940 by the U.S. Forest Service.

Vertical control for structure contouring was obtained over most of the coal field photogrammetrically, or with a telescopic alidade from bench marks previously established by the Coast and Geodetic Survey and the Geological Survey. In the southeastern quarter of the Spanish Peaks quadrangle vertical control was taken from recent topographic maps by the U.S. Geological Survey. The drainage, culture, and geology were transferred from aerial photographs to base maps by use of stereoscopic plotters or vertical projectors.

The author wishes to express appreciation to Mr. J. H. P. Fiske of the engineering firm of Douglas, Corey, and Fiske in Walsenburg, Colo., who kindly supplied much information consisting of mine maps, diamond-drill records, and the descriptions of coal seams.

PREVIOUS WORK

Coal has been known in this general area for almost a century and a half, and many reports have been written on the geology, paleontology, and coal resources of the Trinidad field. Geologic features were described by American exploration parties before the region was acquired by the United States in 1845. The expedition of Major S. H. Long to the Rocky Mountains in 1819 and 1820 reported coal near Canon City, Colo. (James, 1821; Long, 1823). Military expeditions by Abert (1848) and Emory (1848) discovered coal in the Trinidad coal field in 1846, and Abert collected fossil plants near Trinidad which Bailey (1848) determined to be "younger than Carboniferous".

Territorial surveys under the leadership of F. V. Hayden visited the coal field, described the rocks, and referred the coal-bearing rocks to the Tertiary (Hayden, 1867, 1868a, 1868b, 1873, 1876a, 1876b, and 1877). Le Conte (1868) in a survey for the Union Pacific Railway examined fossil plants and shells near Trinidad, Colo., and concluded that the coal was of "middle Cretaceous" age. In a report on mines and mining west of the Rocky Mountains, Raymond (1870) described coal beds at several localities in the Raton Mesa region.

Lesquereux (1871, 1872a, 1872b, 1873, 1874a, 1874b, 1874c, 1878, and 1883) described specimens of fossil plants from near Trinidad, along the Purgatoire River, and several other localities, and regarded these plants as being Eocene in age. However, Newberry (1874) took issue with the views of Hayden and Lesquereux, and stated that the coal-bearing beds are of Cretaceous age. In a description of the Raton coal field of New Mexico, St. John (1876) agreed with Hayden and Lesquereux that the coal beds are of Tertiary age. Endlich (1877) made the first detailed study of the Trinidad coal field in 1875, and concluded that the coal should not be assigned to either the Cretaceous or Tertiary, but should form a transition between them (Endlich, 1877, p. 211). Stevenson (1879, 1881, 1885, and 1889), during the field seasons of 1878 and 1879, made a thorough examination of the coal field south of the Spanish Peaks, and Riggs (1887) later reported natural coke along the Purgatoire River.

About this time, Hills began his studies of the Trinidad coal field, and wrote a detailed article on the field in his report on the coal fields of Colorado (Hills, 1893). This article was followed by his excellent folios describing the geology of the Elmoro (Hills, 1899), Walsenburg (Hills, 1900), and Spanish Peaks (Hills, 1901) quadrangles.

In 1889 Lakes began his series of reports (1889, 1891, 1899, 1902, 1903a, 1903b, 1904a, 1904b, 1905a, 1905b, 1905c, 1905d, 1905e, and 1911) on the fuel resources of the region and on the various coal mines and districts of the Trinidad coal field. Papers by Mead (1900), Hosea (1904a, 1904b, and 1905), Plumb (1905), and Whiteside (1909) described several coal mines and mining districts in the field.

Lee (1909), while studying the Raton coal field in New Mexico, divided the coal-bearing rocks into the Vermejo formation of Late Cretaceous age and the Raton formation of Eocene age. He divided the formations at the base of a prominent conglomerate which he defined as the basal bed of the Raton formation, and which he interpreted as reflecting an unconformity between the Cretaceous and Tertiary systems. In later papers (1911a, 1911b, 1914, and 1916) Lee vigorously supported the existence of an unconformity between the Vermejo and Raton formations. His extensive work in the Trinidad and Raton coal fields culminated in a comprehensive report on the Raton Mesa region (Lee, 1917). Lee collected the fossils that were described and identified by Knowlton (1913, 1917).

Richardson (1910) presented a detailed account of the coal resources of the Trinidad coal field, and continued to refer the coal-

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bearing beds to the Laramie formation of Late Cretaceous age. Willis (1912), as a result of a short visit to the region, agreed to the separation of the coal-bearing rocks as advocated by Lee, but referred the Vermejo to Montana time and the Raton formation to earliest Tertiary or latest Cretaceous time.

The Cretaceous-Tertiary boundary in the Trinidad coal field was later determined by Brown (1943) to be several hundred feet above the base of the Raton formation; he assigned the upper part of the Raton formation to the Paleocene. Later reports in this region by the Geological Survey have followed the age assignments of Brown.

As part of the present investigation, areal reports on the geology and coal resources of parts of the Trinidad coal field have been published by Wood, Johnson, Eargle, and others, 1951; Johnson and Stephens, 1954a, 1954b; Wood, Johnson, and Dixon, 1956, 1957; Johnson, 1958a, 1958b; and Harbour and Dixon, 1959. The coal deposits of the Raton basin were briefly reviewed by Carter in 1956, and in that year Johnson and Wood (1956) described the uppermost Cretaceous and Tertiary stratigraphy of the basin.

GEOGRAPHY

LAND FEATURES

The Trinidad coal field (pl. 12) is in large part a highly dissected upland area in the westernmost part of the Great Plains province; its western margin lies along the eastern foothills of the Sangre de Cristo Mountains. The coal field is made up of rocks that are limited to the deepest part or trough of the Raton structural basin (Johnson and Wood, 1956, p. 707) of Colorado and New Mexico. Along the western and eastern boundaries of the field the more resistant beds of the Trinidad sandstone separate the coal field from the surrounding lowland areas that are underlain by the Pierre shale.

The southern margin of the Trinidad coal field along the Colorado-New Mexico State line is marked by a high, relatively flat, and intricately dissected divide between the Purgatoire and Canadian Rivers. In the northern part of the field, north of the Cuchara River, the hills are low and rolling, and they diminish in height to the north where the Raton Mesa region merges into Huerfano Park.

Surface altitudes range from 6,150 feet near Trinidad and 6,230 feet near Walsenburg, along the eastern edge of the coal field, to altitudes of 12,708 feet on East Spanish Peak and 13,623 feet on West Spanish Peak. These two conical mountains rise abruptly above the surrounding country, and are the dominant landmarks of the region. The land surface slopes from the Spanish Peaks to the north, east, and south in a series of discontinuous steplike platforms. The igneous masses that comprise Dike Mountain and the Black Hills in the northwestern extremity of the coal field are also prominent topographic features. Igneous dikes crisscross the coal field, and because of their resistance to erosion they stand as relatively straight vertical walls as much as 100 feet above the surrounding country.

DRAINAGE

The Trinidad coal field is drained by streams tributary to the Arkansas River. The Huerfano, Cuchara, Apishapa, and Purgatoire Rivers are the main streams that drain the area (pl. 12); they flow generally eastward from the mountains to the plains.

The headwaters of the Huerfano River are near the crest of the Sangre de Cristo Mountains. The Huerfano River flows across Huerfano Park and south of the southernmost extension of the Wet Mountains, where it passes within 2 miles of the northern end of the Trinidad coal field and then flows northeastward across the plains to the Arkansas River. Within the coal field a low rolling divide separates the drainage system of the Huerfano River from that of the Cuchara River to the south.

North and west of the Spanish Peaks the Trinidad coal field is drained chiefly by the Cuchara River and its tributaries. The Cuchara River heads near the crest of the Sangre de Cristo Mountains west of West Spanish Peak, skirts the coal field for a short distance, and then crosses the field through a wide valley in a northeastward direction. It crosses the plains to flow into the Huerfano River a few miles above its conjunction with the Arkansas River. A high rugged divide culminated by the Spanish Peaks and marking the Huerfano-Las Animas County line separates the drainage system of the Cuchara River from the drainage systems of the Apishapa and Purgatoire Rivers to the south.

The Apishapa River starts on the southwest slope of West Spanish Peak in the western part of the Trinidad coal field, and flows across the field in a general eastward direction. On the plains it flows in a northeastward direction to its confluence with the Arkansas River. An intricately dissected divide in the coal field, locally known as "Pine Ridge", separates the drainage basin of the Apishapa River from the drainage area of the Purgatoire River to the south. To the west the two drainage systems are parted by a high rolling divide, which, near the Huerfano-Las Animas County line, separates the three basins drained by the Cuchara, Apishapa, and Huerfano Rivers.

The southern part of the Trinidad coal field is drained by the Purgatoire River and its tributaries. The Purgatoire River is the largest perennial stream in the coal field. Three main branches, North Fork, Middle Fork, and South Fork, flow into the Purgatoire in the western part of the field. The Purgatoire flows across the area in an eastward direction, but where it reaches the plains it flows northeasterly to the Arkansas River. The North Fork begins within a few hundred feet of the headwaters of the Cuchara River on the flanks of Trinchera Peak at the crest of the Sangre de Cristo Mountains. A high, relatively flat and intricately dissected divide at the Colorado-New Mexico State line separates the drainage system of the Purgatoire River from that of the Canadian River.

CLIMATE

The climate of the Trinidad coal field ranges from semiarid in the plains to subhumid in the mountainous areas. The average annual rainfall ranges from less than 14 inches at Walsenburg to almost 30 inches near the summits of the Spanish Peaks, and the number of rainy days on the peaks is probably three times the number of rainy days on the plains. Most of the precipitation occurs from April to September, with a general tendency toward drought in June. The rainfall occurs during the summer months at lower elevations as infrequent heavy thunderstorms, which convert the streams into temporary torrents.

Temperatures decrease steadily with increase in altitude. Although the mountains are generally colder than the plains, diurnal and annual temperature changes are much greater on the plains.

The following table gives recorded temperature and precipitation for the area.

Winds across the coal field are usually from the west throughout the year. Wind movement is slow near the foot of the mountains and increases in velocity to the east. Wind velocity is generally greatest in the afternoon, and the annual peak in wind velocity is in the spring.

VEGETATION

With altitudes ranging between 6,150 feet and 13,623 feet, the Trinidad coal field includes four floral life zones: the foothills (transition) zone, the montane (Canadian) zone, the subalpine (Hudsonian) zone, and the alpine (Arctic) zone.

About 80 percent of the coal field is in the foothills zone, which at this latitude generally is between the altitude of 6,000 feet and 8,000 feet. The entire eastern and northern parts of the coal field (pl. 12) are in this life zone, and open coniferous forests and grasslands typical to the foothills zone reach the western margin of the field along the valleys of the Purgatoire and Cuchara Rivers.

Climatological data for Trinidad coal field and surrounding area

[From U.S. Weather Bureau reports]

Station	Years of record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean precipitation, in inches														
Cuchara Camps	27⅓	0.75	1.57	2.16	2.93	2.27	1.54	3.64	2.68	1.65	1.81	1.50	1.27	23.77
Gardner	18	.58	.65	.80	1.51	1.50	.72	1.60	1.41	.72	.48	.54	.41	10.92
Hoehne	27½	.33	.71	.73	1.82	1.74	1.24	2.34	1.77	1.19	.96	.57	.80	14.20
La Veta Pass	45	1.45	1.75	2.59	2.20	2.01	1.18	2.15	2.10	1.28	1.55	1.65	1.57	21.48
Madrid	13⅓	.21	.69	.85	1.93	1.34	1.59	2.96	2.00	.98	1.27	.42	.51	14.75
North Lake	63	.87	1.34	1.79	2.30	2.23	1.58	3.50	3.02	1.48	1.27	.97	1.06	21.41
Sarcillo	6	.62	.11	.58	1.94	1.63	.76	2.28	2.32	1.99	.78	.42	.74	14.17
Stonewall	11⅓	.20	.50	.58	2.28	1.71	1.62	4.78	2.87	1.15	1.28	.51	.49	17.97
Trinidad	57	.50	.79	.97	1.81	2.02	1.74	2.29	2.16	1.39	1.17	.78	.64	16.26
Trinidad Airport	20	.41	.40	.82	1.42	2.21	1.32	1.60	1.91	1.17	.76	.49	.39	12.90
Walsenburg	22	.58	.70	1.32	1.99	2.33	.84	1.55	1.51	.81	.81	.73	.56	13.73
Mean temperature, in °F														
Trinidad	16	32.8	36.3	40.6	49.7	58.0	67.5	72.4	71.3	64.7	53.9	41.1	35.1	52.0
Trinidad Airport	15	29.9	34.2	38.9	49.2	57.8	67.0	72.7	71.8	64.4	53.8	39.2	33.2	51.0
Walsenburg	15	33.2	36.1	40.2	49.1	57.7	66.0	71.4	70.7	63.2	54.5	41.8	36.7	51.8
Mean snowfall, in inches														
Cuchara Camps	5	10.1	18.3	18.3	19.4	14.1	0.0	0.0	0.0	1.6	4.2	14.3	8.9	109.2
Gardner	12	9.1	9.0	11.8	7.1	1.5	.1	trace	.0	trace	.5	5.0	6.9	51.0
La Veta Pass	20	21.9	24.4	31.0	32.3	11.5	.8	.0	trace	1.6	8.2	16.7	16.0	164.4
North Lake	21	13.3	15.4	21.3	18.0	5.9	.1	trace	trace	1.1	3.6	10.1	10.2	99.0
Trinidad	16	8.4	9.3	10.0	8.5	2.0	.0	.0	.0	.9	.8	8.0	6.3	54.2
Trinidad Airport	15	7.4	5.1	7.8	6.1	.6	trace	trace	trace	.2	.1	5.3	6.2	38.8
Walsenburg	14	7.6	8.4	14.7	10.1	1.2	.0	.0	.0	1.1	3.3	7.8	7.4	61.6

The montane zone comprises about 18 percent of the area of the Trinidad coal field, and typical coniferous forests and aspen groves are found at altitudes between 8,000 and 10,000 feet on the flanks of the Spanish Peaks and in the upland areas in the western part of the field south of the Spanish Peaks.

The subalpine zone ranges in altitude from approximately 10,000 feet to timber line, which is at 11,500 feet on the south slopes and about 11,000 feet on the north slopes of the Spanish Peaks. The subalpine zone constitutes only about 2 percent of the area of the coal field, and is characterized by dense coniferous forests.

Less than one percent of the area of the coal field is in the alpine zone above timberline on the Spanish Peaks. This is an area of steep slopes, a short growing season, and rapid runoff of water, and therefore vegetation is sparse.

UTILITY

The land surface of the Trinidad coal field with the exception of that above timberline is suitable for grazing, farming, or lumbering. Most of the land is favorable for grazing cattle and sheep, and livestock is the major agricultural product of the area. Grazing conditions differ with locality, and upland meadows have an abundance of grass. Irrigation farming is practiced along the valleys of the major streams, and alfalfa and some of the larger grains are the principal crops. Dry farming is practiced on upland terraces and open fields at intermediate elevations, and timothy, millet, rye, and beans are produced. Apples and plums are grown in valleys where there is sufficient water. Lumbering has been carried on for many years within the coal field, and sawmills still furnish timber to ranchers and the mining industry. The most important product of the region is coal, which has been used for coking and domestic purposes for more than 80 years.

SETTLEMENT

The three largest communities in the Trinidad coal field are along the eastern margin where the three major streams flow from the upland areas of the coal field onto the plains (pl. 12). Trinidad, with a population of about 12,200 in 1950, is on the Purgatoire River; Walsenburg, with about 5,600 people in 1950, is on the Cuchara River; and Aguilar, with about 1,000 people in 1950, is on the Apishapa River. The rural population is centered mainly in small ranching and farming communities along the Purgatoire, Cuchara, and Apishapa Rivers.

The population of the coal field has decreased steadily since 1930 due in large part to the decline in coal mining. Many of the mining camps are now abandoned. The population of Las Animas County diminished from 32,368 in 1940 to 23,902 in 1950, and the population of Huerfano County decreased from 16,088 in 1940 to 10,549 in 1950. The population of the towns and cities declined almost without exception during this period, and it is suspected that the number of people on ranches and farms also dwindled.

TRANSPORTATION AND ACCESSIBILITY

The Trinidad coal field is easily reached by major railroads and highways and by an airline; many secondary roads and several freight rail lines extend into the coal field from population centers. The main line of the Atchison, Topeka, and Santa Fe Railway passes through Trinidad and crosses the southeastern corner of the coal field. The Colorado and Southern Railway passes through Walsenburg and Trinidad. A branch line of the Denver and Rio Grande Western Railroad serves Walsenburg and La Veta. A short branch line from Walsenburg skirts the northern end of the coal field. The Southern Division of the Colorado and Wyoming Railway extends from its junction with the Atchison, Topeka, and Santa Fe Railway up the

Purgatoire River to the Allen mine near Stonewall. Trinidad is served by Continental Airlines.

SEDIMENTARY ROCKS

Sedimentary rocks of Paleozoic, Mesozoic, and Cenozoic agė crop out in or near the Trinidad coal field. Rocks of pre-Cretaceous age are exposed in the Sangre de Cristo Mountains and the Wet Mountains west and north, respectively, of the coal field, and crop out in the canyons of the Huerfano, Cuchara, Apishapa, and Purgatoire Rivers northeast and east of the field. Cretaceous and younger rocks crop out in and adjacent to the coal field.

Exposures of sedimentary rocks of Late Cretaceous and Tertiary age are generally fair throughout the coal field. The rocks in areas adjacent to the Cuchara and Huerfano Rivers are not so well exposed as in those areas adjacent to the Apishapa and Purgatoire Rivers to the south, but are better exposed than those on the timbered mountain flanks at altitudes between 9,000 and 11,500 feet. Exposures of rocks above the timberline are excellent. The sedimentary rock sequence is summarized graphically on plate 12, and the areal distribution of the formations is shown on the geologic map.

Quaternary alluvium is present in most of the stream bottoms and on adjacent flood plains. Soil and pediment deposits cover large parts of the area. Landslide debris surrounds the mountains.

MESOZOIC ROCKS

ROCKS OF CRETACEOUS AGE

TRINIDAD SANDSTONE

The Trinidad sandstone (Hills, 1899, p. 2) of the Montana group (Eldridge, 1888, p. 93) was first described southeast of Trinidad in the Elmoro quadrangle. Hills divided the formation into the lower and upper Trinidad with a thickness of 75 feet for the lower part and 70 to 80 feet for the upper part. Later he changed the name to Trinidad sandstone (Hills, 1901, p. 1), but retained the same formational boundaries. Lee (1917, p. 48) redefined the formation by assigning the lower Trinidad to the Pierre shale and by retaining the upper Trinidad as the Trinidad sandstone. In general, recent reports by the Geological Survey have followed Lee's definition of the Trinidad sandstone.

The formation is 45 feet thick southeast of Trinidad, and it increases in thickness westward to 260 feet near Stonewall on the western margin of the coal field. However, the formation ranges in thickness from a thin edge at the northwestern edge of the coal field, where it has been truncated by Paleocene erosion, to a maximum thickness of 310 feet in a well drilled southwest of the Black Hills. The Trinidad sandstone is very well exposed along the eastern margin of the coal field between Trinidad and Walsenburg as a massive cliff or series of ledges. Elsewhere it is covered or poorly exposed, but nevertheless forms a bench above the softer underlying Cretaceous shale beds.

The Trinidad sandstone consists of one to three light-gray, gray, and buff slightly arkosic sandstone beds with thin interbeds of light-gray, gray, and light-tan silty shale. The sandstone is medium-thick to thick bedded, and is most commonly in tabular beds. However, the bedding may be occasionally irregular and infrequently lenticular. The sandstone is quartzose with some weathered feldspar, mica, and ferromagnesian minerals. The sandstone is predominantly fine grained but the grains range from very fine to medium size. Cementing materials are calcium carbonate, clay, and silica, and cementation varies from good to poor. Casts and molds of *Halymenites* sp. are abundant.

VERMEJO FORMATION

The Vermejo formation (Lee, 1913, p. 531) of Montana and post-Montana age rests conformably on the Trinidad sandstone over most of the Raton Mesa region. The base of the formation is drawn at the top of the highest sandstone bed in the Trinidad sandstone. The formation is apparently absent several miles southeast of Trinidad, but increases irregularly in thickness northwestward to a maximum of 550 feet southeast of Cuchara Pass. West of La Veta the average thickness of the Vermejo is about 375 feet, but the thickness varies from a thin edge where it is truncated by the erosion surface at the base of the Poison Canyon formation. The Vermejo formation is generally poorly exposed throughout the Trinidad coal field, except along canyon walls, gullies, and road cuts.

The formation consists of complexly interbedded gray to black carbonaceous, coaly, and silty shale; buff, gray, and gray-green slightly arkosic sandstone; buff, gray, and dark-gray carbonaceous siltstone; and many coal beds. Most of the thinner sandstone beds have parallel bedding and parallel lamination, but the thicker beds are lenticular and irregular. Grains in the sandstone beds range from very fine to medium, and most are quartz with fewer grains of weathered feldspar, mica, and ferromagnesian minerals. The cementing materials are clay and calcium carbonate. Coal is interbedded with beds of siltstone and shale a few inches to many feet thick (fig. 19). The lower few feet of the Vermejo formation are usually made up of shale, siltstone, and coal throughout much of the coal

FIGURE 19.—Cokedale coal bed in upper part of Vermejo formation north of Purgatoire River. Conglomeratic sandstone at base of Raton formation caps bluff to left. Three-fourths of a mile south of Cokedale, Colo. View is eastward.

field, but locally the basal part is made up of sandstone beds somewhat similar to those of the Trinidad sandstone.

Lee (1917, p. 64) believed that the rocks of the Vermejo formation were partly removed from the western part of the coal field and entirely removed from the eastern part by widespread post-Cretaceous erosion. However, no evidence has been found of a regional unconformity between the Vermejo formation and the overlying Raton formation. The contact is sharp, and the southeastward thinning of the Vermejo seems to be due to nondeposition rather than pre-Raton erosion.

MESOZOIC AND CENOZOIC ROCKS

ROCKS OF CRETACEOUS AND TERTIARY AGE

RATON FORMATION

The Raton formation (Lee, 1913, p. 531) is of Late Cretaceous and Paleocene age (Brown, 1943, p. 83), and comprises the surface rocks over large parts of the Trinidad coal field. The formation is usually well exposed along the eastern edge of the coal field between the Apishapa and Purgatoire Rivers, along the Purgatoire River, and south to the State line. North of Santa Clara Creek and along the western edge of the coal field the formation is generally poorly exposed. The formation is completely truncated by the erosion surface at the base of the Poison Canyon formation at the northern limits of the coal field, but thickens to 1,700 feet southeast of the Spanish Peaks.

South of the Spanish Peaks, where rocks of the Raton formation are well exposed, the formation has been divided into three unnamed members (Wood, Johnson, Eargle, and others, 1951; Wood, Johnson, and Dixon, 1956; and Wood, Johnson, and Dixon, 1957, p. 24–25). Harbour and Dixon (1959, p. 458) also separated the formation into three major units, but these do not correspond to the members differentiated in the earlier reports. The formation has not been subdivided elsewhere in the coal field, but it generally consists of a thin basal conglomerate overlain by interbedded sandstone, siltstone, shale, and many coal beds.

The basal conglomerate is extremely variable in lithology and thickness, and varies from siliceous granule to pebble conglomerate to silicified conglomeratic sandstone beds. Color varies locally from gray, purple gray, and olive green to buff. The conglomerate ranges in thickness from a thin edge southeast of Trinidad to 250 feet near Stonewall. This basal unit consists of one to three thin to massive cliff- or ledge-forming beds, the lower of which is generally conformable with the uppermost beds of the Vermejo formation. Bedding is usually obscure, but locally crossbedding is distinct. The matrix is composed of fine to very coarse sand grains. Quartz granules and both fresh and weathered feldspar granules are scattered throughout the conglomeratic sandstone. Chert pebbles are found in the eastern part of the coal field, and pebbles of quartzite, granite, and gneiss are dominant in the western part. Grains and granules are angular to subrounded, and the pebbles are subangular to well rounded. The conglomeratic unit is usually very well cemented by silica; however, at a very few places it is extremely friable.

Above the conglomerate is an alternating sequence of graywacke, arkose, and quartzose sandstone with interbedded siltstone, shale, and coal. Sandstone beds are light gray to buff, and are thin bedded to massive. Thicker beds are commonly cross stratified, and they are generally lenticular but may be irregular or parallel. The grains range from very fine to medium size, but are coarse locally. Grains vary from subangular to subrounded, well to poorly sorted, and most are of quartz with fewer grains of white weathered feldspar, ferromagnesian minerals, and rock fragments. The sand grains are cemented by calcium carbonate and clay. Shale and siltstone beds are gray to black, and most of the beds are thicker than the beds of sandstone. The shale is mostly plastic and nonfissile, and its content of silt, sand, and carbonaceous material ranges widely. Shale varies from pure claystone through silty shale and shaly siltstone into siltstone, and the carbonaceous shale may grade into impure coal and then into pure coal. Coal beds occur throughout the formation at many horizons (fig. 20), but near the top are more lenticular, less pure, and less numerous. Irregularly shaped ironstone concretions occur locally in the shale. Local intraformational angular unconformities are common in the Raton formation and are especially well exposed in the valley of the Purgatoire River.

ROCKS OF TERTIARY AGE

POISON CANYON FORMATION

North of the Spanish Peaks the Poison Canyon formation (Hills, 1888) of Paleocene age unconformably overlies the Raton and older formations. However, in the central and southern parts of the coal field the upper beds of the Raton formation intertongue with, and locally grade vertically and laterally into, the lowest beds of the Poison Canyon formation. Thus at most places in the central and southern part of the field the contact between the formations is difficult to determine. However, the position of the contact is drawn at the base of the lowermost sandstone that contains unweathered grains of pink feldspar. Sandstone beds are generally coarser grained in

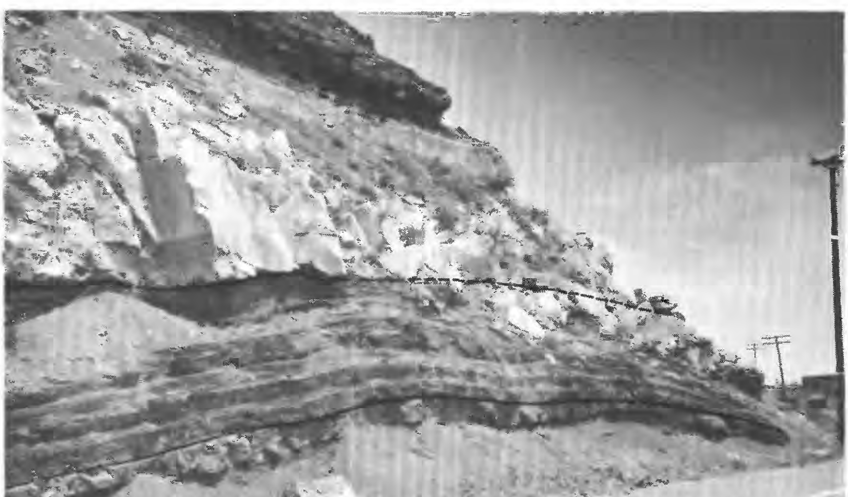

FIGURE 20.—Frederick coal bed in Raton formation exposed in axis of small anticline, and unconformably overlain by lenticular sandstone. Along Colorado State Route 12 north of Purgatoire River and Valdez, Colo. View is northward.

the Poison Canyon formation, shale beds contain very little carbonaceous material, and coal is present at only a few places at the base.

About 50 to 100 feet above the contact with the Raton formation, the Poison Canyon contains massive buff to red arkosic sandstone and conglomerate beds and thin yellow shale beds. The sandstone beds are coarse to medium grained, and contain much fresh feldspar. Conglomerate beds contain pebbles of granite, gneiss, and quartzite. Most beds of sandstone and conglomerate are lenticular and crossbedded, and where they crop out they weather into cavernous cliffs. Shale beds are plastic and slightly silty and generally show poor fissility. The Poison Canyon formation ranges in thickness from a thin edge in Huerfano Park to about 2,500 feet directly south and east of East Spanish Peak.

CUCHARA FORMATION

The Cuchara formation (Hills, 1891) of probable early Eocene age (Osborn, 1929, fig. 51) crops out in the trough of the basin, and extends from south of the Spanish Peaks into Huerfano Park. Throughout most of the coal field the Cuchara formation overlaps the Poison Canyon formation with marked unconformity. Directly east and northeast of East Spanish Peak the contact between the Cuchara and Poison Canyon formations appears to be conformable and transitional, but owing to lack of exposures the true relations could not be determined.

The Cuchara formation is composed of red, pink, and white sandstone beds interbedded with bright-red, gray, and tan claystone. The sandstone beds are thin bedded to massive, parallel to cross stratified, and fine to very coarse grained. Red and pink sandstone beds are conglomeratic at many places, and are generally well consolidated. Claystone beds are thin to thick bedded, plastic, and contain very small amounts of silt. The thickness of the Cuchara formation is as much as 5,000 feet in the center of the sedimentary basin on the north slope of West Spanish Peak.

HUERFANO(?) FORMATION

Strata that overlie the Cuchara formation on West Spanish Peak and in a small area southwest of the peak (pl. 12) are tentatively assigned to the Huerfano formation (Hills, 1888) of Eocene age (Osborn, 1929, p. 74). Hills (1901, p. 2) correlated these rocks with the Huerfano formation. He states:

> Lithologically, only the basal zone is comparable with the typical beds on the Huerfano River, which, however, is accounted for by the difference in the character of the local debris at the time of deposition. In both localities the beds rest upon the Cuchara formation, which outcrops continuously between them, and thus places the fact of their identity almost beyond question.

Later, however, Willis (1912, p. 758) concluded after a brief reconnaissance of this region "that the Huerfano Lake deposition did not extend as far to the east and south as the Spanish Peaks, and that variegated beds observed there are of older origin." Although differing greatly in lithology from typical beds of the Huerfano formation in Huerfano Park (Johnson, 1959, p. 102), these strata are tentatively assigned to the Huerfano formation until sedimentary and paleontological studies are completed.

The lowermost beds of the Huerfano(?) formation seem to be conformable with the uppermost beds of the underlying Cuchara formation on the north and east flanks of West Spanish Peak. However, south and west of the peak the two formations are unconformable.

The Huerfano(?) formation consists of interbedded, lenticular, poorly sorted beds of arkose and graywacke conglomerate, conglomeratic sandstone, and siltstone with a few beds of claystone. Conglomerate and conglomeratic sandstone beds vary from reddish brown to tan to gray. The bedding is medium thick to massive and lenticular. Torrential crossbedding is very distinct. The matrix of conglomerate and conglomeratic sandstone beds consists of poorly sorted, angular to subrounded grains of quartz, feldspar, ferromagnesian minerals, and rock fragments. Grains range in size from clay to coarse sand, and are poorly to well cemented by clay, microscopic rock fragments, and silica. The coarse fragments consist of subrounded to rounded pebbles, cobbles, and boulders of quartzite, gneiss, chert, sandstone, siltstone, claystone, and shale. Locally, red and green clay balls and stringers of ferromagnesian minerals are found in these beds. Siltstone beds are gray to reddish brown, thin bedded, with isolated well-rounded pebbles of quartzite. Near the base of the formation many calcareous nodules are found within the siltstone beds, and irregular masses of siliceous, coaly material and scattered carbonaceous matter are locally present. Claystone beds are brownish red, silty, plastic, and thick bedded.

Although the Huerfano(?) formation consists mainly of conglomerate and conglomeratic sandstone beds, the rock units become more definitely conglomeratic upward; the top of the formation contains boulders as large as 10 feet in diameter. The formation is approximately 3,000 feet thick on the south flank of West Spanish Peak, and grades into a complex of sills and metamorphosed sedimentary rocks that is associated with the West Spanish Peak intrusive.

DEPOSITS OF QUATERNARY AGE

Deposits of alluvium consisting mainly of gravel cover most of the stream bottoms and valley flats. Landslide debris and talus cover many of the mountain slopes, and alluvial fans are at many places along the base of mountains. Coarse morainal deposits are present at the lower termination of the cirque basin on the north side of West Spanish Peak. Soil and extensive pediment deposits cover large areas of the coal field at many different elevations. The Quaternary deposits are mostly derived from formations that crop out nearby, and are poorly sorted and generally unconsolidated. They range in thickness from a few inches to many feet.

METAMORPHIC ROCKS

The large syenodiorite stock of West Spanish Peak and its associated basalt sills have altered, by contact metamorphism, beds of the Huerfano(?) and Cuchara formations for at least 900 feet from the main intrusive. Conglomerate, sandstone, and shale beds have been altered to conglomeratic quartzite, quartzite, hornfels, and locally to slate. The contact is gradational from well-consolidated metamorphic rocks to loosely consolidated sedimentary rocks. In contrast, there is no apparent alteration of the sedimentary rocks of the Cuchara formation at the contact with the much larger granite and granodiorite porphyry stock of East Spanish Peak. Metamorphism was noted only where stringers of the main mass intrude a faulted block of highly fractured sedimentary rocks that lies between West Spanish Peak and East Spanish Peak (pl. 12). The block is composed of slate and quartzite that were originally shale and sandstone beds of the Pierre shale, Trinidad sandstone, Vermejo formation, and Raton formation. This block was probably torn from its position at depth and moved upward to its present position by the magma of the East Spanish Peak intrusive.

Alteration of shale to slate has been fairly extensive away from the contact of the White Peaks and the Black Hills intrusives. Elsewhere, the alteration of sandstone does not extend beyond several feet from the margin of the intrusive. Alteration of the coal beds to natural coke appears to be no more extensive than the alteration of sandstone and shale beds. At several localities sills have replaced coal or altered it to natural coke over several square miles (fig. 21).

IGNEOUS ROCKS

The Spanish Peaks region is recognized in geologic textbooks as a classic area for the occurrence of many types of igneous features. Stocks, laccoliths, plugs, dikes, and sills have been intruded into the sedimentary rocks in and adjacent to the Trinidad coal field.

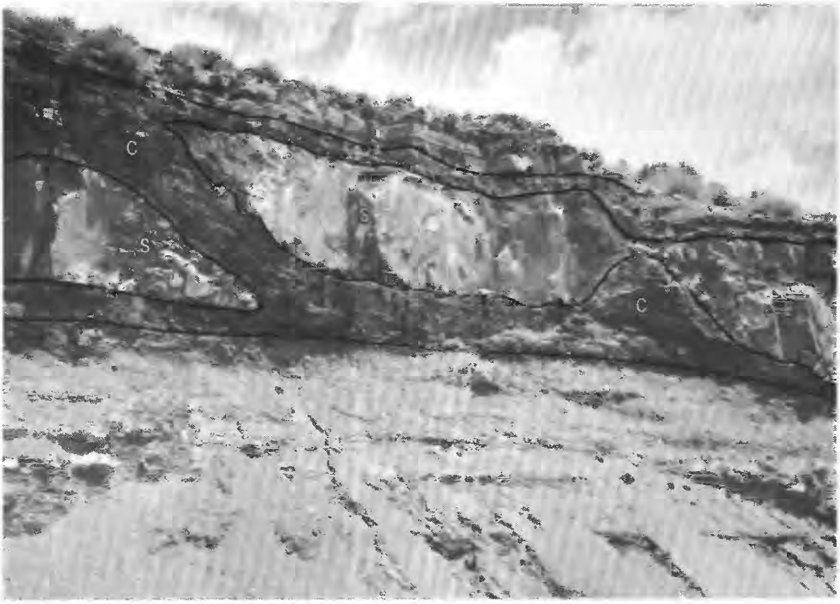

FIGURE 21.—Coal bed in Raton formation intruded by igneous sill. Sill, *s*, is discontinuous along outcrop, and has replaced a large part of the coal, *c*. Along Colorado State Route 12 about one-half mile east of Medina Plaza, Colo. View is eastward.

STOCKS

Large stocks make up the Spanish Peaks that topographically dominate the Trinidad coal field. Other stocks make up Dike Mountain northwest of La Veta and the White Peaks southwest of La Veta. A feature that may be a stock with several apophyses is intruded along the axis of the Cuatro syncline southwest of Tercio.

The West Spanish Peak stock of syenodiorite porphyry intrudes the Huerfano(?) and Cuchara formations near the axis of the La Veta syncline. The western part of the mass caps the sedimentary rocks near the top of the peak, and the base cuts across them at a relatively low angle. However, near the center of the intrusive, the base steepens sharply downward so that the contact between the igneous mass and the sedimentary rocks is several thousand feet lower than at the western part of the stock. There is no apparent doming of the sedimentary rocks about the stock. Hills (1901, p. 4) termed the rocks of the West Spanish Peak stock augite diorite, and Knopf (1936, p. 1735) stated that the West Spanish Peak stock consists of plutonic rock of several facies of syenodiorite. The stock of West Spanish Peak is surrounded by an impressive system of nearly radial dikes, which seems to have its focus in the area occupied by the stock (Johnson, 1958b, p. 1731).

The East Spanish Peak stock of granite porphyry and granodiorite porphyry intrudes the Cuchara formation of Eocene age and older sedimentary rocks of Paleocene and Cretaceous age. Doming of these sedimentary rocks is quite extensive along the southern and western flanks of the peak. Hills (1901, p. 4) states that an augite-granite porphyry occupies the summit and the western face of the East Spanish Peak, and a granite porphyry forms the main mass of the East Spanish Peak and the ridge extending northwestward from it. He believed that this rock grades upward into the augite-granite porphyry through a very narrow zone. Knopf (1936, p. 1735–1736) classified Hills' augite-granite porphyry as a grandiorite porphyry, and considered it intrusive into the granite porphyry. Knopf's contention is confirmed by the discovery by the author of a black fine-grained border facies where the granodiorite porphyry has been chilled against the granite porphyry. This facies could be traced throughout the southeast quadrant of the peak. The intrusive that metamorphosed the sedimentary rocks in the faulted block southwest of the stock is the granite porphyry. A few thin dikes of gabbro lamprophyre and basalt cut the East Spanish Peak stock near the southeastern margin.

The granite porphyry stock that forms the three hills known as North, Middle, and South White Peaks is intruded into the Pierre shale, the Trinidad sandstone, the Vermejo formation, the Raton formation, and the lower part of the Poison Canyon formation. There is no apparent doming due to the invasion of the magma in the sedimentary rocks next to the igneous mass. No dikes cut the intrusive, and dikes of grandiorite porphyry, syenite porphyry, and syenodiorite porphyry that are radial from West Spanish Peak extend westward only as far as the eastern margin of the White Peaks stock. However, several dikes of gabbro lamprophyre and diorite porphyry and microdiorite cut older rocks directly west of the White Peaks stock.

Four small apophyses of what may be a concealed stock of syenite porphyry intrude the Poison Canyon formation along the axis of the Cuatro syncline about 4 miles southwest of Tercio in the extreme southwestern part of the Trinidad coal field. These offshoots form small rounded hills, and the contacts are not well exposed. The invasion of the magma does not seem to have warped or metamorphosed the surrounding sedimentary rocks.

The Dike Mountain stock of syenodiorite porphyry is on the northwest margin of the coal field, and thus probably affects the coal-bearing rocks. The stock intrudes the Cuchara formation near the axis of the La Veta syncline. The contact of the intrusive with the surrounding sedimentary rocks is covered, but there does not appear to be doming or metamorphism of the enclosing rocks. A very striking and conspicuous swarm of dikes radiate from Dike Mountain in all directions. The rocks of the dikes are similar to the rock of the main intrusive, and are facies of syenodiorite.

LACCOLITH

The Black Hills laccolith of syenodiorite porphyry has been intruded between the Pierre shale and the Poison Canyon formation on the axis of the Greenhorn anticline at the north end of the coal field. The base of the laccolith is generally well exposed, and metamorphism and doming of the enclosing sedimentary rocks is evident. Beds of the Poison Canyon formation arch over the southern part of the Black Hills intrusive, but have been eroded from the mass elsewhere. Several small, circular isolated outcrops of igneous rock bordering the Black Hills are thought to be offshoots of the main mass. Hills (1900, p. 3) thought that the Dike Mountain and Black Hills intrusive rocks were genetically related, but, although they are megascopically similar, no surface connection is visible.

PLUGS

Goemmer Butte is an igneous plug of latite that intrudes the Cuchara formation about 2½ miles southwest of La Veta. The rock is dark gray and very fine grained. Knopf (1936, p. 1778–1779) concluded that Goemmer Butte is a volcanic neck, and identified the rock as latite. A small plug of microgranite intrudes the Cuchara formation about 5½ miles northeast of La Veta. The rock is light gray to white and very fine grained.

DIKES

Many dikes intrude Upper Cretaceous and Tertiary sedimentary rocks throughout the Trinidad coal field except south of the Purgatoire River where there are only a few short dikes. The dikes range in width from 1 to more than 100 feet, and extend for a maximum of almost 14 miles. They are generally more resistant to erosion than the rocks of the intruded formations, and consequently they stand as relatively straight vertical walls as much as 100 feet above the surrounding country. However, some of the more mafic dikes weather more rapidly than the intruded sedimentary rocks to form trenches. Polygonal joints normal to the dike walls are common. At some

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places metamorphosed country rock adheres to the dikes. The dikes range from microgranite and granite porphyry to olivine gabbro lamprophyre.

The distribution of dikes in the Trinidad coal field suggests the presence of at least five superimposed groups or swarms. The most conspicuous is the swarm that is radial from West Spanish Peak. The greatest concentration of dikes in this swarm is west of West Spanish Peak where they are generally short. The dikes rarely intrude the metamorphosed uppermost beds of the Huerfano(?) formation. These dikes range from microgranite and granite porphyry to gabbro lamprophyre and basalt.

A second system of dikes transects those that radiate from West Spanish Peak. This system is made up of subparallel dikes that strike from N. 60° E. in the northern part of the field to N. 86° E. in the southern part. Dikes of this system crop out from about 37°10′ to 37°40′ north latitude. The trend of the dikes is normal to the general trend of the folded sedimentary rocks. Dikes of this system are the longest within the coal field; they range in length from 2 to almost 14 miles. These dikes range from syenite porphyry and lamprophyre to olivine gabbro lamprophyre.

The swarm that is radial from Dike Mountain 20 miles northwest of West Spanish Peak is another conspicuous system. Like the West Spanish Peak system, the dikes radiating to the west are shorter than those radiating to the east. The longest dikes extend east-northeastward to within a few hundred feet of the intrusive mass that makes up the Black Hills. The dike rocks are similar to those of Dike Mountain and the Black Hills, and are facies of syenodiorite.

A large dike of microsyenodiorite southwest of Walsenburg extends across the eastern part of the coal field in an east-west direction. It is generally arcuate in plan and concave toward the south. The strike varies from N. 83° E. at its western extremity to N. 85° W. at its eastern extremity.

Throughout the Trinidad coal field there are many isolated single or small sets of basaltic and lamprophyric dikes that show no apparent pattern or general associations with the large dike systems or other types of intrusions. The dikes are thin and short.

SILLS

Basalt, gabbro lamprophyre, and microsyenodiorite sills intrude the sedimentary rocks of the Trinidad sandstone, Vermejo formation, and Raton formation as well as the beds of the Huerfano(?) formation near the West Spanish Peak stock. Sills are most abundant and extensive in the eastern part of the coal field from latitude 37°30′

north southward to the latitude of Trinidad and the drainage of the Purgatoire River to a point about a mile west of Weston. There are few sills in the coal field north of the Cuchara River, and they are uncommon or absent in the Trinidad sandstone, Vermejo formation, and Raton formation along the western margin of the coal field.

Several dikes radiating northwestward from West Spanish Peak are apparently parallel to the strike of strata in the Poison Canyon and Cuchara formations west of the Cuchara River, and seem to be sills in this area. Although the sedimentary beds are steeply dipping at 25° to 51°, the dikes are nearly vertical, and probably cut across the beds below the surface.

Only two sills, except for those intruding the metamorphosed beds of the Huerfano (?) formation adjacent to the West Spanish Peak stock, intrude as high in the stratigraphic sequence as the Poison Canyon formation, and these are in the lowermost beds of the Poison Canyon south of the South Fork of the Purgatoire River about 2 miles east of Tercio and southwest of Morley. Knopf (1936, p. 1774) reported a sill of microgranite 20 feet thick near the Spanish Peaks on the upper reaches of the South Fork of Trujillo Creek.

The sills in the Trinidad coal field are commonly complex or multiple intrusions that have invaded the shaly or coaly units of the Upper Cretaceous and Tertiary formations. They are generally more resistant than the shale or coal and commonly form strike ridges and ledges. They generally are not thick individual sheets, but are made up of anastomosing stringers of igneous rocks that seem to be concentrated in narrow zones. Some of the sills seem to cut across bedding, but poor exposures make determination of the exact relations difficult. Near Santa Clara Creek and south to Trinidad, sills are connected with dikes at several places. These dikes are lithologically similar to the sills. They are part of the dike systems that strike in a general east-west direction across the coal field, and cut the swarm radiating from West Spanish Peak.

The sill rock is dark gray and fine grained. Away from their contacts with the intruded rocks some of the thicker sills are coarse grained with diabasic texture. The sills range in thickness from a few inches to 40 feet, and extend over several square miles.

GEOLOGIC STRUCTURE

The principal structural feature of the Trinidad coal field is the Raton basin, which is a broad asymmetrical trough whose axis trends generally northward from near Ute Park, N. Mex., into Huerfano Park, Colo. The Colorado part of the trough has been named the La Veta syncline (Johnson and Stephens, 1954a; Wood, Johnson, and

Dixon, 1956). The eastern limb of the syncline has a gentle dip, whereas the western limb dips steeply and is vertical to overturned in places. The Greenhorn anticline plunges southward from the Wet Mountains, and splits the La Veta syncline into a major syncline to the west, and a minor one, the Delcarbon syncline (Johnson and Stephens, 1954a), to the east. In cross section the Delcarbon syncline is shallower and more symmetric than the La Veta syncline.

THRUST FAULTS

One to three thrust faults parallel the east front of the Sangre de Cristo Mountains along the steep western margin of the coal field. Two fault blocks northwest of La Veta are composed of two or possibly three imbricate thrust plates east of the Sangre de Cristo thrust fault. One plate, with which the coal-bearing Vermejo formation is associated, is complicated by an overturned and compressed syncline and anticline whose axial planes parallel the trace of the major thrust faults and are inclined to the west. The anticline has been strongly sheared by a thrust fault.

At the southern terminus of a thrust fault south of Cuchara Pass near the west margin of the coal field two tear faults trend southeastward, and cut the coal-bearing formations.

NORMAL FAULTS

Normal faulting is not characteristic of the coal field, but isolated groups of normal faults occur throughout the area. Two normal faults at the north end of the coal field cut the two flanks of the Delcarbon syncline, and trend generally parallel to the axis of the syncline with the upthrown sides toward the axis of the syncline. The throw of each fault is less than 50 feet.

The highly fractured and altered block of sedimentary rocks that lies between the Spanish Peaks seems to have been brought from depth by the intrusion of the East Spanish Peak magma. The relations of the faulting are obscured by cover, but the faults seem to be normal. The rocks are highly fractured and faulted, and only the major faults were mapped. The vertical displacement along these major faults may be as much as 6,000 feet.

Several small normal faults occur northeast of Weston. These faults trend north, east, northeast, and northwest, and seem to be related to a small anticline or dome. Faults north of the dome have been downthrown on the southern, southeastern, and southwestern sides; whereas faults south of the dome have been downthrown on the western, northwestern, and northeastern sides. Most of the faults are nearly vertical and have displacements of less than 50 feet.

Solitary vertical or nearly vertical normal faults occur locally, and are of such small displacement and extent that they are not shown on the geologic map (pl. 12).

FOLDS

The Greenhorn anticline, which splits the La Veta syncline, plunges southward into the Trindad coal field. The intrusion of the Black Hills magma on the nose of the anticline has further domed the intruded sedimentary rocks, and beds of the Poison Canyon formation arch over the southern part of the intrusive mass. They have been eroded from the Black Hills elsewhere.

The intrusion of the East Spanish Peak stock has domed beds of the Cuchara formation directly west and south of the stock, but beds to the north and east of it have not been folded by the invasion of the magma.

A narrow, slightly sinuous monoclinal flexure is located 3 miles northwest of Aguilar. The monocline trends northeastward through beds of the Trinidad sandstone and the Vermejo, Raton, and Poison Canyon formations. The rocks on the northeast side of the monocline are downfolded through a zone less than one-fourth of a mile wide. Dips may be as much as 50° at places. The vertical displacement is about 50 feet at the eastern edge of the coal field, and it increases southwestward to a maximum of nearly 200 feet. The fold is sharp, and at places along the edges of the flexure the rocks increase in dip from less than 2° to more than 40° within horizontal distances of less than 400 feet (Harbour and Dixon, 1959, p. 464).

At Morley a large mafic sill, which does not crop out in the map area, has been intruded between the Purgatoire formation and the Dakota sandstone of Early Cretaceous age, and has arched the beds above it into an irregular dome called the Morley dome. Raton Creek, which flows across the western flank of the dome, has breached the anticline to expose beds of the Poison Canyon, Raton, and Vermejo formations, the Trinidad sandstone, and older Cretaceous rocks.

In the southwestern part of the coal field are the Tercio anticline and the Cuatro syncline. Rincon Creek and the South Fork of the Purgatoire River have breached the anticline to expose beds of the Poison Canyon, Raton, and Vermejo formations, the Trindad sandstone, and older Cretaceous rocks. The anticline may have a closure of almost 1,000 feet.

Several long, narrow, irregular folds of low structural relief are prevalent south of the Spanish Peaks. The axes of these folds have no preferred orientation (Wood, Johnson, and Dixon, 1957, pl. 2).

COAL RESOURCES

The coal-bearing formations of the Trinidad coal field are the Vermejo and Raton formations. Thin noncommercial beds of coal occur locally in the lowermost strata of the Poison Canyon formation. The coal-bearing formations are poorly exposed except along the Purgatoire River and most of its tributaries and in the area between Aguilar and Trinidad. Coal beds are exposed intermittently along the outcrops of the coal field. The coal beds dip into the troughs of the La Veta, Delcarbon, and Cuatro synclines so that a large part of the coal lies more than 3,000 feet beneath the surface (pl. 12), and cannot be reached by present mining methods.

Coal beds are more numerous, thicker, and considerably more extensive in the Vermejo formation than in the Raton formation. Thick coal beds in the Raton formation are generally local in extent, and are mainly in the lower part of the formation. Some beds of coal in the Raton formation undoubtedly occur at depth in the trough of the La Veta syncline in the northern part of the coal field where the Raton formation is bevelled and unconformably overlain by the Poison Canyon formation.

COAL BEDS OF THE VERMEJO FORMATION

The Vermejo formation contains from 3 to 14 coal beds more than 14 inches thick everywhere in the coal field. These coal beds are lenticular, irregular in thickness, and are interbedded with shale and siltstone. The floors and roofs of mines are generally carbonaceous shale and claystone, but locally they may be carbonaceous siltstone and sandstone. Bony coal, carbonaceous shale, and carbonaceous siltstone form partings in the coal beds. The coal is brittle and friable with a bright luster, and consists of vitrain alternating with bands of fusain and durain. It has prismatic or cubic cleat and platy cleavage. Spheroidal coal similar to that in the Stonewall-Tercio area (Wood, Johnson, Eargle, and others, 1951) occurs at many places. Impurities, common in most of the beds, are mainly pyrite and elemental sulfur with some grains of silt and sand. Root impressions are imperfectly preserved at many localities in the carbonaceous shale and siltstone beds that underlie the coal beds. Conversion of the coal by intrusion of sills to natural coke is common in the southeastern part of the coal field (Wood, Johnson, and Dixon, 1957, p. 53; Harbour and Dixon, 1959, p. 462, 472).

The coal from the area north of the Spanish Peaks is a nonagglomerating and nonweathering high-volatile C bituminous coal, and that from south of the peaks is an agglomerating and weathering high-volatile A and B bituminous coal. This is indicated in the accompanying table of analyses of coal (table 1) from mines in the Trinidad coal field, and the system of coal classification (table 2) of the American Society for Testing Materials.

The coal beds of the Vermejo formation have been mined extensively along the eastern and northern parts of the coal field, and much less extensively along the western outcrop of the formation. Coal beds near the base of the formation are more extensive than those in the upper part, and minable beds occur within a few feet of the top of the Trinidad sandstone at most localities. A few of the coal beds are directly overlain by the conglomerate bed at the base of the Raton formation at a few places.

COAL BEDS OF THE RATON FORMATION

The Raton formation locally contains many coal beds more than 14 inches thick. There are only four coal beds in the Raton formation that are sufficiently thick and extensive to be of economic importance. They are the Ciruela bed (Wood, Johnson, Eargle, and others, 1951), the Frederick and Primero beds (Wood, Johnson, and Dixon, 1957, p. 33–35), and the Delagua No. 1 bed (Harbour and Dixon, 1959, p. 471). The coal beds of the Raton formation are generally thinner, more lenticular, and more irregular in thickness, and more widely spaced than those of the Vermejo formation. Partings of bony coal, carbonaceous shale, and carbonaceous siltstone are more common in the coal beds of the Raton formation. The coal beds are interbedded in shale and siltstone. The roof and floor rocks of the coal beds in the Raton formation are generally of carbonaceous siltstone and shale; however, at many places the roof is a thick sandstone bed (fig. 20). Root impressions and carbonized fossil roots are quite common beneath many of the coal beds in the Raton formation.

The coal in the Raton formation consists of approximately equal parts of durain and vitrain with lesser amounts of fusain. The coal is brittle and friable with bright to dull luster, and has cubic or prismatic cleat and platy cleavage. Conchoidal fracture is common, as is spheroidal coal at some localities. The coal is generally pure, but such impurities as pyrite, elemental sulfur, quartz sand grains, and limonite are generally present in small quantities. A few coal beds have been destroyed by the intrusion of igneous sills, and most of these beds are along the Purgatoire River valley.

As in the Vermejo formation, the coal of the Raton formation from north of the Spanish Peaks is generally a high-volatile C nonagglomerating and nonweathering bituminous coal, but that from south

TABLE 1.—*Analyses of coals from the Trinidad coal field*

[Source of data: George, 1937, p. 36–43, 76–85, and 92–100]

Mine	Sample No.	Proximate analysis (percent)				Ultimate analysis (percent)					Heating value		Softening temperature ° F (average)
		Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu	
Alamo	A4194	7.5	37.4	46.6	8.5	0.6	5.5	66.9	1.1	17.4	6,506	11,710	2360
Alamo No. 1	A87016	6.2	37.6	47.1	9.1	.6	5.5	67.3	1.2	16.3	6,628	11,930	2380
Bear Canyon No. 3	A19460	1.9	39.1	47.7	11.3	.8	5.4	72.3	1.5	8.7	7,311	13,160	
Bear Canyon No. 6	A74090	2.5	35.1	49.9	12.5	.6	5.4	71.7	1.5	8.3	7,117	12,810	2610
Berwind No. 3	6456	3.3	32.6	53.7	10.4	.7	5.3	72.6	1.2	9.8	7,328	13,190	2530
Boncarbo	A11868	2.9	32.1	49.0	16.0	.6	4.9	68.5	1.5	8.5	6,783	12,210	2430
Brennan	33563	7.3	38.4	46.8	7.5	.7	5.6	68.4	1.3	16.5	6,694	12,050	
Brodhead No. 9	32952	4.4	36.8	51.0	7.8	.4	5.3	73.1	1.5	11.9	7,239	13,030	2320
Brodhead No. 10	32953	3.1	36.5	49.6	10.8	.5	5.0	70.9	1.4	11.4	6,972	12,550	2430
Calumet No. 1	A64616	6.8	37.9	46.2	9.1	.6	5.5	66.7	1.2	16.9	6,567	11,820	2330
Calumet No. 2	A26611	7.0	36.3	46.1	10.6	1.0	5.5	66.8	1.2	14.9	6,456	11,620	2310
Cameron	A59293	4.2	37.2	46.2	12.4	.6	5.4	67.4	1.3	12.9	6,717	12,090	2390
Clark's Prospect	6455	3.1	30.6	58.9	7.4	.7	4.8	75.7	1.1	10.3	7,539	13,570	
Cokedale	11771	2.3	25.8	54.6	17.3	.5	4.6	69.1	1.1	7.4	6,856	12,340	2660
Delagua	11443	3.3	34.3	52.1	10.3	.6	5.1	71.6	1.4	11.0	7,061	12,710	2410
Delagua No. 2	114–D	2.9	36.3	53.0	7.8	.5					7,356	13,240	2300
Empire	32931	2.6	33.0	51.3	13.1	.7	4.9	71.0	1.3	9.0	7,028	12,650	2360
Engle	104–D	2.8	29.4	48.8	19.0	.6					6,622	11,920	
Fern	A1562	6.1	34.8	45.3	13.8	1.8					6,328	11,390	2260
1st East Primero	14060	1.5	30.8	54.4	13.3	.5	5.0	73.1	1.7	6.4	7,222	13,000	2400
1st North Delagua	31426	4.3	36.5	52.0	7.2	.6	5.4	73.9	1.4	11.5	7,272	13,090	2570
1st North Primero	14059	1.4	32.3	53.4	12.9	.5	5.0	73.5	1.7	6.4	7,267	13,080	
1st West Primero	14058	2.0	30.4	52.8	14.8	.6	4.9	71.4	1.7	6.6	7,050	12,690	
Forbes No. 9 (Cox)	11930	2.2	30.7	56.6	10.5	.6	5.0	75.3	1.3	7.3	7,511	13,520	
Francisco	231–D	1.6	29.2	59.5	9.7	.7					7,717	13,890	
Frederick	A58382	2.0	30.3	58.3	9.4	.6	5.4	76.3	1.7	6.6	7,661	13,790	2380
Gordon	33566	6.8	35.7	46.7	10.8	.8	5.1	64.7	1.3	17.3	6,444	11,600	2290
Hastings	254–D	1.5	34.7	54.2	9.6	.6					7,589	13,660	2740
Kebler No. 2	A59310	7.9	36.3	47.0	8.8	.5	5.7	65.8	1.1	18.1	6,461	11,630	2190
Las Animas No. 4	6536	2.4	35.1	56.4	6.1	.4	5.3	76.9	1.2	10.1	7,528	13,550	

Las Vega	101-D	2.3	34.0	52.7	11.0	0.7					7,467	13,440	
Lester	34195	3.3	36.8	49.1	10.8	.6	5.2	70.9	1.4	11.1	7,056	12,700	2520
Maitland	33817	6.1	34.4	45.1	14.4	.6	4.9	63.2	1.2	15.7	6,267	11,280	2400
Maitland No. 2	99944	5.7	36.1	46.1	12.1	.7					6,450	11,500	2390
Morley	A59287	1.9	31.9	53.1	13.1	.6	5.3	72.5	1.3	7.2	7,217	12,990	2350
Mutual	33949	4.8	36.1	44.2	14.9	.5	5.0	64.8	1.2	13.6	6,378	11,480	2500
Oakdale	13529	7.8	38.5	44.8	8.9	.5	5.2	65.5	1.1	18.8	6,411	11,540	2480
Peerless-Annex	6528	2.2	34.8	54.8	8.2	.7	5.0	75.1	1.2	9.8	7,456	13,420	
Pictou	A59280	5.0	38.1	47.7	9.2	.7	5.8	69.5	1.3	13.5	6,833	12,300	2410
Piedmont	10218	5.8	26.2	53.8	14.2	.6	5.2	69.5	1.2	9.3	6,917	12,450	2835
Piñon	10189	6.9	37.0	48.5	7.6	.6					6,661	11,900	2340
Piñon No. 3	222-D	5.3	36.4	46.3	12.0	1.2					6,506	11,710	
Prairie Canyon	A1537	3.2	35.0	52.0	9.8	.5					7,294	13,130	2620
Primero	6370	2.3	29.8	58.7	9.2	.5	5.2	74.2	1.1	9.8	7,656	13,780	
Primrose	6530	3.0	34.4	53.6	9.0	.4	5.1	72.0	1.3	12.2	7,183	12,930	
Pryor	6540	3.4	35.6	51.4	9.6	.8	5.2	71.0	1.2	12.2	7,106	12,790	
Rapson	6533	3.7	33.7	52.1	10.5	.6	5.3	70.9	1.2	11.5	7,028	12,650	
Ravenwood	31408	4.8	38.2	48.9	8.1	.7	5.4	71.0	1.4	13.4	7,000	12,600	2510
Red Robin	257-D	2.3	36.1	47.0	14.6	.6					6,961	12,530	
Robinson No. 1	A59274	3.9	37.6	47.7	10.8	.6	5.5	69.6	1.2	12.3	6,856	12,340	2420
Robinson No. 2	33896	4.8	36.5	48.2	10.5	.5	5.2	69.3	1.2	13.3	6,806	12,250	2380
Royal	32932	2.7	33.4	52.4	11.5	.7	5.1	72.5	1.3	8.9	7,167	12,900	2780
Sopris	31949	2.1	28.3	51.9	17.7	.7	4.8	69.3	1.3	6.2	6,867	12,360	2790
Starkville	12198	2.5	28.9	52.0	16.5	.6	4.8	69.1	1.1	7.8	6,883	12,390	2920
Suffield	481-D	3.0	32.5	50.5	14.0	.7					6,939	12,490	
Sunnyside	33657	8.5	36.7	46.3	8.5	.7	5.1	64.2	1.3	20.2	6,417	11,550	2500
Tabasco	A59305	2.1	32.7	52.6	12.6	.6	5.3	71.9	1.3	8.3	7,178	12,920	2590
Thor	86191	2.4	33.7	52.7	11.2	.8	5.4	72.3	1.4	8.9	7,211	12,980	2820
Toller	A59299	1.8	33.2	54.2	10.8	.8	5.3	73.3	1.4	8.4	7,356	13,240	2790
Toltec	33492	5.7	37.9	46.6	9.8	.8	5.2	67.9	1.3	15.0	6,750	12,150	2700
Vesta	33567	6.5	38.6	45.6	9.3	.6					6,650	11,970	2670

TABLE 2.—*Classification of coals by rank*[1]

[From American Society for Testing Materials (1938)]

Class	Group	Limits of fixed carbon or Btu mineral-matter-free basis	Requisite physical properties
I. Anthracitic	1. Meta-anthracite	Dry F. C., 98 percent or more (dry V. M., 2 percent or less).	
	2. Anthracite	Dry F.C., 92 percent or more and less than 98 percent (dry V.M., 8 percent or less and more than 2 percent).	
	3. Semianthracite	Dry F.C., 86 percent or more and less than 92 percent (dry V.M., 14 percent or less and more than 8 percent).	Nonagglomerating.[2]
II. Bituminous[3]	1. Low volatile bituminous coal.	Dry F.C., 78 percent or more and less than 86 percent (dry V.M., 22 percent or less and more than 14 percent).	
	2. Medium-volatile bituminous coal.	Dry F.C., 69 percent or more and less than 78 percent (dry V.M., 31 percent or less and more than 22 percent).	
	3. High-volatile A bituminous coal.	Dry F.C., less than 69 percent (dry V.M., more than 31 percent); and moist[4] Btu, 14,000[5] or more.	
	4. High-volatile B bituminous coal.	Moist[4] Btu, 13,000 or more and less than 14,000.[5]	
	5. High-volatile C bituminous coal.	Moist Btu, 11,000 or more and less than 13,000.[5]	Either agglomerating or nonweathering.[6]
III. Subbituminous	1. Subbituminous A coal.	Moist Btu, 11,000 or more and less than 13,000.[5]	Both weathering and nonagglomerating.
	2. Subbituminous B coal.	Moist Btu, 9,500 or more and less than 11,000.[5]	
	3. Subbituminous C coal.	Moist Btu, 8,300 or more and less than 9,500.[5]	
IV. Lignitic	1. Lignite	Moist Btu, less than 8,300	Consolidated.
	2. Brown coal	Moist Btu, less than 8,300	Unconsolidated.

Legend: F.C. = Fixed carbon. V.M. = Volatile matter. Btu = British thermal units.

[1] 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 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

[2] If agglomerating, classify in low-volatile group of the bituminous class.

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

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

[5] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

[6] 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.

of the peaks is an agglomerating and weathering high-volatile A and B bituminous coal. This is shown in the table of analyses of coal (table 1) from mines in the Trinidad coal field, and the system of coal classification (table 2) of the American Society for Testing Materials. It is likely, however, that some of the beds, for which information is not available, may be of coking quality north of the peaks and of domestic quality (that is, nonagglomerating) south of the peaks.

Coal beds in the Primero, Frederick, and Delagua No. 1 Mines have been exploited extensively, and coal is being removed from the Ciruela bed by the recently opened Allen mine near Stonewall.

COAL RESERVES

The original reserves of coal in the Trinidad coal field occurring in beds more than 14 inches in thickness and with less than 3,000 feet of overburden are estimated to have been 16,367 million short tons (table 3). This estimate is based on scattered measurements of the thickness of coal beds at the outcrop, logs of diamond drill holes, and published (George, 1937, p. 184–198, 216–238) measurements of thickness of coal beds measured in coal mines. In table 4 the reserves are divided according to township, amount of overburden, and thickness of beds, and classified as measured and indicated, and inferred, terms which indicate the reliability of the estimates.

The reserves of coal are given in table 4 in three thickness categories: 14 to 28 inches, 28 to 42 inches, and more than 42 inches. In order to estimate tonnage in each category, isopach maps of the coal beds were drawn. The areal extent and average thickness of each coal bed within each isopach interval were determined, and from this information the tonnage of coal reserves was calculated.

TABLE 3.—*Total estimated original coal reserves in the Trinidad coal field, Colorado*

[All coal is of bituminous rank, in thousands of short tons]

Area (fig. 18)	Total reserves on a coal bed basis	Total reserves on a coal zone basis	Total reserves
La Veta	120, 900	201, 900	322, 800
Walsenburg	667, 500	974, 440	1, 641, 940
Spanish Peaks	106, 808	386, 620	493, 428
Trinidad-Aguilar	1, 215, 590	1, 869, 666	3, 085, 256
Gulnare, Cuchara Pass, and Stonewall	524, 130	1, 755, 940	2, 280, 070
Cuatro	262, 146	767, 950	1, 030, 096
Stonewall-Tercio	490, 969	1, 895, 131	2, 386, 100
Starkville-Weston	880, 320	4, 364, 170	5, 244, 490
Total Trinidad coal field	4, 268, 363	12, 215, 817	16, 484, 180

TABLE 4.—*Estimated original reserves (in thousands of short tons), on a coal-bed basis, in the Trinidad coal field, Huerfano and Las Animas Counties, Colorado*

[All coal is of bituminous rank]

Amount of overburden (feet)	Reserves of coal (thousands of short tons) for beds of thickness shown (inches)								Total reserves			
	Measured and indicated				Inferred							
	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Grand total
T. 27 S., R. 66 W.												
Less than 1,000	200	200	1,200	1,600	100	100	100	300	300	300	1,300	1,900
T. 27 S., R. 67 W.												
Less than 1,000	21,700	36,700	44,500	102,900	9,000	9,700	14,500	33,200	30,700	46,400	59,000	136,100
From 1,000 to 2,000	300	1,200	4,000	5,500	6,500	2,300	25,500	34,300	6,800	3,500	29,500	39,800
From 2,000 to 3,000					200	1,300	10,500	12,000	200	1,300	10,500	12,000
Total	22,000	37,900	48,500	108,400	15,700	13,300	50,500	79,500	37,700	51,200	99,000	187,900
T. 27 S., R. 68 W.												
Less than 1,000	1,500	1,700	6,400	9,600	500	1,200	7,800	9,500	2,000	2,900	14,200	19,100
From 1,000 to 2,000	700	600	3,700	5,000	400	1,400	4,000	5,800	1,100	2,000	7,700	10,800
Total	2,200	2,300	10,100	14,600	900	2,600	11,800	15,300	3,100	4,900	21,900	29,900
T. 28 S., R. 66 W.												
Less than 1,000	28,000	36,300	21,600	85,900	30,200	12,900	8,800	51,900	58,200	49,200	30,400	137,800
From 1,000 to 2,000	1,300	1,100		2,400	9,100	600		9,700	10,400	1,700		12,100
Total	29,300	37,400	21,600	88,300	39,300	13,500	8,800	61,600	68,600	50,900	30,400	149,900

T. 28 S., R. 67 W.												
Less than 1,000	2,800	7,900	3,800	14,500	12,800	14,900	3,600	31,300	15,600	22,800	7,400	45,800
From 1,000 to 2,000			100	100	18,900	15,600	3,500	38,000	18,900	15,600	3,600	38,100
From 2,000 to 3,000					6,200	10,800	500	17,500	6,200	10,800	500	17,500
Total	2,800	7,900	3,900	14,600	37,900	41,300	7,600	86,800	40,700	49,200	11,500	101,400
T. 28 S., R. 68 W.												
From 1,000 to 2,000		200	1,200	1,400	3,300	4,600	400	8,300	3,300	4,800	1,600	9,700
From 2,000 to 3,000					7,200	2,600		9,800	7,200	2,600		9,800
Total		200	1,200	1,400	10,500	7,200	400	18,100	10,500	7,400	1,600	19,500
T. 28 S., R. 69 W.												
From 2,000 to 3,000						500		500		500		500
T. 29 S., R. 65 W.												
Less than 1,000	5,174	7,216	26,611	39,001	5,796	12,014	12,225	30,035	10,970	19,230	38,836	69,036
From 1,000 to 2,000			99	99	99	98	97	294	99	98	196	393
Total	5,174	7,216	26,710	39,100	5,895	12,112	12,322	30,329	11,069	19,328	39,032	69,429
T. 29 S., R. 66 W.												
Less than 1,000	29,094	28,604	25,220	82,898	28,173	33,788	13,858	75,819	57,267	62,392	39,058	158,717
From 1,000 to 2,000	13,200	11,500	9,800	34,500	33,995	38,239	13,272	85,506	47,195	49,739	23,072	120,006
From 2,000 to 3,000	1,000			1,000	29,200	2,600		31,800	30,200	2,600		32,800
Total	43,294	40,104	35,000	118,398	91,368	74,627	27,130	193,125	134,662	114,731	62,130	311,523
T. 29 S., R. 67 W.												
From 2,000 to 3,000					4,800			4,800	4,800			4,800

TABLE 4.—*Estimated original reserves (in thousands of short tons), on a coal-bed basis, in the Trinidad coal field, Huerfano and Las Animas Counties, Colorado*—Continued

[All coal is of bituminous rank]

Amount of overburden (feet)	Reserves of coal (thousands of short tons) for beds of thickness shown (inches)								Total reserves			
	Measured and indicated				Inferred							
	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Grand total
T. 29 S., R. 69 W.												
Less than 1,000	2,931	475	20,000	23,406	2,953	1,000	614	4,567	5,884	1,475	20,614	27,973
From 1,000 to 2,000	1,135	100	10	1,245	5,668	530	764	6,962	6,803	630	774	8,207
From 2,000 to 3,000					6,551	1,561	70	8,182	6,551	1,561	70	8,182
Total	4,066	575	20,010	24,651	15,172	3,091	1,448	19,711	19,238	3,666	21,458	44,362
T. 30 S., R. 65 W.												
Less than 1,000	40,413	38,438	19,730	98,581	42,018	29,860	2,797	74,675	82,431	68,298	22,527	173,256
From 1,000 to 2,000	319	2,527	1,151	3,997	35,166	32,496	2,287	69,949	35,485	35,023	3,438	73,946
Total	40,732	40,965	20,881	102,578	77,184	62,356	5,084	144,624	117,916	103,321	25,965	247,202
T. 30 S., R. 66 W.												
Less than 1,000					4,461	11,602		16,063	4,461	11,602		16,063
From 1,000 to 2,000					38,160	38,366	429	76,955	38,160	38,366	429	76,955
Total					42,621	49,968	429	93,018	42,621	49,968	429	93,018
T. 30 S., R. 68 W.												
From 1,000 to 2,000						46	27	73		46	27	73
From 2,000 to 3,000					34	8,545	3,359	11,938	34	8,545	3,359	11,938
Total					34	8,591	3,386	12,011	34	8,591	3,386	12,011

T. 30 S., R. 69 W.												
Less than 1,000	722	2, 661	4, 334	7, 717	675	5, 621	5, 933	12, 229	1, 397	8, 282	10, 267	19, 946
From 1,000 to 2,000	589	2, 679	2, 515	5, 783	1, 497	9, 998	8, 223	19, 718	2, 086	12, 677	10, 738	25, 501
From 2,000 to 3,000		77		77	2, 182	10, 283	5, 478	17, 943	2, 182	10, 360	5, 478	18, 020
Total	1, 311	5, 471	6, 849	13, 577	4, 354	25, 902	19, 634	49, 890	5, 665	31, 319	26, 483	63, 467
T. 31 S., R. 64 W.												
Less than 1,000	1, 220	5, 572	11, 320	18, 067	850	266	7, 570	8, 686	2, 070	5, 793	18, 890	26, 753
T. 31 S., R. 65 W.												
Less than 1,000	28, 086	16, 857	54, 644	99, 587	75, 753	35, 713	55, 295	166, 761	103, 839	52, 570	109, 939	266, 348
From 1,000 to 2,000					1, 242	765		2, 007	1, 242	765		2, 007
Total	28, 086	16, 857	54, 644	99, 587	76, 995	36, 478	55, 295	168, 768	105, 081	53, 335	109, 939	268, 355
T. 31 S., R. 66 W.												
Less than 1,000					7, 378			7, 378	7, 378			7, 378
T. 31 S., R. 68 W.												
Less than 1,000	40	20		60			30	30	40	20	30	90
From 1,000 to 2,000					240	120	560	920	240	120	560	920
From 2,000 to 3,000	630	520	20	1, 170	170		840	1, 010	800	520	860	2, 180
Total	670	540	20	1, 230	410	120	1, 430	1, 960	1, 080	660	1, 450	3, 190
T. 31 S., R. 69 W.												
Less than 1,000	2, 190	2, 230	3, 190	7, 610	1, 845	852	1, 400	4, 097	4, 035	3, 082	4, 590	11, 707
From 1,000 to 2,000	1, 570	1, 350	1, 650	4, 570	3, 198	2, 300	650	6, 148	4, 768	3, 650	2, 300	10, 718
From 2,000 to 3,000	680	1, 570	610	2, 860	5, 819	4, 584	640	11, 043	6, 499	6, 154	1, 250	13, 903
Total	4, 440	5, 150	5, 450	15, 040	10, 862	7, 736	2, 690	21, 288	15, 302	12, 886	8, 140	36, 328

TABLE 4.—*Estimated original reserves (in thousands of short tons), on a coal-bed basis, in the Trinidad coal field, Huerfano and Las Animas Counties, Colorado*—Continued

[All coal is of bituminous rank]

Amount of overburden (feet)	Reserves of coal (thousands of short tons) for beds of thickness shown (inches)								Total reserves			
	Measured and indicated				Inferred							
	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Grand total
T. 32 S., R. 64 W.												
Less than 1,000	19,805	21,422	40,698	81,925	14,728	40,586	24,722	80,036	34,533	62,008	65,420	161,961
From 1,000 to 2,000					792	4,650		5,442	792	4,650		5,442
Total	19,805	21,422	40,698	81,925	15,520	45,236	24,722	85,478	35,325	66,658	65,420	167,403
T. 32 S., R. 65 W.												
Less than 1,000	27,021	21,214	20,219	68,454	53,039	18,448	6,601	78,088	80,060	39,662	26,820	146,542
From 1,000 to 2,000					8,615	5,220		13,835	8,615	5,220		13,835
Total	27,021	21,214	20,219	68,454	61,654	23,668	6,601	91,923	88,675	44,882	26,820	160,377
T. 32 S., R. 66 W.												
Less than 1,000	153		4,222	4,375	5,678	5,828	3,696	15,202	5,831	5,828	7,918	19,577
T. 32 S., R. 67 W.												
Less than 1,000					10			10	10			10

T. 32 S., R. 68 W.												
Less than 1,000	7, 150	4, 290	37, 690	49, 130	3, 600	10, 390	5, 380	19, 370	10, 750	14, 680	43, 070	68, 500
From 1,000 to 2,000	2, 990	4, 380	15, 840	23, 210	8, 590	7, 600	14, 810	31, 000	11, 580	11, 980	30, 650	54, 210
From 2,000 to 3,000	160	10	1, 770	1, 940	28, 740	4, 760	18, 110	51. 610	28, 900	4, 770	19, 880	53, 550
Total	10, 300	8, 680	55, 300	74, 280	40, 930	22, 750	38, 300	101, 980	51, 230	31, 430	93, 600	176, 260
T. 32 S., R. 69 W.												
Less than 1,000	350	60	570	980	230		1, 030	1, 260	580	60	1, 600	2, 240
T. 33 S., R. 63 W.												
Less than 1,000	97	1, 513	2, 596	4, 206	28	96		124	125	1, 609	2, 596	4, 330
T. 33 S., R. 64 W.												
Less than 1,000	23, 250	48, 160	46, 870	118, 280	30, 240	32, 140	6, 130	68, 510	53, 490	80, 300	53, 000	186, 790
From 1,000 to 2,000					460	450		910	460	450		910
Total	23, 250	48, 160	46, 870	118, 280	30. 700	32, 590	6, 130	69, 420	53, 950	80, 750	53, 000	187, 700
T. 33 S., R. 65 W.												
Less than 1,000	15, 679	14, 384	34, 242	64, 305	28, 433	17, 460	12, 956	58, 849	44, 112	31, 844	47, 198	123, 154
From 1,000 to 2,000					2, 311	392		2, 703	2, 311	392		2, 703
Total	15, 679	14, 384	34, 242	64, 305	30, 744	17, 852	12, 956	61, 552	46, 423	32, 236	47, 198	125, 857
T. 33 S., R. 66 W.												
Less than 1,000	21, 430	4, 910	42, 010	68, 350	17, 605	8, 910	76, 543	103, 058	39, 035	13. 820	118, 553	171, 408

TABLE 4.—*Estimated original reserves (in thousands of short tons), on a coal-bed basis, in the Trinidad coal field, Huerfano and Las Animas Counties, Colorado*—Continued

[All coal is of bituminous rank]

Amount of overburden (feet)	Reserves of coal (thousands of short tons) for beds of thickness shown (inches)								Total reserves			
	Measured and indicated				Inferred				14 to 28	28 to 42	>42	Grand total
	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Total				
T. 33 S., R. 67 W.												
Less than 1,000	43, 240	56, 650	8, 240	108, 130	41, 240	11, 000	29, 080	81, 320	84, 480	67, 650	37, 320	189, 450
From 1,000 to 2,000					10, 360	1, 580	30	11, 970	10, 360	1, 580	30	11, 970
From 2,000 to 3,000	3, 600			3, 600					3, 600			3, 600
Total	46, 840	56, 650	8, 240	111, 730	51, 600	12, 580	29, 110	93, 290	98, 440	69, 230	37, 350	205, 020
T. 33 S., R. 68 W.												
Less than 1,000	13, 500	14, 220	45, 610	73, 330	24, 188	42, 070	17, 358	83, 616	37, 688	56, 290	62, 968	156, 946
From 1,000 to 2,000	30	2, 480	4, 070	6, 580	10, 090	38, 760	6, 120	54, 970	10, 120	41, 240	10, 190	61, 550
From 2,000 to 3,000	10			10	10, 510	1, 490		12, 000	10, 520	1, 490		12, 010
Total	13, 540	16, 700	49, 680	79, 920	44, 788	82, 320	23, 478	150, 586	58, 328	99, 020	73, 158	230, 506
T. 34 S., R. 63 W.												
Less than 1,000	1, 040	470	660	2, 170	4, 020	810	970	5, 800	5, 060	1, 280	1, 630	7, 970
T. 34 S., R. 64 W.												
Less than 1,000	19, 680	15, 100	14, 440	49, 220	62, 790	42, 670	18, 510	123, 970	82, 470	57, 770	32, 950	173, 190
From 1,000 to 2,000					1, 800			1, 800	1, 800			1, 800
Total	19, 680	15, 100	14, 440	49, 220	64, 590	42, 670	18, 510	125, 770	84, 270	57, 770	32, 950	174, 990

T. 34 S., R. 65 W.												
Less than 1,000	20,000	30,160	39,680	89,840	35,730	10,020	1,530	47,280	55,730	40,180	41,210	137,120
From 1,000 to 2,000					270			270	270			270
Total	20,000	30,160	39,680	89,840	36,000	10,020	1,530	47,550	56,000	40,180	41,210	137,390
T. 34 S., R. 66 W.												
Less than 1,000	19,559	4,696	220	24,475	35,077	6,106		41,183	54,636	10,802	220	65,658
From 1,000 to 2,000	288			288	3,297	17		3,314	3,585	17		3,602
Total	19,847	4,696	220	24,763	38,374	6,123		44,497	58,221	10,819	220	69,260
T. 34 S., R. 67 W.												
Less than 1,000	42,410	14,140	3,750	60,300	33,470	5,070	3,780	42,320	75,880	19,210	7,530	102,620
From 1,000 to 2,000												
From 2,000 to 3,000					490	90		580	490	90		580
Total	42,410	14,140	3,750	60,300	33,960	5,160	3,870	42,900	76,370	19,300	7,530	103,200
T. 34 S., R. 68 W.												
Less than 1,000	32,793	42,995	45,106	120,894	47,538	42,238	94,088	183,864	80,331	85,233	139,194	304,758
From 1,000 to 2,000	235	3,121	8,473	11,829	2,638	1,147	36	3,821	2,873	4,268	8,509	15,650
From 2,000 to 3,000		1,049	1,781	2,830	992	80	121	1,193	992	1,129	1,902	4,023
Total	33,028	47,165	55,360	135,553	51,168	43,465	94,245	188,878	84,196	90,630	149,605	324,431
T. 34 S., R. 69 W.												
Less than 1,000	2,498	759	4,797	8,054	2,011			2,011	4,509	759	4,797	10,065
From 1,000 to 2,000	2,766	4,216	6,819	13,801	3,269	262		3,531	6,035	4,478	6,819	17,332
From 2,000 to 3,000	934	1,782	4,394	7,110	4,782	1,416	1,399	7,597	5,716	3,198	5,793	14,707
Total	6,198	6,757	16,010	28,965	10,062	1,678	1,399	13,139	16,260	8,435	17,409	42,104

TABLE 4.—*Estimated original reserves (in thousands of short tons), on a coal-bed basis, in the Trinidad coal field, Huerfano and Las Animas Counties, Colorado*—Continued

[All coal is of bituminous rank]

Amount of overburden (feet)	Reserves of coal (thousands of short tons) for beds of thickness shown (inches)								Total reserves			
	Measured and indicated				Inferred							
	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Grand total
T. 35 S., R. 63 W.												
Less than 1,000	390	850	1,690	2,930					390	850	1,690	2,930
T. 35 S., R. 64 W.												
Less than 1,000	6,120	9,630	15,920	31,670	26,640	13,290	970	40,900	32,760	22,920	16,890	72,570
T. 35 S., R. 65 W.												
Less than 1,000	3,855	370		4,225	2,685			2,685	6,540	370		6,910
T. 35 S., R. 66 W.												
Less than 1,000	4,669			4,669	8,951			8,951	13,620			13,620
T. 35 S., R. 67 W.												
Less than 1,000	3,100	530		3,630	5,170			5,170	8,270	530		8,800
From 1,000 to 2,000												
From 2,000 to 3,000					588			588	588			588
Total	3,100	530		3,630	5,758			5,758	8,858	530		9,388

T. 35 S., R. 68 W.												
Less than 1,000	6,470	10,980	8,420	25,870	5,790	10,040	530	16,360	12,260	21,020	8,950	42,230
From 1,000 to 2,000	2,830	12,030	3,180	18,040	11,890	18,670	1,590	32,150	14,720	30,700	4,770	50,190
From 2,000 to 3,000	10	1,210	310	1,530	8,350	22,890	4,450	35,690	8,360	24,100	4,760	37,220
Total	9,310	24,220	11,910	45,440	26,030	51,600	6,570	84,200	35,340	75,820	18,480	129,640
T. 35 S., R. 69 W.												
Less than 1,000	5,260	3,651	4,182	13,092	575	164		739	5,835	3,815	4,182	13,832
From 1,000 to 2,000	4,090	2,901	3,333	10,324	538	376		914	4,628	3,277	3,333	11,238
From 2,000 to 3,000	3,008	1,727	3,306	8,041	4,769	4,012	2,564	11,345	7,777	5,739	5,870	19,386
Total	12,358	8,279	10,821	31,458	5,882	4,552	2,564	12,998	18,240	12,831	13,385	44,456
Grand total												
Less than 1,000	503,589	505,982	664,361	1,673,932	711,968	486,852	438,396	1,637,216	1,215,557	992,834	1,102,757	3,311,148
From 1,000 to 2,000	32,342	50,384	65,940	148,666	222,385	226,582	82,295	531,262	254,727	276,966	148,235	679,928
From 2,000 to 3,000	10,032	7,945	12,191	30,168	121,577	77,511	48,031	247,119	131,609	85,456	60,222	277,287
Total Trinidad coal field	545,963	564,311	742,492	1,852,766	1,055,930	790,945	568,722	2,415,597	1,601,893	1,355,256	1,311,214	4,268,363

Estimates of measured and indicated reserves are based on specific measurements of coal in outcrops, wells, and mine workings. Where geologic evidence permits, estimates are made of coal assumed to lie as much as one mile from a point of observation. Inferred reserves are based on an inference from geologic observations regarding the underground extent of the individual coal beds. All coal included in this category lies more than one mile from the point of observation.

Reserves are also classified according to the thickness of overburden. The classifications are: 0 to 1,000 feet; 1,000 to 2,000 feet; and 2,000 to 3,000 feet. Much of the coal in the Vermejo and Raton formations in the Trinidad coal field is covered by more than 3,000 feet of overburden (pl. 12), and is therefore not included in the reserves. Additional estimates of reserves on a zone basis are based on the assumption that the coal-bearing rocks contain as much coal at depth as at the outcrop.

MINING

Coal mining activity in the Trinidad coal field began in 1873, reached a climax between 1900 and 1930, and has tapered off since 1930. Few mines are now being operated in the coal field. The most important in 1957 was the Allen mine owned by the Colorado Fuel and Iron Corporation, which produced 577,248 tons in 1956 (Colorado Coal Mine Inspection Department, 1957, p. 19). The large Morley mine closed down in 1956, and the Frederick mine had a slightly reduced production of 354,457 tons in 1956 (Colorado Coal Mine Inspection Department, 1957, p. 20). Other mines that are seasonally worked produced between 79 and 15,707 short tons in 1956 (Colorado Coal Mine Inspection Department, 1957, p. 18–20).

The accompanying table of depletion (table 5) of coal reserves includes all available data. Because the tonnage figures for some years are missing the depletion figure of 217,601,743 short tons is approximate only. Early production figures included Huerfano and Las Animas Counties with other counties to the north. Separate production figures for Huerfano and Las Animas Counties are continuous from 1884, except for the years 1889 and 1890. Coal production prior to 1884 probably was not large, and it is likely that table 5 approximates the amount of the coal produced. Mine names have been changed and duplicated through the years, and some errors may have been made in tracing the sequence of names.

No data are available regarding the percentage of coal recovered by mining operations in the Trinidad coal field, but it may be assumed, from mining averages in the western United States, to be 50 percent. On that basis, the amount of coal recovered and lost in mining in the area to January 1, 1957, is about 435 million short tons. The remain-

TABLE 5.—*Coal mined in the Trinidad coal field of Colorado from 1884 to 1956*

[Source of data: Colorado Coal Mine Inspection Department, 1957]

Coal mine	Coal mined, in short tons, during the periods													
	1884–90 [1]	1891–1900	1901–10	1911–20	1921–30	1931–40	1941–50	1951	1952	1953	1954	1955	1956	Total
Alamo					604,620	341,800								946,420
Alamo No. 2-Barbour-Butte Valley					328,850	389,910	472,448	13,127	2,490					1,206,825
Allen								7,463	144,426	430,051	396,994	568,720	577,248	2,124,902
Anchor-Toller			176,119	1,307,197	1,936,701	117,877	134,362	403	1,320	931	917	80	140	3,676,047
Baldy			29,556	40,685	19,040	55,658	120,757	11,452	8,061	7,138	7,603	6,884	3,819	310,653
Beacon			34,986	149,813										184,799
Bear Canyon				170,682	282,745									453,427
Bear Canyon No. 6					358,732	268,072	466,410	46,430	36,324	12,465	104			1,188,537
Berwind		1,265,799	3,855,375	2,424,699	1,324,724									8,870,597
Big Four			205,165	469,002										674,167
Black Diamond			329,594	103,093	6,051									438,738
Boncarbo				487,409	2,122,903	976,730	928,877							4,515,919
Bowen		57,526	1,684,164	936,553	16,529	28,600	3,483							2,726,855
Breen				172,000										172,000
Brodhead		23,710	698,670	1,027,973	1,258,258	596,151	5,994	2,584	1,851	2,177	3,021	2,830	3,024	3,626,243
Bunker Hill		56,001	49,591	10,328	18,943	9,869								144,732
Calumet No. 1-Turner			9,883	564,608	2,535,949	168,318								3,278,758
Calumet No. 2-Brennan				70,922	637,270	650,285	1,199,556	57,895	14,336	16,843	15,870	16,847	15,707	2,695,531
Cameron			185,564	1,401,863	1,783,584	1,921,516	1,096,123							6,388,650
Cass				167,684	383,969									551,653
Champion		15,332	199,266											214,598
Chicosa	16,966	205,701												222,667
Cokedale			1,095,968	1,862,509										2,958,477
Cuatro			260,358											260,358
Delagua			3,975,954	5,154,109	3,880,101	1,783,851	1,116,183	110,252	25,733					16,046,183
Dix					526,978	252,962	335,621							1,115,561
Empire			105,373	312,689	722,854	116,396								1,257,312
Forbes-Cox		14,392	1,245,831	1,223,021	289,372	11,074	7,460	330						2,791,480
Francisco-Frisco			179,020			14,596	3,808							197,424
Frederick			722,860	3,186,809	3,586,907	3,524,709	5,659,974	501,430	433,076	489,705	312,943	352,795	354,457	19,125,665
Gordon			106,315	329,477	558,777	395,878	691,136	13,230	23,116	14,042	11,661	10,188	11,740	2,165,560
Green Canyon			488,539											488,539
Greenville			579,130	442,961	105,182									1,127,273
Hastings		736,342	4,199,442	1,304,185	34,943									6,274,912
Hezron			732,143	102,379	60,620									895,142

TABLE 5.—*Coal mined in the Trinidad coal field of Colorado from 1884 to 1956*—Continued

[Source of data: Colorado Coal Mine Inspection Department, 1957]

Coal mine	Coal mined, in short tons, during the periods													
	1884–90 [1]	1891–1900	1901–10	1911–20	1921–30	1931–40	1941–50	1951	1952	1953	1954	1955	1956	Total
Huerfano			301, 740	111, 358										413, 098
Ideal			109, 615	1, 149, 155	1, 210, 863									2, 469, 633
Jeffries				228, 732	74, 092	30, 029	6, 325							339, 178
Jewel-Crestone			52, 051	205, 743	383, 173	264, 799	96, 432	5, 215	3, 858	1, 988				1, 013, 259
Jobol				116, 786	85, 284									202, 070
Kenneth			151, 731	279, 692	251, 391	550, 702	474, 063							1, 707, 579
La Belle		30, 500	329, 373	67, 108	87, 691	3, 711								518, 383
Larimore					107, 786									107, 786
Leader				75	71, 861	79, 166	52, 047	2, 637	2, 722	1, 749	1, 996	2, 239	2, 132	216, 624
Lester				1, 050, 568	1, 429, 640									2, 480, 208
Ludlow			450, 278	892, 976	685, 695	432, 768	662, 269	57, 649	14, 538					3, 196, 173
Maitland		159, 562	788, 400	307, 252	286, 557	101, 624	96, 613	12, 032	13, 659	7, 398	5, 419	6, 933	6, 858	1, 792, 307
Majestic		55, 280	1, 280, 600	223, 783										1, 559, 663
Midway		58, 881	1, 318, 795											1, 377, 676
Moore				55, 047	109, 579									164, 626
Morley			1, 167, 274	2, 427, 157	3, 496, 656	1, 173, 691	1, 941, 159	175, 442	145, 440	196, 650	124, 612	146, 654	51, 443	11, 046, 178
Morning Glory-Vesta				196, 091	147, 156	203, 005	848, 115	25, 199	21, 400	17, 514	13, 698	16, 806	17, 120	1, 506, 104
Mutual				680, 437	795, 189	21, 102								1, 496, 728
New Rouse		303, 302												303, 302
Oakdale			429, 327	1, 995, 204	883, 417	15, 333								3, 323, 281
Old Rouse	48, 710	1, 805, 256	2, 075, 933	1, 773, 849										5, 703, 748
Peerless		475, 209	143, 748	50										619, 007
Pictou		958, 961	1, 336, 447	606, 612	784, 618		253, 359	57, 711	56, 399	26, 996				4, 081, 103
Piedmont			887, 117	1, 001, 115	8, 009	4, 139								1, 900, 380
Pinon			441, 510	146, 464										587, 974
Prairie Canyon				29, 857	167, 029									196, 886
Primero			4, 252, 940	3, 149, 524	781, 539									8, 184, 003
Primrose		1, 942	734, 454	343, 934	34, 130	887	67, 646	1, 007	713	578	72			1, 185, 363
Pryor		171, 288	935, 752	76, 3370	482, 271	493, 589	181, 859	2, 885						3, 031, 014
Quinto			169, 903											169, 903
Rapson		10, 570	152, 798	374, 651	132, 351	110, 566	371, 743	41, 238	51, 139	17, 138	8, 629	12, 202	11, 814	1, 294, 839
Ravenwood			70, 750	660, 152	662, 943	252, 997	11, 299							1, 658, 141
Reliance-Ojo				468, 716	202, 797	108, 181	4, 801							784, 495
Road Canyon		122, 404												122, 404
Robinson	19, 400	374, 961	1, 538, 946	324, 635										2, 257, 942
Round Oak			145, 374	27, 425	5, 343	4, 029								182, 171
Royal				995, 621	1, 422, 400									2, 418, 021
Rugby		44, 045	750, 941	396, 240	32, 081		6, 069	1, 508	526	795	1, 319	1, 329	1, 541	1, 236, 394

Santa Fe				78,043	51,125	6,960	781							136,909
Sopris	134,557	2,523,790	1,429,050	2,431,683	1,559,563	141,837								8,220,480
Southwestern			93,800	140,989	121,516									356,305
Stanley					109,637									109,637
Starkville	852,130	3,096,164	3,053,458	1,690,159	26,686	14,174	5,969	887	83					8,739,710
Suffield-Thor			494,869	484,444	741,409	110,115	115,520							1,946,357
Sunnyside			367,674	571,328	428,744	17,091								1,384,837
Sweet			105,453											105,453
Tabarco			852,430	1,695,735	1,878,612									4,426,777
Tercio			1,133,166	294,344										1,427,510
Three Pines				64,302	183,540									247,842
Tioga-Kebler No. 2			147,359	456,594	693,371	1,298,618	1,490,150	111,784	103,033	46,180				4,347,089
Toltec		216,875	605,863	404,947	492,990	102,107	905							1,823,687
Torrid					85,139	60,882								146,021
Victor		1,717,747												1,717,747
Walsen	478,900	760,533	1,492,184	2,395,883	3,018,004	30,385								8,175,889
Others	95,325	330,547	263,946	1,339,862	512,633	556,674	820,427	50,477	38,387	29,269	28,510	31,676	27,512	4,125,245
Total	1,645,988	15,592,620	51,203,915	56,520,342	48,109,112	17,813,413	19,749,743	1,310,267	1,142,630	1,319,607	933,368	1,176,183	1,084,555	217,601,743

[1] Production figures for years 1889–90 not available.

ing reserves in beds more than 14 inches thick with less than 3,000 feet of overburden total about 3.83 billion short tons on a bed-by-bed basis. When the estimated original reserves on a coal-zone basis are added, the total remaining recoverable reserves of coal in the field are about 8 billion short tons.

FUTURE DEVELOPMENT

Future exploitation of the coal resources of the Trinidad coal field may require mining in deep shafts or on steeply dipping slopes. Extensive beds of bituminous coal of minable thickness, much of it with coking qualities, remain untouched at practical mining depths. The Trinidad coal field offers many advantages to the coal-mining industry, which include access to highways and railroads, supplies of timber and ground water, the general absence of faults, and the generally horizontal beds except along the western edge of the coal field. Several factors, such as uneven floors, weak roof rock, water seepage, and the presence of natural coke along the many dikes and sills, tend to increase the cost of mining. Gas has also been reported in some of the mines. Inasmuch as the coal beds vary greatly in thickness and extent, it would be advisable to outline the extent of the individual beds by drilling in order to develop a mining program.

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