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ECONOMIC GEOLOGY

OF THE

CASTLEGATE, WELLINGTON, AND SUNNYSIDE QUADRANGLES, CARBON COUNTY, UTAH

BY

FRANK R. CLARK

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ECONOMIC GEOLOGY OF THE CASTLEGATE, WELLINGTON, AND SUNNYSIDE QUADRANGLES, CARBON COUNTY, UTAH

By FRANK R. CLARK

CHAPTER I. SUNNYSIDE AND WELLINGTON QUADRANGLES

INTRODUCTION

General features of the area.—The investigation reported herein was undertaken to satisfy the increasing demand for more detailed information regarding the coal that underlies the Sunnyside and Wellington quadrangles in Carbon County, Utah (see fig. 1), to collect data upon which a competent classification and valuation of the land might be based, and to supply to operators additional facts to aid them in developing the field.

The coal, which is of bituminous rank, crops out in the bold southward-facing escarpment which trends southeastward across the central part of the quadrangles. This escarpment in general follows the strike of the beds, which dip 5°–10° NE., into the face of the Book Cliffs. (See pl. 22.) The minimum number of coal beds exceeding 14 inches in thickness are to be found in the escarpment at its southernmost point in the Sunnyside quadrangle, and the number of such beds increases westward to a maximum of nine beds, which crop out in Coal Creek near the west edge of the Wellington quadrangle. As the coal has been extensively burned at the outcrop, it is difficult to ascertain the true character and thickness of the beds. A careful study of all exposures indicates that some of the coal beds are lenticular and that all the beds, though irregular in thickness, are free from serious bone and shale partings. The Lower Sunnyside is the best coal bed, and it was mapped across the quadrangles by means of the continuous outcrop of the underlying sandstone. It is not only the most persistent but in places the thickest bed, ranging from 2 to 14 feet. The coal is thickest at the south edge of the Sunnyside quadrangle and gradually thins toward the northwest, except for local irregularities.

The Lower and Upper Sunnyside beds are so named because they are extensively mined at Sunnyside, where the greater part of the coal produced is converted into coke in beehive ovens. (See pl. 12, *A*.) The coal in each bed is of the same rank and appears to possess like coking qualities. Other coal beds of similar rank are inter-

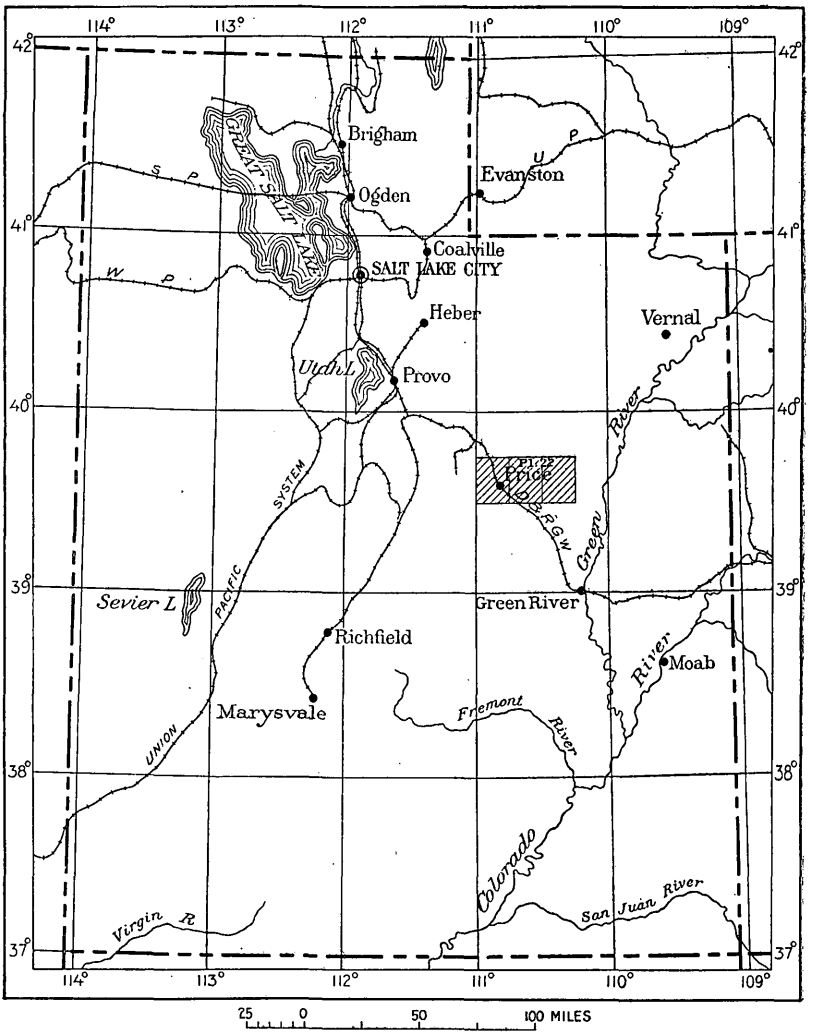


FIGURE 1.—Index map showing location of the Castlegate, Wellington, and Sunnyside quadrangles, Carbon County, Utah

mittently mined at several places for local consumption, but nothing definite is known of the coking qualities of the coal outside the Sunnyside district.

The Book Cliffs coal field, of which these quadrangles form a small part, extends from Grand Junction, Colo., northwestward to the western edge of the Castlegate quadrangle, a distance of about 180

miles. The field as defined by the United States Geological Survey forms the southern rim of the Uinta Basin and lies north of the Denver & Rio Grande Western Railroad and east of the western edge of the Castlegate quadrangle. The Wasatch Plateau coal field extends westward from the western limit of the Book Cliffs field to Pleasant Valley and southward toward Mount Hilgard, Utah. The two fields are continuous and structurally similar, and the coal occurs in rocks of the same age in both.

Previous geologic work.—Among the first published reports of explorations in the Uinta Basin was Frémont's narrative of his travels in 1842–1844,[1] but since his time many expeditions have undertaken to explore and map the geology and mineral resources of this great basin. Many of the explorations were reconnaissances and yielded little detailed information regarding the mineral wealth of the region.

The first paper that described the resources of these quadrangles was written by Taff,[2] who made a reconnaissance survey of that portion of the Book Cliffs coal field lying between Sunnyside and Castlegate and surveyed the Wasatch Plateau coal field approximately as defined above. He mapped only the base and the top of the coal-bearing rocks, because time did not permit detailed study, and the coal beds were measured only at easily accessible places. In the following year Taff[3] made a more intensive study of the coal beds of the Pleasant Valley district, in the vicinity of Castlegate, Pleasant Valley, and Huntington Canyon, but did not include the area here considered. In the later work the outcrop of the lowest bed was located by instrumental measurements, and much additional information was gained regarding the coal beds and the structure of the rocks.

Richardson[4] in 1906 made a rapid reconnaissance survey of the Book Cliffs coal field from Grand Junction, Colo., as far west as Sunnyside, Utah, connecting with Taff's work of 1905. In this work time did not permit detailed study, but the top and bottom of the coal-bearing rocks were mapped in a general way, and detailed sections of the coal beds and the associated rocks were measured at several places. These reports served well their purpose as a basis for a general classification of the land into coal-bearing and non coal-

[1] Frémont, J. C., Narrative of the exploring expedition to the Rocky Mountains in the year 1842 and to Oregon and north California in the years 1843–44, pp. 277–280, Syracuse, 1848.

[2] Taff, J. A., The Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, pp. 289–302, 1905.

[3] Taff, J. A., The Pleasant Valley coal district, Carbon and Emery Counties, Utah: U. S. Geol. Survey Bull. 316, pp. 338–358, 1906.

[4] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, 1909.

bearing territory and gave a general idea of the character and amount of coal.

Field work.—The field work on which this report is based was begun at Sunnyside in 1911 and was continued westward during a part of the two succeeding years. The work was done in cooperation with a topographic field party of the United States Geological Survey, who determined with plane table and telescopic alidade the location, both horizontal and vertical, of all points on coal outcrops and of many beds of sandstone that were used as key rocks in tracing and identifying coal beds. These beds are shown on Plate 22. The topographic work was controlled by a system of primary triangulation established in 1910 by the Coast and Geodetic Survey. The geologic work was done in advance of topographic sketching and consisted in meandering the outcrop of each important coal bed in order to measure the thickness of coal in every exposure; in tracing boundaries of geologic formations and economic deposits, faults, and other structural features; and in marking by flag or other distinctive object for the use of the topographer later all points whose locations were necessary for the proper delineation of the geologic features.

The tracing of coal beds was an arduous task because of the nearly vertical face of the escarpment of coal-bearing rocks, which made it necessary to pace the outcrops of coal beds on foot, horses being used to ride only between camp and the base of the cliffs. The cliffs in which the coal crops out are at many places unscalable for stretches of several miles, and it was necessary to walk over much of the ground more than once in order to reach places at which the escarpment could be ascended or descended. The extensive burning of the coal at the outcrop made it necessary to examine every rod of outcrop of the principal coal beds to avoid missing any exposures of unburned coal. Pacing the outcrops is attended with some danger, because many of the coal beds are underlain by a massive sandstone 100 to 150 feet thick, exposed in a vertical cliff above which is a steep slope covered to the very edge of the cliff with loose talus of burned rock. A misstep or the sliding of the loose talus under foot might cause a fall over the sandstone cliff.

The topographer determined the location by triangulation and stadia traverse and the altitude by vertical angles of all reference points designated by the geologist.

The writer was assisted in the field by Gordon W. Clark, who rendered efficient service in tracing coal beds and geologic boundaries and in measuring coal sections, as well as in general camp duties. Mine officials of the several coal companies freely gave information regarding the coal and its mining. Residents of the region were

courteous and gave any information they could regarding the coal and the roads and trails through the country, which materially aided in the prosecution of the work. The writer acknowledges the valuable assistance and constructive criticism of M. R. Campbell in the preparation of this report.

GEOGRAPHY

Location and extent.—The Sunnyside and Wellington quadrangles are situated in Carbon County, in east-central Utah, and are bounded by the parallels 39° 30′ and 39° 45′ and the meridians 110° 15′, 110° 30′ and 110° 45′. Together they include an area of 460 square miles, about three-fifths of which is believed to contain workable coal beds. The coal-bearing portion is a small part of the Book Cliffs coal field, which forms the southern rim of the Uinta Basin and lies north of the Denver & Rio Grande Western Railroad from Colorado River, Colo., to Price River, Utah.

Accessibility.—The most advantageous point of access for mining this coal is determined simply by the cost and the probable returns on the investment, because present engineering knowledge makes it possible to reach the coal at any desired point. Spurs or branches could be built from the main line of the Denver & Rio Grande Western Railroad, which traverses the southwest corner of the Wellington quadrangle, to the principal streams, Deadman, Coal, Soldier, and Dugout Creeks and Pace, Rock, and Bear Canyons, without prohibitive grades. A less grade could be obtained by constructing the line on a more circuitous route. From the end of a branch railroad built to the base of the escarpment the coal outcrop might be reached by any one of the common tramways—cable, incline, or aerial. As the beds dip gently into the face of the escarpment, the most economical point of access for mining the coal is where the outcrop crosses the bottom of a main canyon, giving down grade in favor of loads for the coal above drainage level. Furthermore, very little coal has been burned near the bottoms of canyons, but on the points of ridges entries might have to be driven 1,000 to 2,000 feet from the outcrop to reach marketable coal. The difference between the cost of installing and operating an incline or aerial tramway to the point of a ridge and the cost of the necessary tramway up a canyon to reach the coal would also be an important factor in choosing a point of access.

Settlement.—The region is sparsely settled, there being in the quadrangles at the time of the examination few ranches and only two towns, Sunnyside, a coal-mining town in the southern part of the Sunnyside quadrangle, and Wellington, a farming community on Price River near the southwest corner of the Wellington quadrangle.

The ranches are Young's, on Coal Creek; Edward's and Du Bois's, on Soldier Creek; Demick's, on Dugout Creek; Whitmore's and Pierson's, on Whitmore Canyon Creek; and the Big Spring ranch, in sec. 18, T. 15 S., R. 13 E. Considerable land in the Price River valley above and below Wellington is under cultivation, as well as the land northeast of Wellington and west of lower Coal Creek valley, which is owned by residents of Wellington. Price, 6 miles northwest of Wellington on the Denver & Rio Grande Western Railroad, is the county seat of Carbon County and the principal town and distributing point in southeastern Utah.

Roads and trails.—Few good roads traverse the quadrangles, but there are many trails that can be used by horsemen and pack trains. The two main roads are the Midland Trail between Pueblo, Colo., and Salt Lake City, Utah, which follows the valley of Price River, passing through Wellington and the road that was formerly the overland-mail stage road between Price and Vernal, Utah, which traverses the northwest corner of the Wellington quadrangle, running up Soldier Creek. Secondary roads intersect the main roads at several places and connect ranches or the small towns with the wooded portions of the gravel-capped terraces and mountains or with the small coal mines, such as those in Deadman Canyon and on Dugout Creek. Coal is here mined in small quantities during the fall and winter and hauled by wagon to Price and Wellington for domestic use. Most of the secondary roads have been used to haul wood and fence posts of the scrub cedar and piñon, which grow on the surface of the dissected gravel terraces and in the main valleys. The roads up Whitmore Canyon and its tributaries are used for hauling mine timbers and saw logs for use in the mines at Sunnyside. The road over the divide at Bruin Point and along the ridge east of Range Creek has been used for hauling supplies to the Nutter cattle ranch, on Range Creek. After the accompanying map was completed a road was built from Bruin Point down Range Creek to the Utah Fuel Co.'s pumping station and was used in transporting from Sunnyside machinery for the electric pumping plant.

Trails are few except along the high divides or ridges because most of the canyons that cut the coal-bearing escarpment are impassable except to persons on foot, on account of the vertical cliffs made by the massive sandstone. The canyons through which trails run to the country beyond the escarpment are Deadman, Coal, Soldier, Dugout, Rock, and Whitmore with several of its tributaries. A much used trail traverses Patmos Mountain, the high divide between Whitmore Canyon and Range Creek, thence swerves to the northwest, passing Bruin Point and Mount Bartles, and continues westward through Whitmore and Emma Parks to Colton, Utah.

Climate and vegetation.—These quadrangles, like most of the Plateau province, have an arid or semiarid climate, and their vegetation is scrubby except in favorable places or at high altitudes. The mean annual rainfall at Sunnyside from 1905 to 1909 was 14.86 inches, which is probably greater than that at other stations in this section of Utah. The soil of the lower land outside of Price River valley, in the southwestern part of the Wellington quadrangle, sustains only small brush and early spring grasses, but the top surface of the gravel terraces supports a healthy growth of sagebrush, scrubby cedar, piñon, and some grass. On the face of the coal-bearing escarpment the vegetation is generally scanty, but in places scrubby piñon, cedar, and coarse grasses grow. The cedar and piñon are of value only for firewood or fence posts.

The country back of the coal-bearing escarpment contains an abundance of grasses, which makes it excellent grazing land, and in places pine and quaking aspen grow, but in the vicinity of Sunnyside most of the trees suitable for mine timbers have been cut. At a few favored places small groves of marketable timber may be found.

Surface water supply.—Few perennial streams flow through these quadrangles, but many small springs back of the escarpment supply water to range stock. In places these springs unite, forming small perennial streams that are used for irrigating lands near by. The lands so irrigated are Young's ranch, on Coal Creek; Edward's ranch, on Soldier Creek; Demick's ranch, on Dugout Creek; and Whitmore's ranch, at the mouth of Whitmore Canyon.

Price River, which crosses the southwest corner of the Wellington quadrangle, is the largest stream in this region. Its discharge at Helper, 13 miles northwest of Wellington, for the period between March, 1904, and December, 1908, except May and June, 1904, and April, May, and June, 1907, had a maximum of 1,740 second-feet, a minimum of 4 second-feet, and a mean of 124 second-feet. Most of the water is diverted for irrigation during the summer.

Whitmore Creek, the second largest perennial stream, contains about 1 second-foot, which is used for irrigating Whitmore's ranch, below Sunnyside.

Range Creek, which flows out of the Sunnyside quadrangle at the southeast corner, contains about the same quantity of water as Whitmore Creek. The water is used in part for irrigating Nutter's stock ranch, on Range Creek, about 8 or 10 miles southeast of the Sunnyside quadrangle, and in part for boiler and domestic use at Sunnyside. The water is forced over the high divide east of Sunnyside by electrically driven pumps, which receive power that is generated at the steam power plant at Sunnyside.

Agriculture and stock raising.—Aside from the coal mining at Sunnyside, agriculture and stock raising are the principal industries.

Farming is generally confined to raising grains and hay, but some truck gardening is done at Wellington and on Whitmore's ranch at Sunnyside, and some fruit is raised. The uplands furnish excellent summer grazing lands for sheep and cattle, but the lower land produces very little upon which stock may feed, although it furnishes shelter in winter storms, and stock browse on its brush and coarse grass.

The irrigable land is confined mainly to the Price River valley, an area on Miller Creek, the broad, flat valley north of Wellington and west of lower Coal Creek valley, Clark Valley, and the upper surface of the gravel-capped terraces. Irrigation at present, because of the general scarcity of water and a lack of proper conservation and economical use of the present supply, is limited to the Price River valley proper, a small portion of the valley north of Wellington, and the small ranches above mentioned. These valleys contain fertile soil capable of producing under irrigation good crops of grain and alfalfa. The land of Clark Valley at the time of the examination was not under cultivation except a small tract at the north end, which was irrigated by water diverted from Dugout Creek, and another tract in sec. 1, T. 15 S., R. 12 E., which was irrigated by water from a reservoir that stored the run-off from heavy rains and the melting snows. Few if any serious attempts have been made to farm the land without irrigation, but it is believed that with proper methods wheat and rye might be raised on much of this land without irrigation, especially near the mountains, in the path of local summer showers. It seems unlikely that water sufficient to irrigate all land that is suitably located can ever be developed, yet with proper conservation and economical use of the present water supply much more land might be utilized. Farming and allied industries in this region should be lucrative occupations, because of the fertile soil and the excellent market in the coal-mining towns of this and surrounding areas. Great quantities of hay, grain, and other supplies are shipped to these towns from distant places, because the country immediately surrounding the mines has not produced enough to supply the demand. Local farmers have the advantage of receiving the price that the farmer in remote regions receives, plus the high freight rate and possibly one or more middlemen's profits.

Surface features.—The surface of these quadrangles is generally rough, only small areas being comparatively level. The total relief is 4,967 feet. The lowest point, which is on the railroad at Farnham, is 5,318 feet above sea level, and the highest point, Bruin Point, 10,285 feet. The topographic forms here represented are the result of erosion modified by the character of the rocks and have been little affected by structure. The southwestern part of the Welling-

ton quadrangle is composed of broad valleys bordered by gravel-capped terraces and has a relief of 200 to 400 feet. The valleys are trenched by deep, narrow gullies, which make travel almost impossible except along the roads or trails. The upper surfaces of the terraces slope gently but are not dissected and are generally covered by scrubby cedar and piñon, which in places grow so thickly as to impede travel, even on horseback.

The most striking feature of this region as viewed from Price River valley is the bold, nearly vertical southward-facing escarpment (see pl. 22) which crosses the northern part of the Wellington quadrangle from west to east and in the Sunnyside quadrangle turns southeastward and leaves the quadrangle trending south. This escarpment is composed of thick beds of sandstone, forming cliffs, with intervening sloping shale benches and coal beds. It stands from 1,000 to 1,500 feet above the relatively flat country that it faces. In the highlands which end at the escarpment streams have cut steep-sided canyons that range from 1 mile to several miles in length, leaving long, finger-like ridges that run from the divides at the heads of the streams to the face of the escarpment. Back of this escarpment are other streams, which flow in the opposite direction. The only undissected lands are Emma and Whitmore Parks, in the northern part of the Wellington quadrangle, and the broad, flat-topped ridges in the northeastern part of the Sunnyside quadrangle. These gently sloping surfaces correspond in dip with the underlying beds of rock, and roughly represent their structure.

The high divide between Whitmore Canyon and Range Creek has a flat top, and its west face in some respects resembles the escarpment above described.

Drainage.—The quadrangles are drained by tributaries of Green and Price Rivers. The divide that separates the drainage systems formed by these rivers runs southeast and south from Whitmore Park to Patmos Head, at the south edge of the Sunnyside quadrangle, and thence southeastward to Green River.

The main tributaries of Price River are Deadman, Coal, Soldier, and Dugout Creeks and Pace, Rock, Bear, Whitmore, Water, and Horse Canyons, but these streams supply water to Price River only during the spring run-off or during heavy floods resulting from cloudbursts. At these times the channels of the streams are filled to overflowing with roaring masses of water loaded with mud and rocks, which sometimes continue to flow for 10 or 12 hours. When the channels again become empty they show many effects of gouging and wearing by the flood. These floods occur most frequently in Coal and Soldier Creeks, principally because a great catchment area is afforded by Emma and Whitmore Parks and because not much of

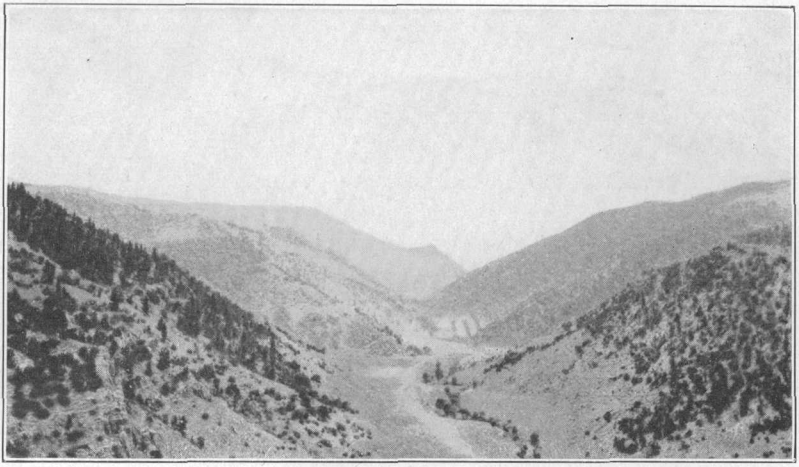
the rainfall penetrates the soil in these parks, for they contain little timber and are traversed by many well-beaten sheep and other stock trails, along which the water is rapidly carried off. So sudden are many of these floods that the water forms an abrupt face several feet high as it rolls over itself down the recently dry channel. These floods are probably among the most efficient agents of erosion that act in an arid region.

The main streams that form parts of the Green River system are Pole, Stone Cabin, and Dry Creeks and Cow, Sheep, and Cottonwood Canyons, whose waters flow first into Ninemile Creek and thence into Green River. Range Creek empties directly into Green River 10 or 12 miles above the confluence of the Price with the Green. Floods are not so frequent in these streams as in the Price River drainage system, because there is generally more timber and less bare ground in their basins. The slopes that are not timbered are well protected by grass, which retards the flow of the water, even in heavy cloudbursts, so that the water penetrates the soil. The region drained by these streams is an excellent summer range for stock. Sheep have not been permitted in it to any great extent, and this practice has an important influence on the run-off, for it is the habit of sheep even when grazing to follow one another in single file, so that a band of 3,000 to 5,000 head soon make deeply worn trails in which the rain water collects and rapidly runs off.

GEOLOGY

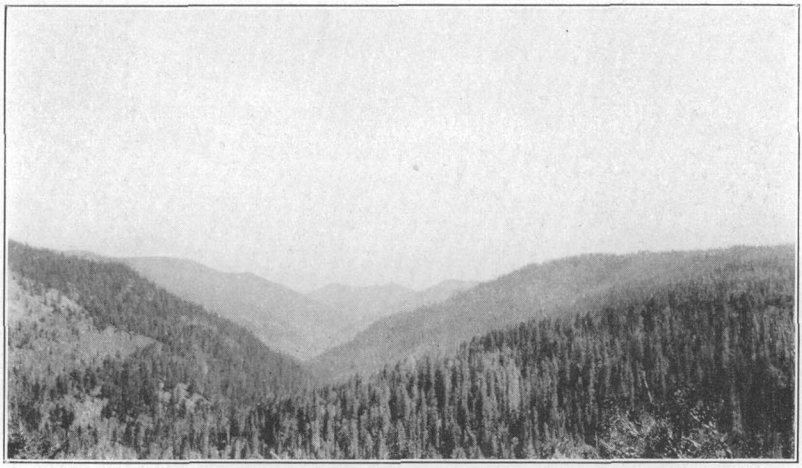
STRATIGRAPHY

General features.—The rocks exposed in these quadrangles are, from the evidence now available, classed as Cretaceous (?), Upper Cretaceous, Tertiary (Eocene), and Quaternary. There is some evidence of an unconformity separating the Cretaceous (?) from the Upper Cretaceous, and a known unconformity lies between the Mesaverde group and Wasatch formation. The Cretaceous (?) beds exposed belong to the Morrison formation; the Upper Cretaceous beds are the Dakota (?) sandstone, Mancos shale, and Mesaverde group; and the Tertiary beds are the Wasatch and Green River formations. The following summarized description of the rocks exposed in the quadrangles is given in tabular form for convenient reference and direct comparison.



A. WHITMORE CANYON

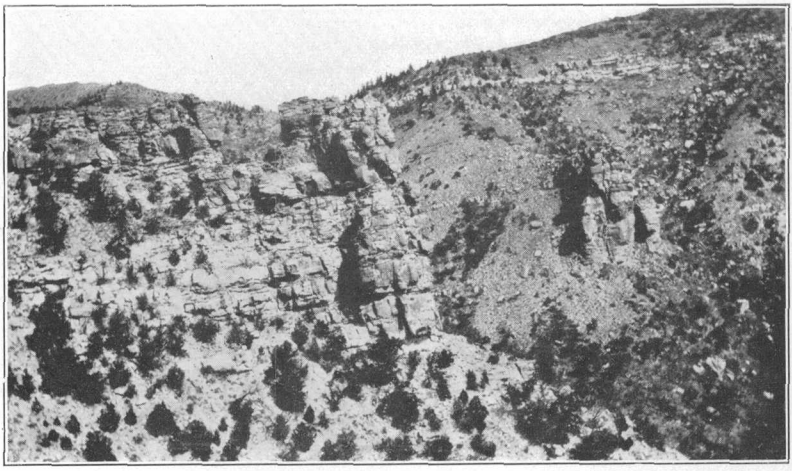
Sunnyside in the distance



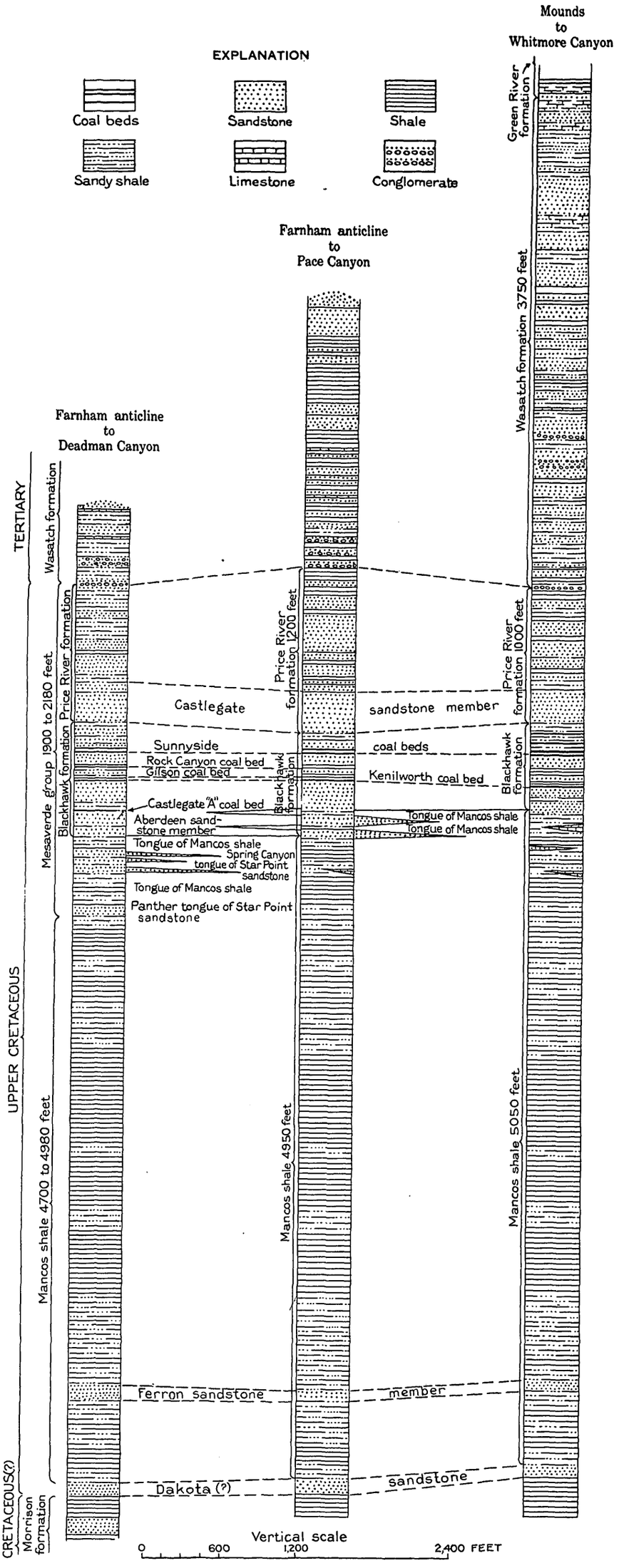
B. VIEW SOUTHEAST DOWN RANGE CREEK

Showing stand of timber and configuration of plateau surface

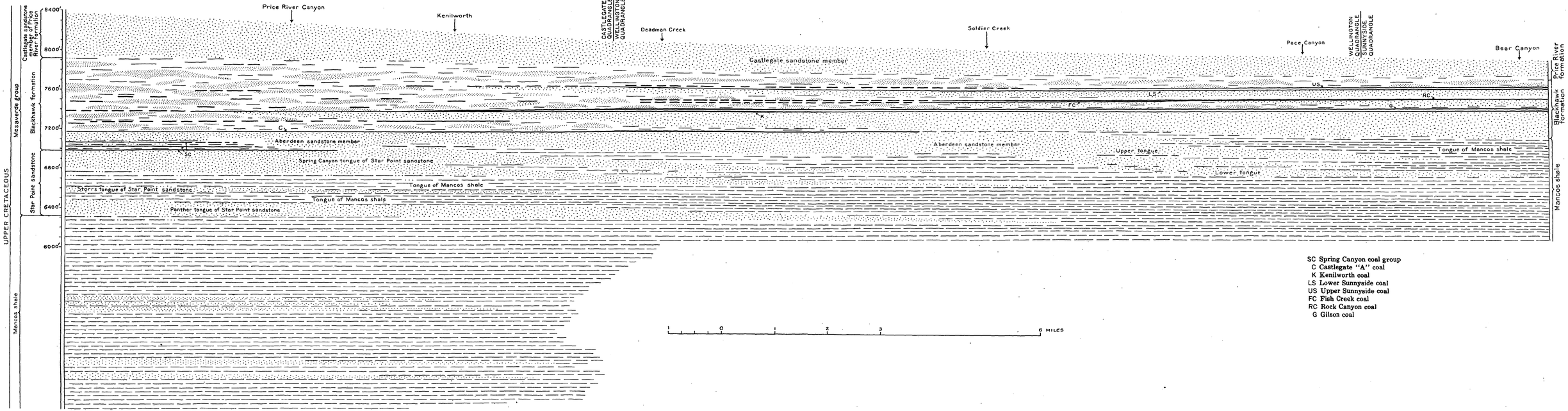
A. FERRON SANDSTONE MEMBER OF MANCOS SHALE IN SECS. 1 AND 12, T. 15 S., R. 11 E.



B. CLIFF 250 FEET HIGH FORMED BY CASTLEGATE SANDSTONE IN SEC. 7, T. 13 S., R. 11 E.



GENERALIZED SECTIONS OF ROCKS EXPOSED IN THE SUNNYSIDE AND WELLINGTON QUADRANGLES



SC Spring Canyon coal group
C Castlegate "A" coal
K Kenilworth coal
LS Lower Sunnyside coal
US Upper Sunnyside coal
FC Fish Creek coal
RC Rock Canyon coal
G Gilson coal

LINEAR AND VERTICAL SECTION OF THE ROCKS EXPOSED IN THE BOOK CLIFFS THROUGH T. 13 S., RS. 9-13 E.

Showing in general the history of the deposition of these rocks and the relative distribution in a west-east direction of the coal and sandstone beds

Rock formations that crop out in the Sunnyside and Wellington quadrangles, Utah

Geologic age	Group, formation, and member	Character of rocks	Thickness (feet)	Economic value
Quaternary.		Remnants of alluvial fans representing several periods of erosion. The gravel ranges from boulders of sandstone weighing several tons to sand or fine gravel. The coarser material is nearest the source, the Book Cliffs. The pebbles consist of yellowish-gray sandstone and gray and drab limestone.	0–50	In places supports a thick growth of scrubby piñon and cedar, which make good firewood and fence posts.
Unconformity.				
	Green River formation.	Mainly grayish-drab fine-grained and thin-bedded sandstone and sandy shale, in places calcareous, and some dark-brown shale containing more or less carbonaceous matter. The rocks weather gray to white. Full thickness not exposed.	150+	Contains beds of oil shale.
Tertiary (Eocene).	Wasatch formation.	Mainly coarse-grained sandstone (conglomeratic in places), sandy shale, and several beds of conglomerate and impure limestone. The beds are yellowish and greenish at the base, red and pinkish tints predominate in the middle, and gray quartzitic sandstone with greenish and purplish sand and calcareous shale in the upper 1,500 feet. These beds produce a rough surface in the process of weathering.	3,750	The upper 1,200 feet of the beds are locally saturated with asphaltum. This is the water-bearing formation of the region.
Unconformity.				
Upper Cretaceous	Mesaverde group: Price River formation: Non coal-bearing member.	Mainly sandstone, shale, and sandy shale, gray to buff, with a prominent bed of sandstone, in places 200 feet or more in thickness, white at the top and buff near the base, near the middle of the member. The upper surface was eroded before the overlying Wasatch was deposited.	650–1,000	In places contains beds of carbonaceous shale but no coal beds of economic value. Building stone and sandstone perhaps pure enough for glass sand.
	Mesaverde group: Price River formation: Castlegate sandstone member.	Massive gray to buff sandstone. The grains are semirounded quartz fairly well cemented. The rock is continuously exposed and in most places forms a vertical cliff 100 feet or more high.	150–500	Used in places for building stone.
	Mesaverde group: Blackhawk formation: Coal-bearing member.	Thick sandstones with intervening beds of shale, sandy shale, and coal. The original color of the rocks is gray to buff, but the burning of the coal at surface has greatly altered the rock in color and composition. It is now predominantly red. The coal beds occur in the middle portion of this member.	500–1,000	Contains thick and extensive beds of bituminous coal, some of which is coked at Sunnyside.
	Mesaverde group: Blackhawk formation: Aberdeen sandstone member.	Tongues of medium-grained buff sandstone separated by tongues of Mancos shale.	60–200	

Rock formations that crop out in the Sunnyside and Wellington quadrangles, Utah—Continued

Geologic age	Group, formation, and member	Character of rocks	Thickness (feet)	Economic value
	Star Point sandstone.	In these quadrangles consists of eastward-extending tongues of massive buff medium-grained sandstone separated by westward-extending tongues of Mancos shale, the whole occupying an interval of about 600 feet.	600±	
Upper Cretaceous.	Mancos shale.	Mainly dark-drab or bluish shale and sandy shale, with the Emery sandstone member in the upper part and the Ferron sandstone member near the base. At the contact between the Mancos shale and the Mesaverde group westward-pointing tongues of Mancos shale interfinger with eastward-pointing tongues of Mesaverde sandstones. (See pl. 15.)	4,700–5,000	Clay and perhaps building stone.
	Dakota (?) sandstone.	Mainly well-indurated sandstone, in places conglomeratic, with thin beds of shale.	15	
Unconformity (?).				
Cretaceous (?).	Morrison formation.	Variegated sandy shale and sandstone with thin beds of indurated conglomerate. The portion exposed in the Farnham anticline is gray with pinkish, greenish, and yellowish bands interbedded. Only upper part exposed.	400+	

The columnar sections (pls. 3 and 15) measured in the Sunnyside, Wellington, and Castlegate quadrangles give the general character of the beds exposed from the top of the Morrison to the base of the Green River formation. They show the character of the rocks only at localities where the sections were measured but are fairly representative of the rocks elsewhere. The number and general stratigraphic position of the principal coal beds and associated rocks are shown in detailed columnar sections in Plate 5.

CRETACEOUS (?) ROCKS

MORRISON FORMATION

The upper 400 feet of the Morrison formation is exposed in the middle of the Farnham anticline, northeast of Farnham on the Denver & Rio Grande Western Railroad. The rocks consist of pink, maroon, and light-green shale and sandy shale and dense sandstone and conglomerate. The upper portion contains beds of sandstone and conglomerate, which are separated by thin beds of varicolored shale, and the basal portion contains for the most part variegated shale with some thin bands of calcareous sandstone. The sandstone and

conglomerate at the top resemble the Dakota (?) sandstone, but the interbedded varicolored shale indicates that it is probably Morrison and not Dakota (?).

UPPER CRETACEOUS ROCKS

DAKOTA (?) SANDSTONE

The beds here called Dakota (?) sandstone are exposed in a narrow belt partly surrounding the Farnham anticline in the southwestern part of the Wellington quadrangle. The outcrop is not continuous because it is partly cut out by faults or is concealed by later deposits. It consists of a coarse-grained quartzose well-indurated sandstone about 15 feet thick, in places conglomeratic, and cemented with carbonate of lime. It is believed to rest unconformably upon the Morrison, but no conclusive evidence of an unconformity was found.

MANCOS SHALE

The Mancos shale overlies the Dakota (?) sandstone and is exposed in broad, flat valleys from the Farnham anticline, at the south edge of the Wellington quadrangle, east and north to the base of the Book Cliffs. In the Sunnyside and Wellington quadrangles it is marine in origin and is essentially grayish blue to brown clay shale and sandy shale except for sandstone lentils near the base and top. It aggregates about 4,700 to 5,050 feet in thickness. These figures are approximate, because the broad outcrop and lack of distinct key beds make it difficult to measure this shale accurately.

Ferron sandstone member.—The sandstone near the base of the Mancos shale is the Ferron sandstone member,[5] which crops out about 650 feet above the base of this shale. It forms a prominent ledge or rim which borders the Farnham anticline on the north, east, and west sides and has been traced southwestward to Mount Hilgard. At Farnham, in the north end of Castle Valley, the Ferron sandstone is only about 25 to 30 feet thick, but at the south end of Castle Valley, 80 miles to the southwest, it has increased to about 800 feet and south of Emery becomes an important coal-bearing member.

The fossils listed below were collected from the Ferron sandstone or from beds closely associated with it at exposures surrounding the Farnham anticline.

Leda? sp.
Inoceramus fragilis Hall and Meek.
Inoceramus exogyroides Meek and Hayden?

[5] Lupton, C. T., op. cit.

Inoceramus labiatus Schlotheim?
Inoceramus sp. undet.
Ostrea lugubris Conrad.
Ostrea cf. O. coalvillensis Meek.
Ostrea sp.
Anomia sp.
Cardium pauperculum Meek.
Cardium n. sp. related to C. pauperculum Meek.
Tellina modesta Meek.
Tellina isonema Meek.
Tellina? sp.
Cyrena? sp.
Mactra utahensis Stanton.
Siliqua? sp.
Leptosolen sp.
Gyrodes depressa Meek.
Volutoderma ambigua Stanton?
Volutoderma gracilis Stanton?
Pugnellus? sp.
Eulimella? sp.
Teinostoma? n. sp.
Lunatia concinna Hall and Meek?
Baculites sp.
Scaphites warreni Meek and Hayden.
Prionocyclus wyomingensis Meek.
Fish vertebrae, undetermined.

Concerning the significance of these fossils J. B. Reeside, jr., says:

Most of these species belong to one of the most widespread faunas of the Cretaceous of the western interior region. It has been collected from a zone in the lower part of the Mancos shale in Colorado and New Mexico; from the Carlile shale of the Great Plains region, especially the upper part; and from the Carlile shale of Wyoming and southern Montana. *Inoceramus exogyroides* belongs typically to a later fauna, and *Inoceramus labiatus* is most characteristic of an earlier one, but both are identified with doubt from the Ferron sandstone and may actually not occur within it.

Interfingering of upper part of Mancos shale with lower part of Mesaverde group.—About 3,600 feet above the Ferron sandstone the Mancos shale interfingers with the Panther tongue of the Star Point sandstone, the basal formation of the Mesaverde group, which first appears in outcrop on Soldier Creek, in the Wellington quadrangle, where it is composed of lentils of impure limestone, concretions of limestone, and sandy shale. This sandstone tongue gradually increases in thickness westward, and the material composing the bed becomes coarser and more sandy. At the west edge of the Wellington quadrangle it is 30 to 40 feet thick and is composed of friable sugary cliff-forming sandstone, massive at the top and grading downward through sandy shale to shale at the base. It is separated from the overlying Spring Canyon tongue of the Star Point sandstone by about 300 feet of typical Mancos shale. The work of

the writer in the Castlegate quadrangle, to the west, together with unpublished data supplied by E. M. Spieker, who has mapped in detail the Wasatch Plateau coal field south and west of the Castlegate quadrangle, shows that the Panther tongue continues to increase in thickness to the west and southwest and that it finally unites with the basal part of the Star Point sandstone of the Castlegate quadrangle, which forms the basal formation of the Mesaverde group of the Wasatch Plateau. Still higher in the section the Mancos shale is interbedded with other sandstone tongues from the lower part of the Mesaverde group, as shown in Plate 15.

The earlier reports on this part of the Book Cliffs coal field by Taff [6] and Richardson [7] describe sandstone lentils in the upper part of the Mancos shale and mention the dominant feature of the increasing thickness westward, but owing to a lack of time to make detailed studies they did not describe the intertonguing relation of sandstone and shale at the contact of the Mancos shale with the overlying Mesaverde rocks, which is described in detail elsewhere in this report (pp. 16 to 18).

The contact between the Mancos shale and the Mesaverde group here presents some unique conditions in the transition from marine shale into an overlying fresh and brackish water sandstone and shale. From east to west the base of the Mesaverde progressively becomes stratigraphically lower, owing to eastward-projecting tongues of Mesaverde sandstones interbedded with similar westward-projecting tongues of Mancos shale.

MESAVERDE GROUP

The Mesaverde group, in part resting conformably on and in part intertonguing with the Mancos shale, is the uppermost division of the Cretaceous system exposed here. It crops out in a narrow belt extending northwestward across the central part of these quadrangles and forms the bold southwestward-facing escarpment known as the Book Cliffs. The rocks vary considerably in thickness (1,200 to 2,750 feet in the three quadrangles described in this volume), owing to the erosion of their upper surface before the deposition of the overlying Tertiary beds and to the sandstone tongues at their base, which increase in thickness westward and merge into a single unit—the Star Point sandstone. The Mesaverde is essentially of brackish or fresh water origin and is here separated into three formations on the basis of lithologic differences. The basal division consists of several tongues of the Star Point sandstone. These are overlain

[6] Taff, J. A., The Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, p. 291, 1906.

[7] Richardson, G. B., op. cit., pl. 3, p. 12.

by the coal-bearing rocks composing the Blackhawk formation,[8] upon which rests the Castlegate sandstone member of the overlying non-coal-bearing Price River formation.

The contact between the Mancos shale and the Mesaverde is a transition from a marine shale to brackish-water sandstone and shale. In places the transition zone is from 15 to 25 feet thick, and any part of it might be taken as the contact of these formations. In addition to this transition zone there is a lower zone in which westward-projecting tongues of Mancos shale are sandwiched between eastward-projecting tongues of Mesaverde sandstone, which gives a dovetailed boundary line between the formations. These relations are represented in Plate 15. For convenience in mapping and in description these basal subdivisions of the Mesaverde group are here given the following geographic names, arranged in the order of their relative positions from the highest downward:

Aberdeen sandstone member of Blackhawk formation.
Star Point sandstone:
  Spring Canyon tongue.
  Storrs tongue (present in the adjoining Castlegate quadrangle).
  Panther tongue.

In some places the basal part of the Aberdeen sandstone member is represented by the Spring Canyon coal group, which there separates the Aberdeen sandstone from the Spring Canyon tongue of the Star Point sandstone.

The following brief definition of the subdivisions of the Mesaverde group are given in the order of their deposition.

STAR POINT SANDSTONE

General features.—The Star Point sandstone was so named[9] because it is typically developed in Star Point, a prominent headland of the Wasatch Plateau in Carlon County, Utah, about 3 miles west of the southwest corner of the Castlegate quadrangle.[10] In the Wasatch Plateau this formation consists of 200 to 450 feet of medium-grained buff sandstone, of brackish-water origin, but in the adjoining parts of the Book Cliffs coal field it splits up into the three sandstone tongues mentioned above, which finger out into the Mancos shale. In the westernmost part of the Book Cliffs coal field, in the Castlegate quadrangle, the layers of shale between the sandstone tongues are thin and sandy, and the Star Point sandstone is recognizable as a definite unit. East of the Castlegate quadrangle, however, the sandstone tongues that represent the formation are subordinate in

[8] Spieker, E. M., and Reeside, J. B., jr., Cretaceous and Tertiary formations of the Wasatch Plateau, Utah: Geol. Soc. America Bull., vol. 36, pp. 435–454, 1925.
[9] Idem, p. 443.
[10] Spieker, E. M., personal communication.

thickness to the shale, and the Star Point is not recognizable as a unit.

Panther tongue.—The Panther tongue of the Star Point sandstone is named from its exposures in Panther Canyon, in the northeastern part of the Castlegate quadrangle. Where exposed in the eastern part of the Castlegate quadrangle it consists of impure limestone concretions, thin beds of sandstone, and sandy shale. It gradually thickens westward and the material becomes coarser and harder. Wherever exposed in the Castlegate quadrangle it forms a cliff, and at the west edge of that quadrangle it reaches a thickness of 100 to 125 feet. It thins out in the central part of the Wellington quadrangle and is not present in the Sunnyside quadrangle, its place being occupied by Mancos shale. It is separated from the younger Storrs tongue by an interfingering wedge of Mancos shale. To the west it unites with the Storrs tongue, and together they make up the lower half or more of the Star Point sandstone.

Storrs tongue.—The Storrs tongue, the middle tongue of the Star Point sandstone, usually consists of thick-bedded sandstone at the top and thin-bedded sandstone and sandy shale grading into shale at the base. At Kenilworth it is a soft friable sandstone, sugary in appearance, and 10 or 15 feet thick. At Storrs, in the Castlegate quadrangle, it forms a prominent cliff, and from this exposure it takes its name. It gradually thins out to the east, before it reaches the Wellington quadrangle. It is separated from the underlying Panther tongue and the overlying Spring Canyon tongue by interfingering masses of Mancos shale.

Spring Canyon tongue.—The Spring Canyon tongue of the Star Point sandstone consists of a massive bed of grayish sandstone about 150 feet thick, with a conspicuous white layer at its top. It is named from the conspicuous white cliffs that it forms in Spring Canyon, in the Castlegate quadrangle. It is usually overlain by the Spring Canyon coal group, or where the coal group is absent by the Aberdeen sandstone member. In some places it is separated from the Spring Canyon coal group by a few feet of shale. It is underlain by an interfingering mass of Mancos shale. To the west the Spring Canyon tongue unites with the Storrs tongue and merges into the upper part of the Star Point sandstone. To the east it is split into three parts by interfingering masses of Mancos shale.

Its basal part or extension along Soldier Creek, in the Wellington quadrangle, consists of a thin bed of limy concretions, sandstone, and sandy shale. This basal extension of the Spring Canyon tongue gradually increases in thickness to the west, and the material composing it becomes coarse and more sandy. On Deadman Creek this basal extension is 50 feet thick.

The middle extension of the Spring Canyon tongue of sandstone does not reach as far east as the basal and upper extensions.

The upper extension of the Spring Canyon tongue consists of materials similar to those of the middle extension and is about 50 feet thick.

The extensions increase in thickness westward, at the expense of the intervening tongues of Mancos shale, until they unite into one solid sandy unit.

BLACKHAWK FORMATION [11]

Above the Star Point sandstone lies the coal-bearing part of the Mesaverde group of this general region, to which Spieker and Reeside have recently applied the name Blackhawk formation. This formation consists of a basal sandstone, herein named the Aberdeen sandstone member, overlain by massive beds of gray to buff sandstone alternating with beds of sandy shale, shale, and coal.

Aberdeen sandstone member.—The sandstone here named Aberdeen sandstone member of the Blackhawk formation consists of a massive, cliff-forming bed, which ranges in thickness from 100 to 200 feet. It is named from exposures near the Aberdeen mine, northeast of Kenilworth, in the Castlegate quadrangle. In the Price River Canyon it is underlain by the Spring Canyon coal group. To the east, however, this coal group is replaced by sandstone belonging to the Aberdeen member, and there the Aberdeen rests on the Spring Canyon tongue of the Star Point sandstone. Still farther east it rests on a tongue of Mancos shale. It is usually overlain by the Castlegate "A" coal bed. In the Wellington and Sunnyside quadrangles it is split into two parts by interfingering masses of Mancos shale. (See pl. 15.)

In Bear Canyon, in the Sunnyside quadrangle, the lower tongue of the Aberdeen sandstone consists of a thin band of bedded sandstone, sandy shale, and limy concretions, but it increases in thickness westward. In Rock Canyon, in the same quadrangle, it attains a thickness of 100 feet and occurs about 275 feet below the top of the Mancos shale. It is here composed of two beds of sandstone separated near the top by shale. The upper and thinner sandstone thins rapidly to the east and soon disappears.

The upper tongue of the Aberdeen appears in Rock Canyon, in the Sunnyside quadrangle, and is represented by a thin band of bedded sandstone and sandy shale. It increases in thickness westward, and in Pace Canyon, in the Wellington quadrangle, it is about 60 feet thick and occurs about 150 feet below the top of the Mancos shale.

[11] Spieker, E. M., and Reeside, J. B., jr., op. cit., p. 443.

These tongues generally form cliffs and are composed of massive-bedded sandstone, fairly well indurated at the top, grading downward through thin-bedded sandstone and sandy shale to shale at the base. They continue to increase in thickness toward the west, and between Fish Creek and Soldier Creek they merge, by the thinning out of the intervening tongues of Mancos shale. These are the easternmost sandstone tongues of the Mesaverde group in the Sunnyside quadrangle, but it is believed that similar tongues mark the transition of the Mancos shale into the Mesaverde rocks eastward along the Book Cliffs, because lentils of sandstone near the top of the Mancos shale have been observed nearly to the Utah-Colorado boundary.

Coal-bearing beds.—The coal-bearing part of the Blackhawk formation consists of massive beds of gray to buff sandstone, alternating with smaller amounts of sandy shale, shale, and coal beds. The sandstone is composed largely of semirounded quartz grains cemented by carbonate of lime and is reasonably well consolidated but not greatly indurated except some of the fine-grained and highly calcareous beds. The shale, as a rule, is more or less sandy and adjacent to the coal beds usually contains some carbonaceous material. The coal beds have been extensively burned at the surface, and the associated rocks are greatly altered in character and composition. At many places where coal beds have burned the rocks overlying them have been fused, and everywhere they are predominantly red instead of gray and buff, their original colors.

The dominant feature of the coal-bearing part of the Blackhawk formation consists of the massive, cliff-forming beds of sandstone, which lie beneath many of the principal coal beds. Some of these sandstone beds are exposed for 20 to 30 miles in east-west extent.

Examination of the section (pl. 4) will aid the reader to interpret the conditions of sedimentation just preceding and during the time when the coal beds of these quadrangles were being formed. The material that filled this interior basin came from an ancient land mass on the west. The lowest coal beds at the west edge of the section are older than the lowest ones at the east edge, and the Spring Canyon coal group, and the Castlegate "A" coal bed each in turn thins eastward and finally is reduced to a feather edge between massive beds of sandstone. The eastern boundary of the coal-forming swamps is thus well defined; the swamps were either limited by deep water, in which the vegetation could not grow, or were cut off from the open sea by sand bars. As additional proof that deep water was near by it will be noted that within a few miles from the edge of the swamps relatively fine deep-sea shale was being deposited at the same time that vegetation was accumulating in the swamps.

PRICE RIVER FORMATION [12]

Above the Blackhawk formation lies a series of non coal-bearing beds to which the name Price River formation has recently been given by Spieker and Reeside. This formation composes the upper part of the Mesaverde group in the Wasatch Plateau. It consists of a massive basal sandstone (the Castlegate sandstone member) overlain by a succession of beds of shale and sandy shale and one or more beds of massive sandstone.

Castlegate sandstone member.—The Castlegate sandstone member of the Price River formation lies conformably on the Blackhawk formation or coal-bearing part of the Mesaverde group and is near the middle of the group. It is composed mainly of semirounded grains of quartz and is gray to buff. It is continuously exposed across the Wellington and Sunnyside quadrangles and in most places forms a vertical cliff 100 feet or more high. The basal part is usually a transition zone of thin-bedded rocks which grade from sandy shale into sandstone, and the thickness of the beds increases upward. In many places shale and sandy shale are present near the top of the member, which make it difficult to determine the exact boundary between this sandstone and the overlying rocks. The upper surface is more nearly a true plane than the base of the sandstone, hence the variations in thickness from place to place and the marked increase in thickness westward are supposed to be due to increased deposition at the base rather than at the top of the bed. Near Sunnyside the Castlegate sandstone is about 150 feet thick, and at the west edge of the Wellington quadrangle it is 225 to 250 feet thick. It continues to increase toward the west, and near Castlegate, where it forms the gatelike passage in Price River Canyon, it is from 400 feet to 500 feet in thickness.

Non coal-bearing beds.—The non coal-bearing part of the Price River formation lies conformably on the Castlegate sandstone member and is composed of two or more thick beds of sandstone interbedded with thinner beds of shale and sandy shale. The sandstone beds are massive and in many places form cliffs 100 feet or more high. The greater part of the material, especially in sandstone beds, consists of semiangular grains of quartz. The main sandstone occurs about the middle of the non coal-bearing beds. It is white to gray, and the upper white portion is relatively pure quartz sand. (See pl. 2.) The upper surface of the Mesaverde was considerably eroded before the overlying Tertiary sediments were deposited. In places this surface had a relief of several hundred feet, the erosion having cut as far down as the top of the white quartz sandstone above described.

[12] Spieker, E. M., and Reeside, J. B., jr., op. cit., p. 445.

TERTIARY (EOCENE) ROCKS

WASATCH FORMATION

The Wasatch rocks lie unconformably upon the Price River formation, the top formation of the Mesaverde group. The unconformity, which was caused in part at least by erosion, is marked in most places by a basal conglomerate. The relief due to erosion of the old surface of Mesaverde rocks was locally at least several hundred feet. The Wasatch rocks have an aggregate thickness of about 3,750 feet in Whitmore Canyon and its tributaries, Water and Bear Canyons, near the heads of which the high divide is capped with Green River (Eocene) rocks.

The lower part of the Wasatch formation is composed of yellowish and greenish shale and sandy shale with some fresh-water limestone, upon which lies varicolored (predominantly red) coarse-grained conglomeratic sandstone with interbedded highly colored sandy shale. Above the varicolored beds the upper 1,500 feet of the Wasatch is composed of gray massive, locally cross-bedded sandstone with interbedded thin shale, which in places is more or less saturated with asphaltic material. These sandstone beds are known to be asphaltic only in the high divide between Whitmore Canyon and Range Creek and in Range Creek Canyon. The formation is well exposed in the deep canyons in the southeast corner of the Sunnyside quadrangle, where the sandstone is more thinly bedded and a greater amount of varicolored (greenish, purplish, and gray) sandy shale is exposed.

The contact between the Wasatch and Green River formations has been drawn, as shown on the map (p. 22), at the top of the asphalt-saturated sandstone beds. D. E. Winchester, who has done considerable work on the Green River oil shale in Uinta Basin, Utah, has suggested that these asphaltic beds may be the equivalent of the lower part of the Green River rocks on the east and northeast. More detailed work in surrounding areas will be required before this suggested correlation can be definitely settled.

GREEN RIVER FORMATION

The Green River formation, the youngest one exposed in this area, caps the divide for several miles southeast of Bruin Point and the tops of all the high ridges northeast of Bruin Point and east of Range Creek in the Sunnyside quadrangle. All but about 150 feet of the lower part of the formation has been eroded. It contains thin-bedded sandy calcareous shale, sandstone, oil shale, and some impure limestone. The calcareous shale and the oil shale weather white and produce a striking contrast between the Wasatch

and Green River formations. The sandstone is gray to buff, and the shale is predominantly greenish. The contact as represented on the map is based on the difference in appearance and the internal character of the rocks and not on paleontologic evidence. Detailed work in surrounding regions may show that the Wasatch-Green River contact should be drawn from 1,000 to 1,500 feet below the line shown on the map, and this change would include all the asphalt-saturated sandstone in the Green River formation. The Green River, as described here, probably contains beds of oil shale of commercial value, but no detailed study was made of these shales, nor were any samples tested to determine their yield of oil.

QUATERNARY DEPOSITS

Gravel on terraces.—The greater part of the surface of the Mancos shale was at one or more times buried beneath sheets of gravel spread unevenly over it by torrential streams that drained and eroded the adjoining uplands. The character of the surface of the Mancos shale at many places suggests that erosion prior to the deposition of the gravel had partly base-leveled the region. At least three sets of terraces at different levels are now indicated by remnants of alluvial fans, the original extent of which was not determined. To judge from the remnants now left the gravel of the middle terrace was more widely distributed than that of any other and extended south of Price River.

The gravel varies in thickness, but in general it is thickest near the place of origin, the Book Cliffs. At many places close to the Book Cliffs the gravel is 50 feet thick and the largest boulders are 10 feet or more in diameter, but at other places, 12 to 15 miles from the Book Cliffs, the gravel is from 10 to 15 feet thick and the largest pebbles are about 5 to 10 inches in diameter.

This gravel was doubtless derived from the Mesaverde and Wasatch rocks, which are more resistant than the Mancos shale and consequently produce rough and rugged surfaces in the process of weathering. These rugged surfaces gave steep gradients to the streams that carried the coarse material to its present resting place. The gravel is composed principally of Mesaverde sandstone, with minor amounts of Wasatch limestone, sandstone, and conglomerate.

Many interesting facts regarding the history of these gravel-covered terraces may be worked out, but it would be necessary to study the occurrence of the terraces over a greater area before a comprehensive discussion could be given.

The boundaries of the gravel-capped terraces as drawn on the map (pl. 22) are in places only approximate, especially in the Sunnyside quadrangle. In the Wellington quadrangle these gravel

terraces form more distinctive features, and in many places the terraces could be outlined on the map from the character of the surface features that occur there.

STRUCTURE

General features.—The Book Cliffs coal field is a simple northward-dipping monocline resulting from the buckling or unwarping that produced the San Rafael Swell and the La Sal Mountains. The Book Cliffs form the southern rim of the Uinta Basin, in central Utah, which extends in broad curves, in general parallel to the strike of the rocks. The broad structural features are in places modified by local warps or wrinkles, such as the Farnham anticline, in the southwest corner of the Wellington quadrangle. The rocks in these quadrangles form a part of the northern and northeastern flanks of the San Rafael Swell and dip east, northeast, and north, as shown by the structure cross sections on Plate 22. The coal-bearing rocks strike north from the south boundary of the Sunnyside quadrangle to Sunnyside, where the strike is abruptly deflected to the northwest. It holds this trend to Rock Canyon, where another deflection swings the strike due west. The surface rocks dip 12° NE. at Sunnyside, but the dip gradually decreases in all directions, being about 3° E. at the south edge of the Sunnyside quadrangle, 4° N. at the west edge of the Wellington quadrangle, and 2° NE. at the northeast corner of the Sunnyside quadrangle. The abrupt change in strike at Sunnyside produced several faults or displacements in the surface rocks.

The subsurface structural features of the Lower Sunnyside coal bed, as interpreted from surface rocks, are shown on the map (pl. 22) by structure contours. Each contour represents a line connecting points at the base of the coal bed that are of equal altitude above sea level. The difference in altitude between any two adjacent contour lines is the "contour interval." The contour interval on Plate 22 is 100 feet from the coal outcrop to the 6,500-foot contour, 200 feet from the 6,500-foot to the 5,500-foot contour, and 500 feet from the 5,500-foot to the 2,500-foot contour. Where the lines that have the same contour interval are closest together the slope of the coal bed is steepest. The differences in the contour intervals here used roughly indicate the relative certainty with which the structure of the coal bed could be determined. Many determinations of altitude on the outcrop control the contouring for a short distance under cover, but the uncertainty as to the thickness of subsurface rocks, the possible discordance in dip between the Mesaverde and Wasatch formations, and the uncertain amount of erosion at the top of the Mesaverde make it impossible to interpret with certainty the structure of the coal under thick cover.

The structure contours and the surface contours (those showing the surface features) are referred to the same datum (sea level) and therefore may be used to calculate the depth of the coal at any point where the two sets of contours intersect or by interpolation between the structure contours. The Lower Sunnyside coal near the divide between Soldier and Ninemile Creeks in the SE. ¼ sec. 27, T. 12 S., R. 11 E., is estimated on the basis of the structure and surface contours to lie at a depth of 1,950 feet for at this point the 5,500-foot structure contour intersects the 7,450-foot surface contour, and the difference between the two figures is 1,950 feet. On Stone Cabin Creek near the northeast corner of the Sunnyside quadrangle the 2,500-foot structure contour intersects the 7,000-foot surface contour and indicates a depth of 4,500 feet for the coal. The coal lies deepest beneath Bruin Point, in the SE. ¼ sec. 33, T. 13 S., R. 14 E., where the 5,000-foot structure contour intersects a surface altitude of 10,285 feet above sea level, and the Lower Sunnyside coal is therefore more than 5,000 feet below the surface. By a similar calculation the approximate depth to the coal may be determined at any point in the area, the position of the coal at points between structure contours being obtained by interpolation.

Farnham anticline.—The Farnham anticline is a small upfold on the flanks of the San Rafael Swell. It is northeast of Farnham, a flag station on the Denver & Rio Grande Western Railroad, in the southwestern part of the Wellington quadrangle. Rocks of the Morrison formation crop out in the middle of the anticline and are surrounded by Dakota (?) sandstone and Mancos shale. Faults roughly parallel with the axis displace the surface rocks on the east and west sides of the anticline. (See cross section on pl. 22.) Its axis trends south, and the rocks dip from 5° to 10° away from a common point near the center of sec. 12, T. 15 S., R. 11 E., except adjacent to the strike faults, where the dip is steeper, at one place reaching 85°. This warping of the strata affects the surface rocks only throughout a few square miles, beyond which the normal monoclinal dip prevails to the Book Cliffs. The oil and gas possibilities of the Farnham anticline have been described by the writer,[18] and according to trade journals a large gas well on this anticline was drilled in by the Utah Oil Refining Co., April 9, 1923.

Faults.—Several well-defined faults displace the surface rocks near and south of Sunnyside. Three roughly parallel faults strike south of west from sec. 32 into sec. 31, T. 14 S., R. 14 E. The northernmost fault has a vertical displacement of 110 feet at location 319, where the north block has been dropped relatively to the south block.

[18] Clark, F. R., The Farnham anticline, Carbon County, Utah: U. S. Geol. Survey Bull. 711, pp. 1–13, 1919.

This fault splits near the west end of its trace, between locations 330 and 313, producing an elevated block or horst 150 feet wide. The north block at location 312 has been dropped 120 feet, and the south block at location 313, 70 feet relatively to the horst between them. This gives a net vertical displacement of 50 feet, with the north block the lower. (See fig. 2.) The middle fault strikes S. 60° W. and has a vertical displacement of 15 feet at location 320, where the south block has dropped relatively to the north block. The fault splits at locations 314 and 315 and forms step faults, as shown in Figure 2. The middle block has dropped 35 feet relatively to the west block, and the south block has dropped 15 feet relatively to the middle block, making a total displacement of 50 feet between the outside blocks, with the south block the lower. The southernmost fault strikes roughly parallel with the middle fault. The vertical displacement southeast of location 320 is 13 feet, and the south block is relatively lower than the north block. At location 329 the vertical throw is 25 feet, and at location 298 it is 55 feet, with the south block at each place dropped relatively to the north block.

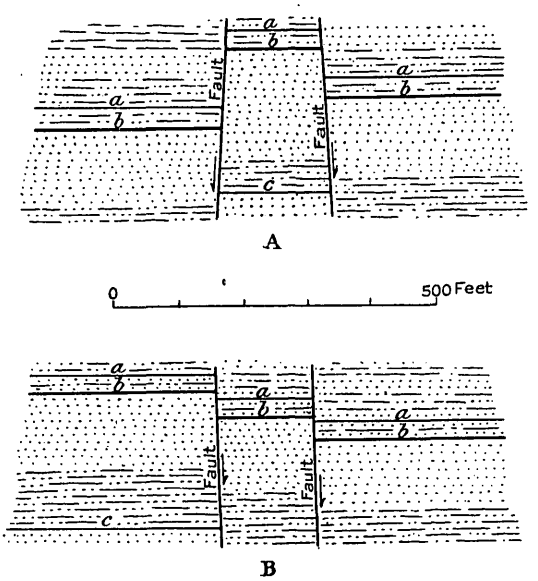


FIGURE 2.—Sketches showing effects of faulting near Sunnyside, Utah, viewed at right angles to the strike of the beds. A, Upthrust block at locations 312 and 313, looking east; B, step faults at locations 314 and 315, looking northeast. *a*, Upper Sunnyside coal bed; *b*, lower Sunnyside coal bed; *c*, Kenilworth coal bed

The faults just described could be traced only short distances, as shown on Plate 22.

Two other faults are present in the Sunnyside region and farther south. The longer fault, the Sunnyside, was traced for about 3½ miles, and the shorter one, the Water Canyon, for about 1½ miles. (See pl. 22.) They are parallel and trend southeast, but neither exactly corresponds with the strike of the beds. The Sunnyside fault is known to the miners as the "30-foot fault" because the vertical displacement in the Sunnyside mine is generally about 30 feet. In the mine just south of Number Two Canyon the throw of the fault is 29 feet, in Water Canyon it is 32 feet, and in the right fork of Water

Canyon it is about 10 feet. The west block at each place has dropped relatively to the east block. Where the break could not be traced it probably passes within a short distance into minor flexures.

The Water Canyon fault displaces the rocks near the mouth of Water Canyon and could be definitely traced northward to the coal-bearing cliffs and southward to the top of the first ridge. Its vertical displacement at location 337 is 26 feet, and the west block is relatively the lower. In the next canyon south, at location 360, a fault displaces the coal beds and trends toward the Water Canyon fault, but the two could not be definitely connected in the field. The vertical displacement at location 360 is 15 feet, with the west block relatively the lower, but the break could not be traced southward.

COAL

GENERAL FEATURES

The coal of economic importance in these quadrangles crops out in a stratigraphic distance of 500 feet, in which a maximum of nine beds and a minimum of two beds are exposed at any one place. The coal is of bituminous rank and is coked at Sunnyside. The beds are generally lenticular and uncertain in thickness, but some of them could be traced with certainty for considerable distances. The Lower Sunnyside and Kenilworth coal beds were traced across the quadrangles, but the Kenilworth bed is known to be absent at several places on the outcrop. The coal beds are nowhere seriously split by bone and shale partings but are confined to one bench.

The coal beds that could be definitely traced in any part of the quadrangles are the following, listed in order from the top downward:

Upper Sunnyside.
Lower Sunnyside.
Rock Canyon.
Fish Creek.
Gilson.
Kenilworth.
Castlegate "A."

ALTITUDES OF COAL BEDS

Altitudes of many points on each coal bed were determined by vertical angles with telescopic alidade and are probably correct within small limits of error. They are listed below. The question marks set against some of the altitudes indicate that they may be slightly in error, but the amount can not be determined. At other locations no altitude was determined.

Altitudes of bottom of coal beds at some localities where sections were measured in the Wellington and Sunnyside quadrangles, Utah

[Locality numbers correspond to those used on Plate 22]

Castlegate "A" bed	Feet
1	7,500
2	7,330
3	7,095
4	7,207
5	7,098
6	7,161
7	7,498
8	7,365
9	7,063
10	7,403
11	7,010
12	7,188
13	7,001
14	6,920
15	6,770
16	6,531
18	6,820
19	7,212
Kenilworth bed	
23	7,569
23–a	7,147
24	7,269
25	7,310
26	7,733
27	7,500
28	7,475
29	7,100
30	7,189
31	7,140
32	6,854
33	6,720
34	6,578?
35	6,617
36	6,860
36–a	**7,155**
37	7,342
38	7,397
39	7,423
40	**7,437**
41	**7,170**
42	6,997
43	6,851
44	7,106
45	**7,213**
46	**7,791**
93	**6,893**

Kenilworth bed—Continued	Feet
94	6,725
95	7,035
96	7,395
97	7,502
98	7,190
99	7,287
100	7,342
101	7,159?
102	7,214
103	7,478
104	7,404
105	7,435
106	7,230?
107	7,373
108	7,363
109	7,290
110	7,113
112	7,005
113	7,483
114	7,633
115	7,190
116	7,346
193	7,163?
194	7,423
195	7,075?
196	7,130
197	7,400
228	7,360
229	7,413
231	7,437
221	7,220
224	7,075
225	7,087
226	7,065
226–a	7,481
222	7,272
223	7,381
224	7,045
227	7,400
240	7,230
241	7,432
241–a	7,175
241–b	7,350
242	7,403
225	7,192
226	7,440

Kenilworth bed—Continued	Feet
287	7,213
288	7,082
291	7,288
293	7,335
297	7,227
301	7,020
305	6,739
305–a	6,683
305–b	6,895
333	6,968
336	6,840
337	6,995
337–a	7,028
338	7,012
339	6,909
339–a	6,727
340	7,036
340–a	6,648
340–b	6,800
Gilson bed	
46	7,809
47	7,586
47–a	7,175
49	7,113
50	7,332
50–a	7,755
51	7,531
52	7,125
53	7,209
53–a	7,142
54	7,150
55	6,870
56	7,000
57	6,595
58	6,636
59	6,950
60	7,414
61	7,444
62	7,456
63	6,976
65	7,127
118	6,913
119	6,750
121	7,103
126	7,546
127	7,225

Gilson bed—Continued	Feet
128	7,333
129	7,226
130	7,160
131	7,219
132	7,402
133	7,286
134	7,402
135	7,315±
136	7,408
139	7,144
140	6,990
142	7,670
143	7,324
143–a	7,414
143–b	7,136
198	7,134
199	7,020
200	7,230
201	7,475
201–a	7,620?
203	7,165
204	7,080
204–a	7,445
228	7,393
229	7,441
230	7,210
231	7,463
232	7,250
234	7,050
236	7,095
237	7,320
238	7,447
239	7,075
240	7,285
241	7,453
242	7,428
Rock Canyon bed	
157	7,028
158	7,155
160	7,120
161	7,035
162	7,612
163	7,276
164	7,398
165	7,409
166	7,005
205	7,032

Rock Canyon bed—Contd.	Feet
206	7,235
207	7,168
208	7,060
243	7,417
244	7,584
245	7,240
246	7,428
247	7,555
248	7,299
250	7,130
252	7,200
253	7,074
254	7,280
Lower Sunnyside bed	
81	7,332
83	7,182
84	7,340
85	7,337
86	6,979
87	6,945
88	6,695
89	7,033
90	7,539
91	7,053
92	7,275
167	7,072
168	7,156
170	6,900
172	6,776
175	7,005
171	7,080
165–a	7,440
165–b	7,447
177	7,802
178	7,709
209	7,220
210	7,115?
211	7,214
212	7,514
213	7,320
214	7,215
215	7,338
216	7,250
255	7,525
256	7,240
257	7,201

Lower Sunnyside bed—Contd.	Feet
258	7,744
259	7,598
260	7,127
262	7,338
263	7,670
265	7,247
266	7,265
267	7,246
268	7,610
269	7,575
270	7,392
306	7,392
307	7,406
308	7,324
309	7,180
310	7,479
311	7,436
312	7,406
313	7,526
314	7,490
315	7,470?
316	7,450?
317	7,289
318	7,050
319	7,036
320	7,063?
341	7,013
342	6,991
344	7,000
345	7,055
347	6,818
348	6,872
349	6,936
350	7,020
352	6,823
353	7,066
354	6,459
357	7,190
358	7,050
359	6,900
360	6,932
361	7,028
362	7,175
363	6,805
364	6,995
365	6,880

Most of the coal beds listed above are intimately associated with massive sandstones, which were regarded as key rocks and afforded the main basis for the field mapping. In some places the coal rests

directly on the sandstone; in others they are separated by a few inches or a few feet of shale. In some places the key sandstone lies above the coal. Many coal beds that are not associated with key sandstones were measured, and for these beds tentative correlations with the beds definitely traced have been suggested in Plate 5.

The coal of these quadrangles has been extensively burned at the outcrop, and exposures showing the complete thickness of the beds are rare, so that it is difficult to interpret properly the character and thickness of the coal beds under cover and their definite relation at the outcrop. The rocks associated with the burned coal beds are generally more or less altered in composition. Many exposures show the bands of ash left from the burning of the coal, but these are of doubtful value in mapping, because the rocks slumped and caved as coal burned out.

STRATIGRAPHY OF THE COAL BEDS AND ASSOCIATED ROCKS

A number of columnar sections of the coal-bearing rocks showing the general lithologic character of the strata and the stratigraphic position and thickness of the coal beds were measured. In Plate 5 sections believed to be on the same beds are connected by broken lines. In arranging sections on the plates certain beds were used as datum planes for convenience—namely, the top of the Aberdeen sandstone between locations 1 and 19, the base of the Kenilworth coal between locations 39 and 194, and the base of the Lower Sunnyside coal between locations 213 and 265. These sections illustrate two striking but common features of the beds of this coal field—the association of massive sandstone beds with several of the principal coal beds or groups of coal beds, and the lenticular shape of the coal beds and the layers of associated rocks.

Each of the principal coal-forming epochs was either preceded or followed by the deposition of beds of sand ranging from 50 to 200 feet in thickness. These beds are now fairly well indurated sandstone, which usually crops out in vertical cliffs and forms the basis for the mapping of coal beds shown in Plate 5. The rocks between these sandstones consist of alternating beds of shale, sandy shale, sandstone, and coal.

Several coal beds have been traced for considerable distances and probably are continuous though of varying thickness on the outcrop between measured sections, the locations of which are shown on Plate 22.

Coal below the Castlegate "A" bed.—The lowest known coal bed in these quadrangles crops out from 40 to 50 feet below the Castlegate "A" bed at locations 1 and 2, in sec. 18, T. 13 S., R. 11 E. These outcrops probably represent small lenses, because no other

coal is exposed east or west of either location, and it is doubtful that a continuous bed is present even between locations 1 and 2.

Castlegate "A" coal.—The next higher coal bed, the Castlegate "A," is the lowest coal mined at Kenilworth, 3 miles west of location 1, and at Castlegate. It lies directly above the massive Aberdeen sandstone, which is 100 feet or more in thickness. This coal bed at many places is exposed in two or more benches, which indicate that favorable conditions for coal forming continued, although locally interrupted by incoming sediments, for a considerable time after the Castlegate "A" bed had been buried. These upper beds or benches may be continuous for comparatively short distances, but on the outcrop they are generally too thin to be of economic value except at a few places near the west edge of the Wellington quadrangle. (See pl. 5.)

The Castlegate "A" coal bed has been traced in a general westerly direction for an air-line distance of 20 miles. The many exposures indicate that the coal extends northward under cover to the north edge of the quadrangles. The eastern limit of valuable coal on the outcrop is in sec. 14, T. 13 S., R. 11 E., and the western limit appears to be in sec. 14, T. 13 S., R. 8 E.

The interval between the Castlegate "A" and Kenilworth coal beds contains no extensive coal beds of economic value, but some coal is exposed at locations 20, 21, 22, 31, 32, and 34. (See pl. 22.) These thin beds crop out at about the same stratigraphic position, but it is unlikely that they represent a continuous coal bed between the extreme locations, and probably the coal is not continuous even between adjacent sections. These beds crop out near the stratigraphic position of the Royal Blue coal at Kenilworth, but it is doubtful whether they are the equivalent of the Royal Blue.

Kenilworth bed.—The next higher bed of economic value is the Kenilworth, so named because it is mined at Kenilworth, west of the Wellington quadrangle, where the coal is 19 feet thick with no heavy partings. The coal decreases in thickness eastward until it is only 2 feet 6 inches thick at location 23, the westernmost exposure in the Wellington quadrangle. This thinning may be due in part to the fact that the Kenilworth bed east of Kenilworth separates to form the Kenilworth and Gilson beds, which are 15 feet apart at the west edge of the Wellington quadrangle. The probability of a "split" in the Kenilworth bed east of Kenilworth is suggested by several exposures mentioned on pages 40 and 41, but the extensive burning of the coal at the outcrop makes it impossible to state with certainty what the true conditions are.

The average distance between the Castlegate "A" and Kenilworth beds is about 200 feet, but at location 46, in sec. 13, T. 13 S., R. 10 E.,

it is 250 feet, and at location 30, in sec. 16, T. 13 S., R. 11 E., it is 160 feet, giving a range of 90 feet between the maximum and minimum distance. These measurements cast some doubt on the accuracy of the mapping, but as the outcrop of each bed was carefully traced by means of the underlying sandstone associated with the bed, the correlations shown in Plate 5 seem to be justified.

The Kenilworth bed was traced across the quadrangles and for a considerable distance farther west, but the coal is thin or absent in many places on the outcrop. At locations 63 and 64, in sec. 13, T. 13 S., R. 11 E., the coal is absent and has been replaced by a massive sandstone. It seems probable that the coal swamp was originally continuous at this locality and that subsequently a channel about 1,000 feet wide, running southeast, was cut by erosion through the coal swamp and into the underlying sand to a depth of about 20 feet. Later this channel was filled with sand, which continued to be deposited until the Kenilworth coal swamp in surrounding territory was buried to a depth of 8 feet. It is not possible to determine the length of this channel, but the water and the sediment that it carried probably came from the west or northwest. This was the only place seen where the Kenilworth coal swamp had been eroded, but many places are known where the swamp did not extend or at least the coal is not now present.

Gilson bed.—The Gilson coal bed, so named because it was mined in Coal Creek many years ago by Sam Gilson, is the first one of economic value above the Kenilworth bed. The distance between these beds is 6 feet at location 31, in sec. 16, T. 13 S., R. 11 E., and 53 feet at location 102, in sec. 21, T. 13 S., R. 12 E., giving a range of 47 feet, or about one-half of the range of distances, 90 feet, between the Castlegate "A" and Kenilworth beds. If the mapping of these coal beds is correct, this wide range in thickness of the deposits between them illustrates the different rates of sedimentation even in comparatively small areas.

The Gilson is at many places the thickest coal bed in the Wellington quadrangle, having a maximum thickness of 9 feet, but at other places it is below what the Geological Survey regards as the minimum workable thickness (14 inches) for the quality of coal in it. In general the coal consists of one bench, but in places thin shale partings separate it into two or more benches. The tracing of the Gilson bed as shown in Plate 5 is fairly certain west of location 119, in sec. 18, T. 13 S., R. 12 E., and east of location 126, in sec. 20 of the same township. Between these localities, however, it was difficult to trace the outcrop, and there is some doubt whether the Gilson coal bed, west of location 119, is the same as that correlated with it east of location 126.

The maximum thickness of the Gilson bed, 9 feet 4 inches, was measured at location 57, on Coal Creek, in sec. 10, T. 13 S., R. 11 E., where it is reported the coal was at one time mined by Sam Gilson. Between locations 57 and 119 the coal lies immediately above a thin but traceable sandstone, but east of location 119 the main bed leaves the sandstone, and at location 128, in sec. 20, T. 13 S., R. 12 E., the distance between the coal and the sandstone is 26 feet. The basis for the mapping of the Gilson bed is its close proximity to the Kenilworth bed. East of location 119 the tracing is facilitated by the massive, ledge-making sandstone which immediately overlies the Gilson bed and separates it from the Fish Creek and Rock Canyon beds.

In Plate 5 is suggested a correlation of several exposures ranging from 10 to 28 feet above the Gilson bed between locations 59 and 119, in T. 13 S., R. 11 E. These sections were measured at exposures having no distinctive features by which correlations could be made in the field. Sections at locations 60–a, 61–a, 63–a, 64–a, 118–a, and the top bench at 119, connected by a broken line in Plate 5, may represent a "split" from the Gilson bed, or they may represent one small lens of coal, or even as many small lenses as there are sections shown in Plate 5.

The Gilson bed does not extend eastward along the outcrop with a thickness that makes it of economic value beyond location 239, in sec. 15, T. 14 S., R. 13 E., but several sections (see pl. 5) showing less than 1 foot 2 inches of coal were measured as far east as location 242, in sec. 25, T. 14 S., R. 13 E., which marks approximately the eastern limit of the swamp in which the Gilson coal bed accumulated.

Fish Creek bed.—The Fish Creek bed, so named because it reaches its maximum thickness on and near Fish Creek, has not been definitely mapped west of location 78, in sec. 13, T. 13 S., R. 11 E., but a tentative correlation is suggested connecting sections as far west as location 69, in sec. 17, T. 13 S., R. 11 E. (see pl. 5), and the correlation might be made to include sections at locations 50–b and 49–a. The tracing west of location 78 is based on the relative stratigraphic position of these exposures. The correlation of sections with the Fish Creek coal is definite and reasonably certain between locations 78, in sec. 13, T. 13 S., R. 11 E., and 166, in sec. 23, T. 13 S., R. 12 E., but the Fish Creek bed either merges with the Rock Canyon bed at location 166 or is not represented there, as there is only one bed east of location 166, known as the Rock Canyon coal (see pl. 5), which lies between thick beds of sandstone.

The distance between the Gilson and Fish Creek beds in areas where definite information was obtained ranges from 25 to 60 feet, and the interval is filled with sandstone, sandy shale, and shale. A

massive sandstone which occupies most of this interval between locations 119 and 153 forms the basis for the mapping throughout that area, but elsewhere the tracing of the Fish Creek bed is based on its stratigraphic position with reference to the Rock Canyon coal and other associated rocks.

Rock Canyon bed.—The Rock Canyon bed, so named because it has been mined in a small way in Rock Canyon, has been tentatively traced as far west as location 49, in sec. 7, T. 13 S., R. 11 E. (see pl. 5, No. 49–c), but it could not be mapped with certainty west of location 157, in sec. 13, T. 13 S., R. 11 E. The Rock Canyon and Fish Creek beds in the area where definite mapping was possible are separated by 10 to 35 feet of sandstone, sandy shale, and shale, but the distance between these coal beds is apparently 50 feet at location 61, in sec. 23, T. 13 S., R. 11 E., where each bed is only a few inches thick and identifications are uncertain.

The tracing of the Rock Canyon bed west of location 157 is not certain, as it is based on the stratigraphic position of the coal as shown in Plate 5 and not on an intimate association with any traceable key rock. The mapping of this bed east of location 157 is reasonably certain, for it is based on its association with sandstone, its stratigraphic position, and its general character and thickness. For the greater part of the distance east of location 157 the Rock Canyon bed is separated from a massive, ledge-making overlying sandstone by only a few feet of sandy shale. This sandstone is continuously exposed across the quadrangles and lies immediately beneath the Lower Sunnyside coal bed. The interval between the Rock Canyon and Lower Sunnyside beds ranges from 60 to 160 feet, with sandstone greatly in excess of shale near the eastern limit of the Rock Canyon coal bed.

East of location 166 the Rock Canyon bed has been extensively burned at the outcrop, but it generally rests on a massive sandstone, by means of which the coal bed was traced. The next exposure of coal found is at location 205, in sec. 29, T. 13 S., R. 13 E., but at location 201, in sec. 30, T. 13 S., R. 13 E., a clinker bed, 32 feet above the Gilson bed, probably represents the Rock Canyon coal. The easternmost exposure of the Rock Canyon bed found is at location 254, in sec. 10, T. 14 S., R. 13 E. The underlying sandstone was traced several miles farther east, but no evidence of coal was seen above it. At several places in T. 13 S., R. 11 E., thin beds of coal crop out between the Rock Canyon and the Lower Sunnyside beds. (See pl. 5.) These exposures were not mapped, and no attempt was made in the field to correlate the sections measured, but in Plate 5 several sections are connected by a broken line, which indicates the probability that the exposures are on the same bed.

Lower Sunnyside bed.—The Lower Sunnyside bed, so named because it is the lower one of the two beds extensively mined at Sunnyside, has been mapped across these quadrangles. The mapping was based on a massive, cliff-making sandstone which lies directly under the coal and is continuously exposed from the southern edge to the western edge of the quadrangles. The coal is generally burned at the outcrop, so that few exposures of coal are left, and definite tracing would be impossible without the underlying sandstone.

The distance between the Lower Sunnyside and Kenilworth coal beds varies considerably from place to place (see pl. 5), reaching a maximum of 250 feet at location 46, in sec. 13, T. 13 S., R. 10 E., and a minimum of 170 feet at location 122, in sec. 23, T. 13 S., R. 12 E. The variation is therefore 80 feet, which illustrates how widely the rates of sedimentation may differ in a given time even in small areas. This great difference in thickness of the rocks between two widespread coal beds might cast some doubt on the mapping if the prominent sandstone beds had not been traced by continuous outcrops.

Although the mapping of the Lower Sunnyside bed is believed to be correct, the thickness and character of the coal can not be determined with accuracy because of the general burning of the coal near its outcrop. Evidence of burning is present west of location 83, in sec. 8, T. 13 S., R. 11 E., and coal crops out only at locations 81 and 83, in secs. 7 and 8 of that township. Eastward the coal is exposed at more places as far as location 175, in sec. 18, T. 13 S., R. 12 E., but between that point and location 177, in sec. 25, T. 13 S., R. 12 E., no coal crops out, and the bed was followed by its underlying sandstone and by the evidence of burning associated with it. East and south of location 177 the coal crops out at many places, and the evidence of burning is extensive.

Coal beds above the Lower Sunnyside bed.—Several coal beds, usually confined to small lenses, occur above the Lower Sunnyside and below the base of the Castlegate sandstone. (See pl. 2, *B.*) The interval between the coal and the Castlegate sandstone ranges from 175 to 250 feet and is occupied by sandstone, sandy shale, and thin coal beds.

The principal coal bed in this interval, and the only one which has been mapped, is the Upper Sunnyside, so named because it is the upper one of two beds mined at Sunnyside. Tentative correlations of this bed have been suggested at several localities (pls. 5–11), but these are indefinite except in the Sunnyside district and south of it. Elsewhere the coal appears to be lenticular, and few exposures of it were found; consequently the tracing was based on the stratigraphic position of this bed with reference to the Lower Sunnyside bed. At many places where successive exposures are several miles apart the rocks along the

line of the exposures are generally more or less altered by heat from burned coal. At many places it is evident that burning was on the Upper Sunnyside coal bed, but at others it is impossible to determine whether or not more than the Lower Sunnyside bed was originally present.

Several coal beds, probably lenticular and economically unimportant, crop out between the Upper Sunnyside bed and the Castlegate sandstone, the base of which marks the upper limit of coal deposition in these quadrangles. In this interval coal beds appear to be more numerous in the Sunnyside district and south of it than in other parts of the field, but a few sections of beds in this stratigraphic interval were measured farther west.

At Sunnyside and farther south (from location 330 to location 371, in sec. 9, T. 15 S., R. 14 E.) several sections were measured, which show the complete series of rocks between the Sunnyside coal beds and the base of the Castlegate sandstone. These are shown in Plate 5.

Further descriptive details together with detailed graphic sections of coal beds are given under each township.

DESCRIPTION OF COAL BY TOWNSHIPS

GENERAL FEATURES

The coal beds in these quadrangles are irregular in thickness and lenticular and therefore can be described best in small geographic units. This method of treatment has advantage for reference, because the information on a small area is condensed and easily found. The details of the coal are given by beds, beginning with the lowest, with townships as units, beginning at the west edge of the Wellington quadrangle. In these descriptions the names of the beds exposed and the location numbers of the sections measured are stated; the thickness and irregularities of each bed are given; a summary of the beds according to their importance is made, also an estimate of the quantity of coal present; and whether the coal crops out in the township or is assumed to be present under cover the accessibility of the beds is described. In addition to the depths stated, the approximate depth to the Lower Sunnyside coal at any place may be calculated by subtracting the altitude shown by the structure contour from that shown by the surface contour.

T. 12 S., RS. 10 AND 11 E.

General features.—The south edge of T. 12 S., Rs. 10 and 11 E., is from half a mile to 2½ miles north of the face of the Book Cliffs, which contain five coal beds that were accurately mapped and several beds that could not be traced. Sections of the beds were measured at many places, and these sections form the basis for the estimate of

the character and thickness of the coal in T. 12 S., Rs. 10 and 11 E. No coal crops out in these townships, but the Lower Sunnyside bed dips below drainage level in Coal Creek in sec. 3, T. 13 S., R. 11 E., about half a mile south of the township line. (See pl. 22.)

Tonnage estimate.—There is every reason to believe that many of the coal beds exposed in T. 13 S., R. 11 E., underlie T. 12 S., Rs. 10 and 11 E., and probably have an average thickness and character equal to that at the outcrop. On this basis it is estimated that a potential quantity of 142,000,000 short tons of coal lies beneath the surface of that part of T. 12 S., R. 11 E., within the Wellington quadrangle, and on the same basis there would be 12,700,000 tons in the small part of T. 12 S., R. 10 E., shown on Plate 22. This gives a total of 154,700,000 short tons. This tonnage includes estimates for the Gilson, Lower Sunnyside, Castlegate "A," Kenilworth, and Rock Canyon (?) coal beds, named in the order of their estimated tonnage yield. The details of the tonnage estimated by beds are given in the table on page 101.

Accessibility.—The coal in T. 12 S., Rs. 10 and 11 E., is relatively of little value at present because it can be reached only by shafting, and this is impracticable considering the great quantities of more readily accessible coal in this region. The coal will be found nearest the surface on Coal Creek and its tributaries, which afford the easiest route by which the coal could be removed to market. The Lower Sunnyside bed is estimated to lie at a depth of 1,700 feet on Summit Creek at the north edge of the Wellington quadrangle in sec. 30, 600 feet at the forks of Coal Creek near the east quarter corner of sec. 34, and 1,300 feet on Coal Creek at the north edge of the quadrangle in sec. 25.

T. 13 S., RS. 10 AND 11 E.

General features.—More coal beds are exposed in T. 13 S., R. 11 E., than in any other township in these quadrangles. The Lower Sunnyside, Gilson, Kenilworth, and Castlegate "A" beds were traced and accurately mapped, and the Upper Sunnyside, Rock Canyon, and Fish Creek beds, though not accurately mapped, were measured at many places, and a tentative correlation of these beds with others in adjoining townships is suggested in Plates 5 and 6. Other coal outcrops were measured, but the beds could not be traced, and the only basis for correlation is their stratigraphic position. (See p. 5.)

Many graphic sections showing the relative position and thickness of coal beds and the character and thickness of the intervening rocks will be found in Plate 5. Other sections are given in detail in the text.

The coal is generally well exposed where it has escaped burning, and 119 coal sections that exceeded 14 inches in thickness were measured in the township, 94 of which are shown in Plate 6.

The following list gives the names of coal beds exposed and the numbers by which the several sections are designated.

Coal beds exposed in T. 13 S., R. 11 E., and a half-mile strip along the east edge of T. 13 S., R. 10 E.

Upper Sunnyside	81–a, 82–a, 88–a
Lower Sunnyside	80–92
Rock Canyon	49–c, 50–c, 67, 68, 74, 75, 71–a, 57–c, 59–c, 60–c, 61–c, 78–a, 79–a
Fish Creek	69, 70, 71, 57–a, b, 60–b, 61–b, 78, 79
Beds not correlated	1, 2, 5–a, 6–a, 7–a, 9–a, 10–a, 20, 21, 22, 46–a, b, 49–a, b, 50–a, b, d, 52–a, 57–d, 60–a, 60–e, f, 63–a, 64–a, 66, 72, 73, 73–a, 76, 77
Gilson	46–65
Kenilworth	23–45
Castlegate "A"	3–19

Castlegate "A" bed.—The Castlegate "A" coal bed in T. 13 S., R. 11 E., west of sec. 14, exceeds the minimum workable thickness of 1 foot 2 inches, but coal of economic value may not be expected east of location 19, in the SE. ¼ sec. 15. An exposure at the forks of the canyon below location 42, in sec. 13, shows 8 inches of coal at the Castlegate "A" horizon, which probably is near the eastern edge of this coal bed. The bed has been traced westward to sec. 23, T. 13 S., R. 8 E., and has been definitely correlated with the lowest coal mined at Kenilworth and with the Castlegate "A" bed, mined at Castlegate.

The Castlegate "A" bed has not been burned at the surface except in the western part of the township, and exposures are reasonably good. Seventeen sections were measured on the bed and are shown in Plate 6. The general relations of the coal and associated rocks are shown in Plate 5. This bed is variable in thickness, ranging from 1 foot 4 inches at location 19, in sec. 15, to nearly 6 feet at location 8, in sec. 19, but the thickness in most exposures ranges from 2½ to 4 feet, and the average for all measurements is 3 feet 2 inches.

The Castlegate "A" bed at locations 1 and 2, in sec. 18, T. 13, S., R. 11 E., has been burned at the surface, but exposures of a lower coal were found at each place. At location 1 coal 1 foot 11 inches thick crops out 42 feet below the Castlegate "A", and at location 2 coal 1 foot 6 inches thick shows 52 feet below the Castlegate "A." (See pl. 5.) These exposures occur at about the same stratigraphic position, but it is not known that they represent a continuous bed between the two locations. As no other exposures of coal were found here, it is probable that they represent small lenses.

Coal beds between Kenilworth and Castlegate "A" beds.—Coal beds, which are probably locally of small economic value, crop out in two zones in the interval between the Kenilworth and Castlegate "A" beds in T. 13 S., R. 11 E.—one about 60 feet below the Kenilworth, and the other from 7 to 35 feet above the Castlegate "A" coal. The interval between these two coal-bearing zones is occupied mainly by sandstone, ranging from 90 to 130 feet in thickness, and is barren of coal.

The coal beds in the lower zone are designated in Plates 5 and 6 by Nos. 3–a, in sec. 18, and 5–a, 6–a, 7–a, 9–a, and 10–a, in sec. 17, and are grouped as one bed in Plate 6, although that may be an erroneous suggestion. These exposures may represent a "split" from the Castlegate "A" bed and may correspond in stratigraphic position to the Castlegate "B" bed mined at Castlegate, Utah. They may be parts of one bed restricted to a small area, or they may represent several small lenses. The coal that crops out at 7–a and 9–a could be profitably mined as a second bench with the Castlegate "A" coal, but elsewhere the coal exposed probably should be considered as two beds. This upper bed of coal is not exposed at location 8, in sec. 17, but it will probably be found of workable thickness under cover. Most of the coal in the upper bed (3–a) has been burned at location 3, in sec. 18, and a clinker bed, 15 feet above the Castlegate "A" at location 1, in sec. 13, T. 13 S., R. 10 E., probably represents the upper bed.

Exposures in the zone 60 feet below the Kenilworth may possibly represent the eastward extension of the Royal Blue bed, which crops out about midway between the Kenilworth and Castlegate "A" beds at Kenilworth, where these three beds are mined. The Royal Blue bed was traced eastward by exposures of coal and evidences of burning nearly to this township. A distance of several miles intervenes between the easternmost exposure known to be the Royal Blue bed and location 20, in sec. 7. It is doubtful whether the coal is present throughout this distance. The sections tentatively referred to the upper coal-bearing zone are shown in Plate 5 and are listed in the following table:

Coal beds exposed below Kenilworth bed in T. 13 S., R. 11 E.

Location	Section	Thickness of coal	Distance below Kenilworth bed	Location	Section	Thickness of coal	Distance below Kenilworth bed
		Ft. in.	*Feet*			*Ft. in.*	*Feet*
20	7	1 4	50	31	16	6	60
25	18	6	54	32	16	10	68
22	19	1 6	65	34	10	9	64

Some of these exposures are at about the same stratigraphic position but probably do not represent a bed that is continuous between adjacent sections. The coal exceeds 1 foot 2 inches, the minimum workable thickness, at only two locations, 20 and 22, but these exposures may represent the margin of a coal lens of more or less value under cover on the north.

A bed of coal 2 feet thick crops out at location 21, in sec. 18, 17 feet below the Kenilworth bed, but as no exposures were seen in either direction this outcrop probably represents a very small lens of no economic value.

Two other thin beds of no economic value crop out at location 34, in sec. 10; an 11-inch bed 14 feet below the Kenilworth, and a 2-inch bed of coal with 8 inches of carbonaceous shale 34 feet below the Kenilworth. No exposures were seen in adjacent sections, and probably no coal of material value will be found at these horizons.

Kenilworth bed.—The outcrop of the Kenilworth bed has been traced with considerable care and reasonable certainty across these quadrangles and westward to Hardscrabble Canyon, in the Castlegate quadrangle, a total distance of 33 miles. The coal is very lenticular, being in some places thin, in others thick, and elsewhere not present. The bed is of considerable economic value in T. 13 S., R. 11 E.; it thickens rapidly westward from this township and is 19 feet thick where it is mined at Kenilworth.

Exposures are reasonably good except where the coal has been burned. Twenty-five sections were measured on the Kenilworth bed in T. 13 S., Rs. 10 and 11 E., and 15 of them are shown in Plate 5 and 17 in Plate 6. The sections in Plate 5 show the relation of the Kenilworth and other coal beds to the associated rocks, and those in Plate 6 show in detail the character and thickness of the bed itself. The Kenilworth bed is lenticular and variable in thickness, ranging from 6 inches at location 49 in sec. 7 to 3 feet 6 inches at location 25 in sec. 18, but in most of the exposures the coal exceeds 1 foot 8 inches in thickness. The bed at location 46 in sec. 13, T. 13 S., R. 10 E., has been burned, but sections farther west indicate that the coal at the west edge of the township is about 2 feet thick. At location 23 in sec. 13, T. 13 S., R. 10 E., and location 24 in sec. 7, T. 13 S., R. 11 E., the bed is about 2½ feet thick, but at location 49, in sec. 7, it contains only 6 inches of coal and 6 inches of carbonaceous shale. Farther east the coal is variable in thickness. In this township it reaches its maximum thickness of 3 feet 6 inches at location 25, in sec. 18. At location 28, in sec. 17, the coal is 1 foot 2 inches thick, and at location 29, in sec. 17, it is 3 feet 4 inches thick. These sections are not shown in Plate 6 because the coal is similar to that at locations 27 and 30, in sec. 16. The bed in parts of secs. 17, 16, 9, and 10 ranges from 2 to 3

feet. At location 36, in sec. 10, only 8 inches of coal crops out, but this exposure may not represent the full thickness of the bed. Two other exposures in sec. 10, at locations 33 and 34, show a good thickness of coal but are not given in Plate 6 because the coal is similar to adjacent sections at location 32, in sec. 9, and location 35, in sec. 10. At location 33 the coal is 2 feet 2 inches thick, and at location 34 it is 2 feet 4 inches thick. The coal bed thins eastward and is of no value at location 59, where only 3 inches of carbonaceous shale is exposed, but at location 37, in sec. 14, the coal is 1 foot 8 inches thick; it gradually increases in thickness farther east, and at location 41, in sec. 13, it is 2 feet 6 inches thick.

The Kenilworth bed has been removed by erosion in the NW. ¼ sec. 13, T. 13 S., R. 11 E., and its place is now occupied by a massive channel sandstone. It is probable that during the final stages of coal deposition a stream cut into the peat bog and underlying material to a depth of about 20 feet. The channel here, between locations 63 and 64, was about 1,000 feet wide and later was filled with sand. The following sections are not shown in Plate 6:

Sections of Kenilworth coal bed in T. 13 S., R. 11 E.

Location 43, sec. 13			Location 44, sec. 13		
	Ft.	In.		Ft.	In.
Sandstone.			Sandy shale.		
Coal	2	4	Coal	2	2
Shale		3	Shale		1
Sandstone.			Sandstone.		
	2	7		2	3

Although the Kenilworth bed is lenticular and variable in thickness in these townships, it probably contains a considerable amount of coal of present economic value.

Gilson bed.—It has been suggested in the section on stratigraphy of the coal beds and associated rocks that probably the Gilson and Kenilworth beds of these quadrangles unite and form the Kenilworth bed at the type locality 3 miles west of T. 13 S., R. 10 E., where the coal is more than 19 feet thick and contains thin local partings in the upper 5 feet.

The "split" in the Kenilworth bed eastward is strongly suggested by sections measured between Kenilworth and T. 13 S., R. 11 E., as follows:

Sections of coal beds in T. 13 S., R. 10 E.

NW. ¼ sec. 16

	Ft.	in.
Shale.		
Coal		10
Shale, carbonaceous		4
Coal		10
Shale		6
Coal	3	
Shale		5
Coal	15	8
Thickness of bed	21	7
Thickness of coal	20	4

Sec. 11

Sandstone.		
Coal		2
Shale	1	
Coal	4	7½
Shale		6
Sandstone	2	
Shale		9
Coal	10	10
Shale		6
Thickness of bed	20	4
Thickness of coal	15	7½

SW. ¼ SW. ¼ sec. 12

	Ft.	in.
Sandstone, altered by heat.		
Ash		(?)
Coal		8
Shale, brown		3
Coal		10
Shale, brown		2
Coal (Gilson?)	2	9
Shale, black	2	9
Coal		4
Shale, brown		1
Sandstone, thinly bedded	3	
Shale, black, probably altered by heat	9	
Coal (Kenilworth)	2	8
Shale, brown	1	6
Shale, gray, sandy	1	6
Sandstone, massive.		
Thickness of bed	25	4+
Thickness of coal	7	3+

Sec. 13

Sandstone.		
Coal	1	
Shale	2	6
Coal (Gilson)	4	11
Shale	12	
Coal (Kenilworth)	2	6
Shale	3	
Sandstone.		
Thickness of bed	25	11
Thickness of coal	8	5

The sandstone beneath the Kenilworth coal bed has been traced by continuous exposures across these quadrangles and westward to Hardscrabble Canyon, in the Castlegate quadrangle, and gives a definite basis for mapping the Kenilworth and Gilson beds. The general relations of coal beds and associated rocks are shown in Plate 5, where adjacent sections on the Gilson bed are connected by a broken line. The details of the coal bed itself are shown graphically in Plate 6.

Exposures of the Gilson bed are reasonably good where the coal has not been burned at the surface. Twenty sections were measured on this bed in T. 13 S., R. 11 E., 16 of which are shown in Plates 5 and 6, and the remainder are given in the text. The sections in Plates 5 and 6 show the general character of the bed and its variable thickness, which ranges from 2 feet 8 inches at location 63, in sec. 13, to 9 feet 4 inches at location 57, in sec. 10. At location 46 the coal is 2 feet 10 inches thick, and it increases eastward to 6 feet 7 inches at

location 49, in sec. 7, then decreases to 3 feet 9 inches at location 53, in sec. 16, and it measures 7 feet at location 52, which seems to mark a local thickening. The maximum thickness of 9 feet 4 inches is obtained at location 57, in sec. 10, and the coal decreases in thickness eastward, being only 3 feet thick at location 65, in sec. 13.

The Gilson bed has been prospected and mined in a small way at two places in T. 13 S., R. 11 E.—at location 49, in sec. 7, by S. S. Young, of Price, who mines some coal during the winter months to supply local demands, and on Coal Creek at location 57, in sec. 10, by Sam Gilson, who, it is reported, mined this coal many years ago and hauled it by wagon up Coal Creek through Emma Park, by way of Soldier Summit, to Provo, Utah, but the long haul would seem to render such an undertaking unprofitable at present.

A part of the coal bed at locations 55 and 56 has been burned; the sections of unburned coal are given below. Sections at locations 62, in sec. 24, and 64, in sec. 13, T. 13 S., R. 11 E., given here, are omitted from Plate 6, because the coal is similar in character and thickness to that in near-by sections.

Sections of Gilson coal bed in T. 13 S., R. 11 E.

Location 55, sec. 9

	Ft.	in.
Shale.		
Ash		2
Coal	4	
Shale.		
Total coal	4	

Location 56, sec. 9

	Ft.	in.
Sandy shale.		
Ash.		
Coal	2	5
Sandy shale.		
Total coal	2	5

Location 62, sec. 24

	Ft.	in.
Shale.		
Coal	3	5
Shale		1
Sandstone.		
Total coal	3	5

Location 64, sec. 13

	Ft.	in.
Shale.		
Coal	3	2
Shale		1
Sandstone.		
Total coal	3	2

The Gilson bed where exposed on its outcrop in these townships exceeds 2½ feet; it is probably the most important and valuable bed in the townships and if properly mined will yield a large tonnage of good coal.

Fish Creek bed.—The Fish Creek bed has been tentatively traced westward as far as location 69, in sec. 17, T. 13 S., R. 11 E., and the bed may possibly extend farther west and include exposures at locations 46–a and 50–b (pl. 5), which occur at about the same stratigraphic position. It can not be determined from the outcrop that they are the Fish Creek bed, and hence the presence of a continuous bed between these exposures is very uncertain.

The coal exposed between the Gilson and Fish Creek beds at location 50–a, the burned bed at 51–a, and the coal at 52–a, west of 69 (pl. 5), probably represent a small lens, but its extent can not be

determined and each exposure may be on a separate bed. The coal at location 49–b appears to have no equivalent in adjacent sections.

The Fish Creek bed in this township, as indicated in Plate 5, may extend westward to location 49–a and eastward to include sections 50–b, 69, 70, 71, 57–a, 59–a, 60–b, 61–b, 78, and 79, which have been tentatively correlated with the Fish Creek. The mapping is based on stratigraphic position, and if it is correct considerable coal may be mined from this bed. The sections suggest that the bed is variable in thickness, ranging from 3 inches at location 61–b to 6 feet at location 71. This coal is less than 1 foot 2 inches thick, the minimum workable thickness, at location 50–b, where it is only 10 inches thick; at locations 59–a, 59–b, and 60–b, where it has been burned at the surface; and at location 61–b, where it is only 3 inches thick. At several places two benches crop out which may elsewhere merge to form one bed, or one bench may be a small lens either above or below the main Fish Creek bed. Two benches, 57–a and 57–b, exposed above location 57, in sec. 10, are thought to represent the Fish Creek coal because of their relative stratigraphic position. The lower bench is 1 foot 4 inches thick, the upper is 2 feet 7 inches thick, and the parting of sandy shale is 8 feet thick. The upper bench is here variable, as is indicated by two sections only 50 feet apart. At one place the bed is 2 feet 7 inches thick, and at the other the coal occurs in two benches—the lower one 2 feet 4 inches, and the upper one 2 feet 9 inches thick, separated by a parting of carbonaceous shale 6 inches thick. East of location 78 the coal appears to be confined to one bench but is variable in thickness, being only 1 foot 7 inches at location 79, in sec. 13, the easternmost exposure in the township.

A thin lens of coal of some economic value lying between the Fish Creek and Gilson beds is exposed between location 57, in sec. 10, T. 13 S., R. 11 E., and location 118, in sec. 18, T. 13 S., R. 12 E. The possibility that this bed is a "split" from the Gilson bed has been suggested above, under "Stratigraphy of the coal beds and associated rocks," and is indicated in Plate 5. The bed is variable in thickness, being of economic value only at location 60–a, where 2 feet 5 inches of coal crops out, but on either side the coal is only 6 inches thick. Between locations 63–a and 118–a the coal exceeds 1 foot 2 inches in thickness and probably is continuous between exposures.

Rock Canyon bed.—The Rock Canyon bed, as shown in Plates 5 and 6, is of considerable value in parts of T. 13 S., R. 11 E., but no definite correlations could be made west of location 49–c, in sec. 7, where 3 feet 8 inches of coal crops out. Above location 46, in sec. 13, T. 13 S., R. 10 E. (see pl. 5), two beds, 1 foot 2 inches and

1 foot 6 inches thick, separated by 36 feet of sandstone and shale, crop out, but these beds can not be definitely correlated with the Rock Canyon and Fish Creek beds and may be merely small lenses, because no coal was found in this zone between locations 46 and 49. East of location 49–c exposures at locations 50–c, 67, 68, 75, 71–a, 57–c, burned bed 59–c, 60–c, 61–c, 78–a, 157, and 79–a are probably on the Rock Canyon bed, although they may represent other beds or coal lenses. Fourteen sections were measured on the Rock Canyon bed. The thickness of coal ranges from 5 inches at location 61–a to 5 feet 6 inches at location 157, but the area between locations 157 and 75 contains no coal of economic value at the outcrop. Clinker beds at several places, however, indicate the possibility of a good thickness beyond the burned coal, and considerable coal of economic value is present in this bed in the township if the sections above referred to are the equivalent of the Rock Canyon bed. Exposures between locations 49–c, in sec. 7, and 68, in sec. 17 (see pl. 5), show coal of good thickness, and the rocks at this horizon between locations 68 and 75, in sec. 9, show evidences of burned coal beds. These conditions suggest that possibly one or more beds in the zone of the Rock Canyon or Fish Creek must have originally been present. Two exposures at locations 74 and 75, in sec. 9, show a good thickness of the Rock Canyon coal bed (see pl. 6), but farther east in this township only two exposures of this bed, at locations 60–c and 157, were noted.

Coal beds between the Rock Canyon and Lower Sunnyside beds.— Tracing and identification of coal beds in the interval between the Rock Canyon and Lower Sunnyside beds was found to be difficult if not impossible. This difficulty is due to the absence of sandstones that could be used as key rocks, to lack of exposure of the coal itself, and to the burning which has obviously taken place. The extent of the burning indicates that originally this interval contained coal beds of considerable thickness and extent, but the information at present available does not warrant a definite statement as to the number, character, or thickness of those beds. In Plate 5 lines that suggest the number and extent of the beds have been drawn, but these must be regarded as provisional only. The topic is discussed at greater length under "Stratigraphy of the coal beds and associated rocks."

Exposures below the Lower Sunnyside bed and at about the same stratigraphic position were found at locations 66, 50–d, 72, and 76, a burned bed at 59–d and 59–e, and two beds each at 73, 77, 60–e, and 60–f. (See pl. 5.) Several of these sections are connected by a line in Plate 5, which indicates that probably they are on one bed, but definite identifications could not be made. The horizontal distance between locations 66, 50–d, and 72 is too great to permit

a definite correlation between them, but it appears probable that a continuous bed may be found between locations 72, 73, 76, 57-d, and the burned bed (59-d), because the horizontal distance between exposures is moderate and the coal crops out at about the same stratigraphic position in each.

Lower Sunnyside bed.—The Lower Sunnyside bed in T. 13 S., R. 11 E., rests on a key sandstone by which it can be traced easily and mapped with certainty. The coal crops out at 13 places in the township and ranges in thickness from 1 to 5 feet. It is thickest (5 feet 1 inch) at location 81, in sec. 7 (see pl. 6), and thins in each direction. On the west, at location 80, in sec. 13, T. 13 S., R. 10 E., it is 4 feet 6 inches thick, and on the east, at location 84, in sec. 16, T. 13 S., R. 11 E., it is only 1 foot 3 inches thick. To the northeast from location 84 the coal increases in thickness and at location 88, in sec. 3, at the mouth of an old prospect, it is 4 feet 11 inches thick and a few feet away in the stream channel it is 4 feet 8 inches thick. (See pl. 5.) East of Coal Creek the bed is apparently "split" by partings and is of little economic value, as shown at location 89, in sec. 11 (pl. 6), and other sections toward the east. The following sections are not shown in Plate 6.

Sections of Lower Sunnyside bed in T. 13 S., R. 11 E.

Location 86, sec. 9

	Ft.	in.
Shale, sandy.		
Coal	4	2
Sand and coal		6
Sandstone.		
Total coal	4	2

Location 90, sec. 24

	Ft.	in.
Shale.		
Coal	1	
Shale	1	11
Coal	1	
Shale	4	
Sandstone	3	
Shale	3	9
Coal	1	1
Shale.		
Total coal	3	1
Total section	15	9

Location 91, sec. 13

	Ft.	in.
Shale.		
Coal		8
Shale		7
Coal	2	1
Shale.		
Total coal	2	9

Location 92, sec. 13

	Ft.	in.
Sandstone.		
Coal		2
Shale, carbonaceous		6
Shale, sandy	1	6
Coal	1	6
Shale.		
Total coal	1	8
Total section	3	8

The coal is extensively burned at the outcrop, and because few exposures remain it is difficult to value this coal bed properly. It is believed that the coal is continuous under cover beyond the zone of burning and that it extends northward beyond the limits of the township. In the absence of definite information it is estimated that the coal has about the same average thickness throughout the township as it has on the outcrop.

Upper Sunnyside (?) bed.—Coal believed to be the Upper Sunnyside bed crops out at only three places in T. 13 S., R. 11 E. It could not be mapped because of the great distance between exposures and because of the absence of a key sandstone that could be traced. Sections at locations 81–a and 82–a, in sec. 7, are probably on this bed, as the distances between them and the Lower Sunnyside bed differ by only 3 feet, being 40 feet at location 81 and 37 feet at location 82. No exposures of coal that may be correlated with the Upper Sunnyside bed were seen west of this township. East of location 82 the coal crops out again at location 88–a, in sec. 3, where 2 feet 11 inches of coal was found 13 feet above the Lower Sunnyside bed. This distance is much less than that at location 82, but this coal is tentatively correlated with the Upper Sunnyside bed. The only coal found in the Upper Sunnyside zone between locations 82 and 88 is at location 86, in sec. 9, where 3 inches of coal crops out about 25 feet above the Lower Sunnyside bed.

The rocks for a considerable distance above the Sunnyside beds are locally considerably altered by heat from the burning of coal beds, but it is impossible to determine the exact position and amount of the coal burned. There is some evidence of burning in the normal position of the Upper Sunnyside bed east of location 146, but it is believed that this bed in this township is of small economic value.

Summary of coal beds.—Several coal beds of economic importance are exposed in T. 13 S., R. 11 E. The Lower Sunnyside, Gilson, Kenilworth, and Castlegate "A" were definitely mapped, but the Upper Sunnyside, Rock Canyon, and Fish Creek were only tentatively traced. (See pl. 5.) In addition to the seven beds named above other exposures of coal were measured in places at different horizons.

The data above set forth indicate that the Gilson bed is the most valuable coal in this township and that the Lower Sunnyside, Rock Canyon, Kenilworth, Castlegate "A," Fish Creek, and Upper Sunnyside probably rank in the order named.

Tonnage estimate.—It is estimated that a considerable tonnage of good coal is present under cover in T. 13 S., R. 11 E. and the part of T. 13 S., R. 10 E. within the Wellington quadrangle. The five beds—Gilson, Lower Sunnyside, Rock Canyon (?), Kenilworth, and Castlegate "A"—that have been definitely traced and mapped may contain about 170,000,000 short tons of coal, and the other beds, including thin local lenses not mapped, may contain 40,000,000 short tons, giving a total of 210,000,000 tons for all the coal in this township. If the same beds are present with the same average thickness, there would be 31,000,000 in the small part of T. 13 S., R. 10 E. that is included in the Wellington quadrangle. The table on page 101 gives the details of the tonnage by beds and townships.

Accessibility.—The coal-bearing escarpment in T. 13 S., R. 11 E., is deeply trenched by Deadman, Coal, and Soldier Creeks, the canyon of any one of which would form a relatively easy means of approach to the coal outcrops. The valley of Deadman Creek, south of the escarpment, has a grade of 150 to 200 feet to the mile, but the valleys of Coal and Soldier Creeks have grades of only 50 to about 100 feet to the mile. The country at the mouths of these creeks is flat and would be suitable for town sites, tipples, and railroad yards. From the end of the steam railroad some form of tramroad could easily be built to the coal outcrops. The shortest distance to the coal would be along a line running to the point of the ridge on either side of the canyon, but the most advantageous point of entry to the coal bed would be where it passes below drainage level. On most beds marketable coal could be mined at this point from the start, and in developing the coal there would be a down grade in favor of the loads for all coal above this level. Coal Creek is the best stream on which to begin large mining operations, because the coal beds are of good thickness and the stream grade is lower than that of the other creeks. Soldier Creek is least desirable, because the coal beds on it are relatively thin and are badly split by bone and shale partings.

T. 12 S., R. 12 E.

General features.—The south line of T. 12 S., R. 12 E., is from 1½ to 4½ miles north of the face of the Book Cliffs, which contain five coal beds whose outcrops were accurately mapped across T. 13 S., R. 12 E. The coal in these beds was measured at many places. These measurements together with exposures in adjoining townships constitute the basis for the estimate of the character and thickness of these beds in T. 12 S., R. 12 E. No coal crops out in this township, and the nearest exposure is on the Lower Sunnyside bed in the NE. ¼ sec. 18, T. 13 S., R. 12 E., where it dips below the level of Soldier Creek.

Tonnage estimate.—T. 12 S., R. 12 E., is so near the outcrop of several thick and extensive coal beds that there is every reason to believe that many of the beds will be found of good quality and thickness under this area. On this basis it is estimated that at least 155,000,000 short tons of coal lies under cover in the part of T. 12 S., R. 12 E., within the Wellington quadrangle. This estimate includes figures for the Rock Canyon and Fish Creek beds combined, the Gilson, Lower Sunnyside, and Kenilworth beds, named in the order of their estimated content of coal. Details of the tonnage estimate by beds are given in the table (p. 101).

Accessibility.—The portion of this township included in the Wellington quadrangle embraces much of Whitmore Park, which is relatively flat and not deeply trenched by erosion channels. There are

only two feasible routes by which this township may be reached by a railroad—one from Colton, on the Denver & Rio Grande Western Railroad, by way of Emma Park to Whitmore Park, and the other from Wellington up Soldier Creek to Whitmore Park. Which of these routes is preferable can not be stated from the information at hand. As the coal in this township can be reached only by shafting, as it is a long distance from a railroad, and as there are beds of coal near by which can be more easily reached, it is at the present time economically inaccessible. The coal will be found nearest the surface on Soldier Creek near the south line of sec. 32. Here the Lower Sunnyside coal bed is estimated to be 950 feet deep; in Whitmore Park, near the west line of sec. 28, 1,800 feet; on the divide between Soldier and Ninemile Creeks, in the SE. ¼ sec. 27, about 1,950 feet, and at the north edge of the quadrangle, in sec. 25, 2,050 feet below the bed of the stream.

T. 13 S., R. 12 E.

General features.—Fewer coal beds crop out in T. 13 S., R. 12 E., than in T. 13 S., R. 11 E., but in each township the coal is exposed under similar conditions. Six coal beds were fairly definitely mapped in T. 13 S., R. 12 E., and have been tentatively traced and connected with beds in adjoining townships, as shown in Plate 5. The six beds mapped, named in order from the lowest upward, are the Kenilworth, Gilson, Fish Creek, Rock Canyon, Lower Sunnyside, and Upper Sunnyside.

The coal in most places is well exposed, if it has escaped burning at the surface, and 104 coal sections were measured in this township, 94 of which are shown in Plate 7 and 53 in Plate 5, together with the interbedded rocks. The mapping of coal beds in the township was facilitated and made more certain by heavy, cliff-forming sandstones which are intimately associated with the Lower Sunnyside, Rock Canyon, Gilson, and Kenilworth beds, and by the relative stratigraphic positions of the coal beds, as well as the general character and thickness of each bed.

The following list gives the names of coal beds exposed and the location number by which each coal section is designated in Plates 5, 7, and 22.

Coal beds exposed in T. 13 S., R. 12 E., and location numbers of sections on each bed

Beds above the Upper Sunnyside bed	186–192, 182–a, b, and 192–a, b
Upper Sunnyside bed	179–185
Lower Sunnyside bed	167–178
Rock Canyon bed	158–166
Fish Creek bed	144–156
Gilson bed	118–143
Kenilworth bed	93–117

Kenilworth coal bed.—The Kenilworth is the lowest coal exposed in the township, and although it is one of the thinnest beds it is the most constant in thickness. Its maximum thickness, 2 feet 8 inch, is attained at several places, and its minimum thickness, 1 foot, is exposed at two or more places. (See pl. 7.)

Twenty-five sections were measured on this bed in the township, 22 of which are shown in Plate 7. The range in thickness is slight, and the average thickness for all the measurements is about 2 feet.

The relative stratigraphic position of the coal bed and the character of the associated rocks are shown in Plate 5. The Kenilworth bed is generally overlain by shale or sandy shale, with a sandstone about 5 to 10 feet above the coal, but in some places sandstone rests directly on the coal, and at about 300 feet east of location 5, in sec. 19, the sandstone forms a horseback in the top of the coal bed. The coal rests on a massive sandstone from 100 to 125 feet thick or is separated from it by a few inches to a few feet of shale or sandy shale. The sections in Plate 7 give practically all the available information regarding the character and thickness of the Kenilworth bed in this township. It appears to be the only coal not seriously reduced in thickness or affected in character in the vicinity of Soldier Creek, in secs. 17, 18, and 19. It is below the average thickness at locations 5, in the SE. ¼ sec. 18, and 6, near the center of sec. 19 (see pl. 7), but the bed is free from partings, which is not true of most of the other beds in this locality.

The following sections were omitted from Plate 7 because they are similar to sections at near-by locations. At location 94, in sec. 18, 2 feet 4 inches of coal crops out and is overlain by shale and underlain by shale and sandstone. At location 114, in sec. 27, there is 1 foot 2 inches with some ash at the base, which indicates that the full thickness of the bed is not exposed. The easternmost section in the township, at location 117, in sec. 25, contains 1 foot 2 inches of coal, which is 2 inches more than at location 116. (See pl. 7.) There is a considerable area in secs. 29, 30, 31, and 32, T. 13 S., R. 13 E., where the Kenilworth bed is probably thin or absent; in a small part of the NW. ¼ sec. 32, however, where 1 foot 11 inches of coal crops out, it is possibly workable.

The Kenilworth bed has been burned on its outcrop less than any other bed in the township. The sections show more nearly its true thickness than sections measured on other coal beds, but this bed has been burned at many places between the exposures measured. The evidence of burning, together with the sections shown in Plate 7, indicates that the Kenilworth bed may be continuous and may exceed 14 inches in thickness throughout the greater part of this township.

Gilson coal bed.—The Gilson bed attains a greater thickness than any other bed in T. 13 S., R. 12 E., but it is extremely variable in thickness, ranging from 8 inches at location 125, in sec. 20, to 10 feet 4 inches at location 143, in sec. 25. In the western part of the township it is relatively unimportant and in the vicinity of Soldier Creek it is thin, lenticular, and badly split by partings. Eastward from location 125 the coal increases in thickness, except for local irregularities (see pl. 7), and the minimum thickness east of sec. 20 is nearly 3 feet.

The Gilson coal has been extensively burned at the outcrop and few exposures remain. Twenty-six sections were measured, 21 of which are shown in Plate 7. The sections west of location 125 range in thickness from 1 foot or less to 2 feet 9 inches and average about 1 foot 9 inches, and those east of location 125 that show the complete bed range in thickness from about 3 feet to 10 feet and average about 6 feet. The following partial sections were omitted from Plate 7:

Sections of Gilson coal bed in T. 13 S., R. 12 E.

Location 133, sec. 21

	Ft.	in.
Sandstone.		
Ash and shale		3
Shale, sandy	1	6
Coal	1	6
Shale, carbonaceous.		
Total coal	1	6+

Location 136, sec. 22

	Ft.	in.
Sandstone.		
Shale, sandy	1	3
"Smut" and ash		9
Coal (altered by heat)	4	4
Shale, sandy	4	3
Coal		6
Sandstone.		
Total coal	4	10+

Location 139, sec. 22

	Ft.	in.
Sandstone (burned).		
Ash and shale		2
Coal (altered by heat)	4	9+
Shale, sandy.		
Total coal	3+	

Location 141, sec. 23

	Ft.	in.
Sandstone.		
Ash and shale		2
Coal (altered by heat)	4	9+
Shale, sandy.		
Total coal	4	9+

Location 142, sec. 27

	Ft.	in.
Shaly sand (burned).		
Ash, etc	1	3
Coal (altered by heat)	4+	
Shale, sandy.		
Total coal	4+	

The identification of the Gilson bed between locations 118, in sec. 18, and 125, in sec. 20, is uncertain, because of its variable thickness and lack of continuity. At location 119, in sec. 18, the bed is separated into two benches by a parting 3 feet thick, composed of clay, shale, and carbonaceous shale. The parting increases to 8 feet at

location 125, where it is mostly sandstone. Between locations 120 and 121 (see pl. 5) only the lower bench, 2 feet 6 inches thick, is exposed, but at location 121, in sec. 18, the two benches are separated by 4½ feet of shale instead of sandstone. At location 123 the parting has increased to 9½ feet of sandstone; here the upper bench contains 1 foot 11 inches of coal and the lower part consists of two benches separated by 2½ feet of shale with 9 inches of coal in each bench. The Gilson bed east of location 125, in sec. 20, consists at most places of one bench, although several sections show partings a few inches thick.

It is believed that, owing to extensive burning, little marketable coal will be found within several hundred feet of the outcrop of clinker and ash, except where the outcrop crosses the main streams. Here, according to the best information available, the burning has penetrated the coal only a short distance, and good coal will usually be found beyond the zone of weathering.

Fish Creek coal bed.—The Fish Creek coal bed as here mapped is confined mainly to T. 13 S., R. 12 E., and is believed to be a "split" (see pl. 5) from the Rock Canyon coal bed, which is well developed on the east. The mapping of this bed in the township is indefinite, because few exposures were found, and the outcrop is not associated with a traceable key rock; hence the correlation of exposures is based largely on the stratigraphic position and thickness of the coal bed. The stratigraphic distance between the Fish Creek bed and the Gilson bed ranges from 26 feet at location 128, in sec. 20 of this township, to 60 feet in sec. 13, T. 13 S., R. 11 E., and averages about 45 feet. (See pl. 5.)

Fifteen sections (locations 144–156) were measured on this bed, 13 of which are shown in Plate 7. These include two sections at locations 78 and 79, sec. 13, T. 13 S., R. 11 E., which were placed in Plate 7 for convenience, because they were the only sections measured in that township that could be definitely connected with the Fish Creek bed.

The Fish Creek coal bed on the outcrop is generally confined to one bench, except at location 78, in sec. 13, T. 13 S., R. 11 E., and at locations 155 and 156, in sec. 22, T. 13 S., R. 12 E., where two or more benches are separated by shale partings. (See pls. 5 and 7.) The thickness of coal varies greatly, ranging from 1 foot 7 inches at location 79, in sec. 13, T. 13 S., R. 11 E., to 5 feet 2 inches, exclusive of partings, at location 152, in sec. 20, T. 13 S., R. 12 E. The average thickness of Fish Creek coal for all sections shown in Plate 7 is 3 feet 3 inches, including only the lower benches at locations 155 and 156. It is probable that this bed, though not known outside of the township, is of a good thickness throughout a considerable area on the north, where it is under deep cover.

The following sections, both in sec. 17, are not shown in Plate 7. At location 149 there is 2 feet 9 inches of coal, overlain by sandstone and underlain by carbonaceous shale. At location 151 there is only 9 inches of coal. This is below normal thickness for the Fish Creek bed, but the thin coal is probably limited to a small area.

Rock Canyon coal bed.—The Rock Canyon bed, like most others in T. 13 S., R. 12 E., is very irregular in thickness, but is one of the most valuable coals in the township. It could not be traced with certainty throughout the adjoining township on the west, but if the correlations suggested there are correct the Rock Canyon bed should be present and of workable thickness under cover to the north edge of the Wellington quadrangle. (See description under T. 13 S. R. 11 E.)

Ten sections were measured on this bed, and all are shown in plate 7, including the section at location 157, in sec. 13, T. 13 S., R. 11 E., because it was the only exposure in that township that could be definitely mapped as Rock Canyon. Where this bed is confined to one bench it ranges in thickness from 3 feet 6 inches to 7 feet 9 inches, and averages, exclusive of partings, for all sections shown in plate 7 about 5 feet.

The bed has a thickness of 5 feet 6 inches at location 157 and 5 feet 7 inches, exclusive of partings, at location 158, in sec. 18, T. 13 S., R. 12 E., but a short distance east, at location 159, the coal is badly "split" into several benches by shale partings. (See pl. 7.)

Few exposures could be found on this bed in secs. 17, 18, and 19, but it is believed that the bed is of small economic value throughout those sections. Sections at locations 159, 160, 161, 162, and 163 (pl. 7) suggest not only variation in thickness but also a tendency at some places to split into two or more benches, which vitally affects the economic value of the coal. Eastward, however, from location 161, in sec. 20, the thickness increases, and at location 165, in sec. 22, it is 7 feet 4 inches. The easternmost section in the township, at location 166, in sec. 23, probably represents both the Rock Canyon and the Fish Creek coal beds, which appear to merge between locations 165 and 166, but this assumption could not be proved in the field.

The fact that exposures of this bed are relatively few is due mainly to the extensive burning of the coal at the surface. The mapping is only tentative and is based on the stratigraphic position and the thickness of the coal. The sections in Plate 7 give all the available information regarding the thickness and character of the bed in this township.

Lower Sunnyside coal bed.—The Lower Sunnyside bed on the outcrop is relatively thin throughout most of T. 13 S., R. 12 E., and is not one of the principal beds. The mapping is more definite than that of other beds because the prominent sandstone on which the

coal rests can be traced easily. The coal has been extensively burned on the outcrop, and few exposures remain.

The stratigraphic distance between the Rock Canyon and the Lower Sunnyside beds ranges from 55 feet at location 166, in sec. 25, to about 180 feet at location 175, in sec. 18, and averages about 120 feet. This distance throughout most of the township is greater than the average of 120 feet because the minimum distance between locations 165, in sec. 22, and 192, in sec. 26, is much less than the normal thickness. (See pl. 5.) The range of 115 feet between the maximum and minimum distance casts doubt on the accuracy of the mapping, but it is believed that the correlations shown in Plate 5 are correct.

Twelve sections, at locations 167–178, were measured on this bed in the township, and all are shown in Plate 7. The coal ranges in thickness from 1 foot 2 inches at location 170, in sec. 18, to 4 feet 11 inches at location 178, in sec. 25. The only exposures in the township containing more than 2 feet 8 inches are at locations 177 and 178, in sec. 25. Locations 167 to 175, all in sec. 18, give information on a relatively small part of the outcrop. Nothing definite is known about this bed between secs. 18 and 25, but its outcrop has been traced across the township by means of the key sandstone immediately beneath it. The coal at most places is either concealed by talus or has been burned at the surface. The only exposure found between locations 175, in sec. 18, and 177, in sec. 25, was at location 176, in sec. 16, where 1 foot 8 inches of carbonaceous shale but no coal is exposed. It is impossible to determine the area over which the coal is absent, but it may be small, and workable coal may be found near by in either direction. This assumption is based on the evidence of extensive burning throughout these localities where no exposures were found, but obviously there is no way of estimating on this basis the thickness of the coal under cover.

Upper Sunnyside coal bed.—The Upper Sunnyside bed is probably of little economic importance in T. 13 S., R. 12 E., because the coal is thin where exposed and in places may be absent. The rocks in the zone of the two Sunnyside beds are altered by heat from burning coal, but it is impossible to determine from this evidence the position and amount of the coal originally present. No exposures were found west of location 179, in sec. 21, and no estimate can be made regarding the thickness and continuity of this bed in the western part of the township.

Seven sections tentatively regarded as the equivalent of this bed were measured, and six of them are shown in Plate 7. At all exposures except that at location 185, in sec. 25, the coal is less than 2 feet thick, and it is only 1 foot thick at location 180, in sec. 21, where the coal is locally reduced by a horseback. Locations 179,

180, and 181, in sec. 21, all within an outcrop distance of 600 to 700 feet, show the character of the bed in a small area. On the east strong evidence of burning suggests the presence of coal in this bed in that direction. At location 182, in sec. 26, 1 foot 8 inches of coal crops out, but it is not shown in Plate 7. The coal increases in thickness eastward, and at location 185, in the NW. ¼ sec. 25, the bed is exposed in two benches—the upper 2 feet 3 inches thick and the lower 3 feet 8 inches thick—separated by 1 foot of shale. The equivalent of this section is not known, but it is similar to one or more exposures of this bed in the township on the east.

The distance between the Upper and Lower Sunnyside beds in the township averages about 20 feet, as nearly as may be determined, and the mapping of the upper bed is based on its stratigraphic distance above the lower bed.

Local coal beds above the Upper Sunnyside bed.—No coal beds exposed above the Upper Sunnyside bed could be definitely traced in the township. Eleven sections were measured, and all are shown in Plate 7. It is not known that any two of these sections belong to the same coal bed, and it is believed that they are on exposures of small lenses. The stratigraphic distance between these exposures and the Lower Sunnyside bed is so variable that that bed forms no definite basis for mapping. The differences in distance are shown by the following figures: At location 186, 55 feet; at 187, 70 feet; at 189, 65 feet; at 190, 60 feet; at 191, 22 feet; at 182–a, 35 feet; and at 192, 34 feet. These distances suggest that sections at locations 186, 187, 189, and 190 are, on the basis of stratigraphic position, on the same bed; that the section at location 191 is on the Upper Sunnyside bed, and that sections at locations 182–a and 192 are on a lens which is not at the horizon of either of the beds just mentioned. The relation of the beds at locations 186, 187, 189, 190, and 192, is shown in Plate 5. The distance between sections 182–a and 182–b is 6 feet. The section at location 188 is on the same bed as the lower bench at location 187.

Summary of coal beds.—Six coal beds were traced for a greater or less distance in the township. The relations of the coal beds and associated rocks are shown in Plate 5, and detailed representative coal sections arranged by beds, are shown in Plate 7.

The Gilson coal is the most valuable bed in this township. The Fish Creek and Rock Canyon beds are about equal in value, but as the Fish Creek bed has been considered a "split" from the Rock Canyon bed and as the distance separating them is relatively small, so that the two may be mined from the same main entries, they may possibly be considered as two benches of one bed. More coal is probably contained in these beds together, than in the Gilson bed. The Kenilworth bed is probably the most persistent and most constant

in thickness of all the beds exposed in this township, but it is relatively thin, the average of all sections measured in this township being about 2 feet. The two Sunnyside beds have been so extensively burned at the surface in this township that it is impossible to determine their thickness and continuity under cover. The position of the Lower Sunnyside bed was identified by means of the heavy sandstone beneath it, and the few exposures measured suggest that the coal in this bed is relatively thin. The average thickness used in estimating the tonnage is 2½ feet.

Tonnage estimate.—It is estimated that 311,000,000 short tons of coal is present under cover in T. 13 S., R. 12 E. This total exceeds by more than 100,000,000 tons the estimate made for T. 13 S., R. 11 E. The difference is due primarily to the larger area underlain by coal, to the greater thickness of the Rock Canyon and Gilson beds, and to the addition of the Fish Creek bed. The Upper Sunnyside coal bed and several other thin beds were measured at certain places but are not included in the tonnage estimate, because the meager information obtained did not warrant it. These thin beds contain minable coal at many places and could make a considerable addition to the total tonnage, therefore the estimate here made is moderate. The details of the tonnage estimate are given in the table on page 101.

T. 12 S., R. 13 E.

General features.—The surface of T. 12 S., R. 13 E., is rough and deeply trenched by the streams. It is drained mainly by Cow Canyon, although Pole Creek and Sheep Canyon drain small parts.

The nearest outcrop of coal is about 4 miles to the south, in T. 13 S., R. 12 E., where at least five coal beds, each of good quality and thickness, are exposed. The continuity and thickness of these beds at the outcrop give substantial reasons for believing that at least the three principal beds—Gilson, Rock Canyon, and Lower Sunnyside—underlie a part of this township within depths that can be reached by shafts and with the same average thickness that they have on the outcrop.

Tonnage estimate.—In making a tonnage estimate of the coal underlying that part of the township in the Sunnyside and Wellington quadrangles, the Gilson, Rock Canyon, and Lower Sunnyside coal beds were considered. It is estimated that 61,000,000 short tons of coal underlie this part of the township, 39,000,000 tons of which is contained in the Lower Sunnyside bed. This bed is slightly thinner than the Rock Canyon bed but underlies about four times as large an area. The details of the tonnage estimate by beds is given in the table on page 102.

Accessibility.—The coal in T. 12 S., R. 13 E., is economically inaccessible at the present time, because it can be mined only by shafts

and there are vast quantities of coal much nearer the railroad and much more easily reached. The coal will be found nearest the surface in the bottoms of the main streams—Pole Creek, Cow Canyon, and Sheep Canyon. In Pole Creek Canyon in the northwest corner of sec. 30 (unsurveyed) the Lower Sunnyside coal is estimated to lie 2,050 feet deep; in Cow Canyon in sec. 27 (unsurveyed), about 2,600 feet; and in Sheep Canyon in sec. 30, T. 12 S., R. 14 E., about 3,300 feet. The transportation of coal brought to the surface by shafts in the township to possible railroad connections would entail some difficulties and large expense. It would be possible to transport the coal by aerial tramway southward beyond the Book Cliffs to convenient railroad connections, but this would not be warranted at present. Before any shafts are sunk for coal in this township several holes should be drilled to determine the depth and thickness of coal present.

T. 13 S., R. 13 E.

General features.—The coal in T. 13 S., R. 13 E., occurs in sinuous outcrop across the southwest corner of the township, but exposures are few because the coal has been extensively burned at the surface. Five beds are exposed and were fairly definitely mapped by means of associated key sandstones. The coal beds, named in the order of their positions from the lowest upward, are the Kenilworth, Gilson, Rock Canyon, Lower Sunnyside, and Upper Sunnyside.

The Kenilworth and Lower Sunnyside beds rest on heavy, ledge-making sandstones, by means of which the coal beds were mapped. Other beds were mapped on the basis of stratigraphic position (distance above or below some traceable sandstone), thickness, and characteristics. The names of the coal beds and the location numbers of the sections measured on each bed are as follows:

Coal beds exposed in T. 13 S., R. 13 E., and location numbers of sections on each of the beds

Upper Sunnyside	217 to 220
Lower Sunnyside	209 to 216
Rock Canyon	205 to 208
Gilson	198 to 204
Kenilworth	193 to 197

Kenilworth coal bed.—The Kenilworth bed is the lowest and least valuable coal cropping out in T. 13 S., R. 13 E. Five sections were measured on this bed and are shown in Plate 8. The coal ranges from 5 inches to 1 foot 11 inches in thickness, but at location 195 there is 1 foot 6 inches of carbonaceous shale and no coal exposed. The sections measured in this and the adjoining townships indicate that the Kenilworth bed is of small value from location 115, in the center of sec. 25, T. 13 S., R. 12 E., to location 221, in the

NE. ¼ sec. 9, T. 14 S., R. 13 E., an air-line distance of 4½ miles. The extent of this thin coal can be ascertained only by extensive drilling or development, but it is believed to be considerable, as inferred from the thickness and continuity of the bed in contiguous territory. On the west the Kenilworth bed is persistent and fairly constant in thickness, though for several miles it is not a thick bed. (See description under T. 13 S., R. 12 E.) On the southeast, in T. 14 S., R. 13 E., the few sections obtained indicate a thin, lenticular, and nonpersistent coal bed.

Gilson coal bed.—The Gilson bed in T. 13 S., R. 13 E., is 30 to 40 feet above the Kenilworth bed and reaches its maximum thickness in the Wellington and Sunnyside quadrangles, 13 feet, at location 198, in the NW. ¼ sec. 30. In sections measured on each side of this locality the bed is much thinner, and the average thickness for this bed in the township is about 7 feet. Seven sections of this bed were measured in the township; five of these are shown in Plate 8, and the other two are given below.

Sections of Gilson bed in sec. 30, T. 13 S., R. 13 E.

Location 199			Location 200		
Clinker.	Ft.	in.	Clinker.	Ft.	in.
Coal	5	5+	Coal	2	8+
Shale		3	Shale	5	6
Sandstone.			Sandstone.		
Total coal	5	5+	Total coal	2	8+

Rock Canyon coal bed.—The Rock Canyon coal bed in T. 13 S., R. 13 E., is 40 to 75 feet above the Gilson coal bed. (See stratigraphic sections, pl. 5.) In the central part of T. 13 S., R. 12 E., it contains a good thickness of coal, but nothing definite is known of its thickness between location 166, at the center of sec. 23, T. 13 S., R. 12 E., and location 205, in the SW. ¼ SW. ¼ sec. 29, T. 13 S., R. 13 E. No exposures of the bed could be found in this stretch of 3½ miles by air line, but extensive burning of the coal indicates that it is present and of considerable thickness.

Four sections were measured on this bed in the township and are shown in Plate 8. They were measured within a distance of 1¼ miles on the outcrop, in secs. 29 and 32, and give information on a small area. At location 205, in sec. 29, which is in the channel of a stream, only part of the thickness of the bed was measured because of the presence of water and gravel. At location 206, in sec. 32, only 2 feet 2 inches crops out, which is less than the average thickness. It is impossible to estimate the limits of this thin coal, but it is believed that the thinning is local, because sections measured on each side of location 206 show a marked increase in thickness. At location 208, in sec. 32, is an entry that was driven 50 feet or

more into the coal bed. A sample was collected at the face of this entry, and its analysis (No. 12792) is given on page 85. This analysis should not be used for direct comparison, because the sample was more or less weathered. The Rock Canyon bed is persistent and of good thickness for some distance to the southeast in T. 14 S., R. 13 E. (See description of that township.)

Lower Sunnyside coal bed.—The Lower Sunnyside bed is 135 to 140 feet above the Rock Canyon bed. It is the most persistent and one of the most valuable beds in the township and is present through the township on the west. It is also the most valuable bed in the township on the southeast. Eight sections were measured in the township, and three of them are shown in Plate 8. The coal ranges from 2 feet 10 inches to 6 feet 7 inches and averages about 4 feet 7 inches in thickness. Sections at locations 209, 210, 211, 214, and 215 show only a part of the bed and are not included in Plate 8 but are given below.

Sections of part of the Lower Sunnyside coal bed in T. 13 S., R. 13 E.

Location 209, sec. 30

	Ft.	in.
Ash and broken sandstone.		
Coal	1	8
Shale, sandy		10
Sandstone, massive.		
Total coal	1	8+

Location 210, sec. 30

	Ft.	in.
Ash.		
Coal and "smut"	1	8

Location 211, sec. 30

	Ft.	in.
Sandstone	5	
Ash.		
Coal	2	6
Shale	1	4
Sandstone, massive.		
Total coal	2	6+

Location 214, sec. 30

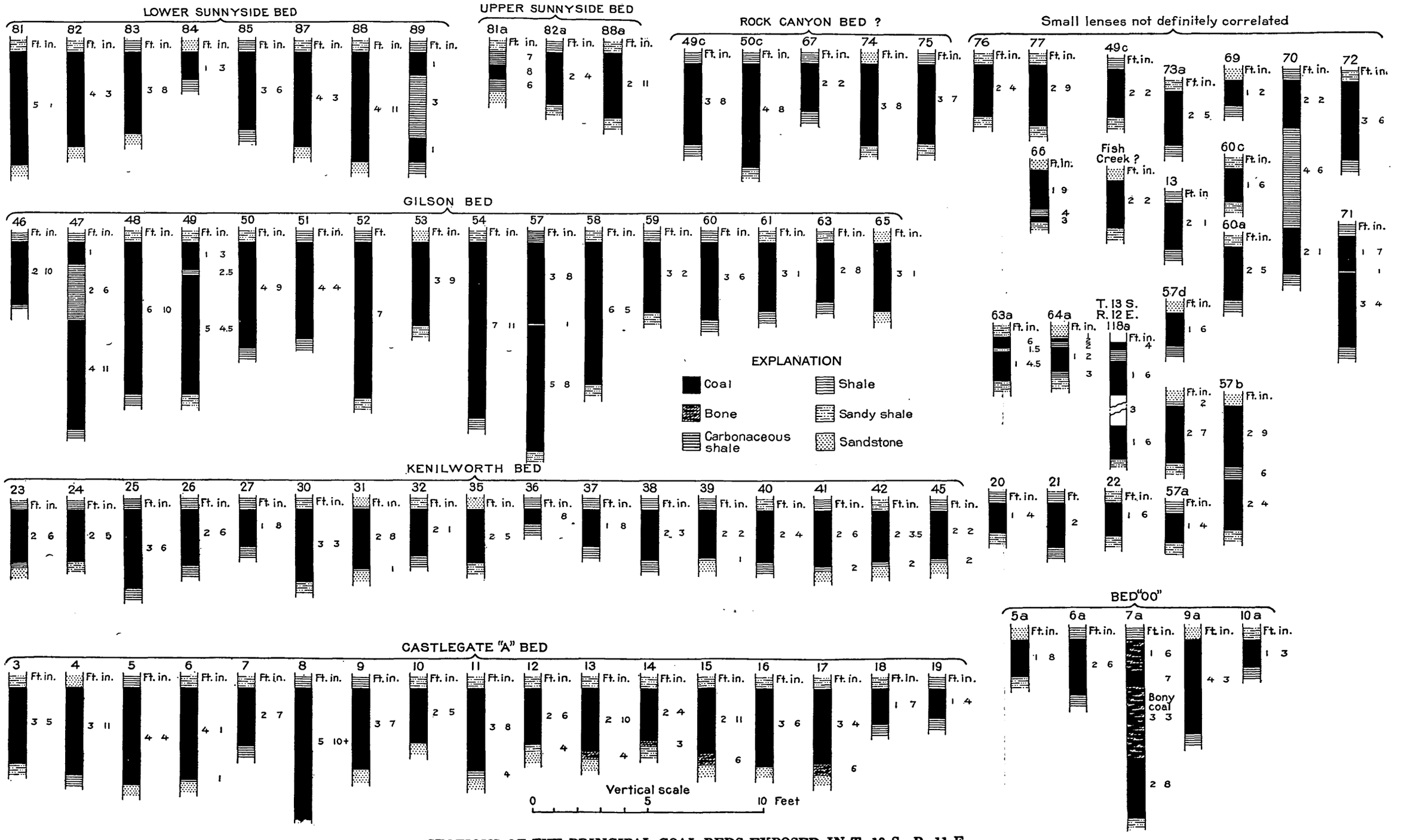
	Ft.	in.
Shale.		
Ash		2
Coal	3	2
Sandstone.		
Total coal	3	2+

Location 215, sec. 32

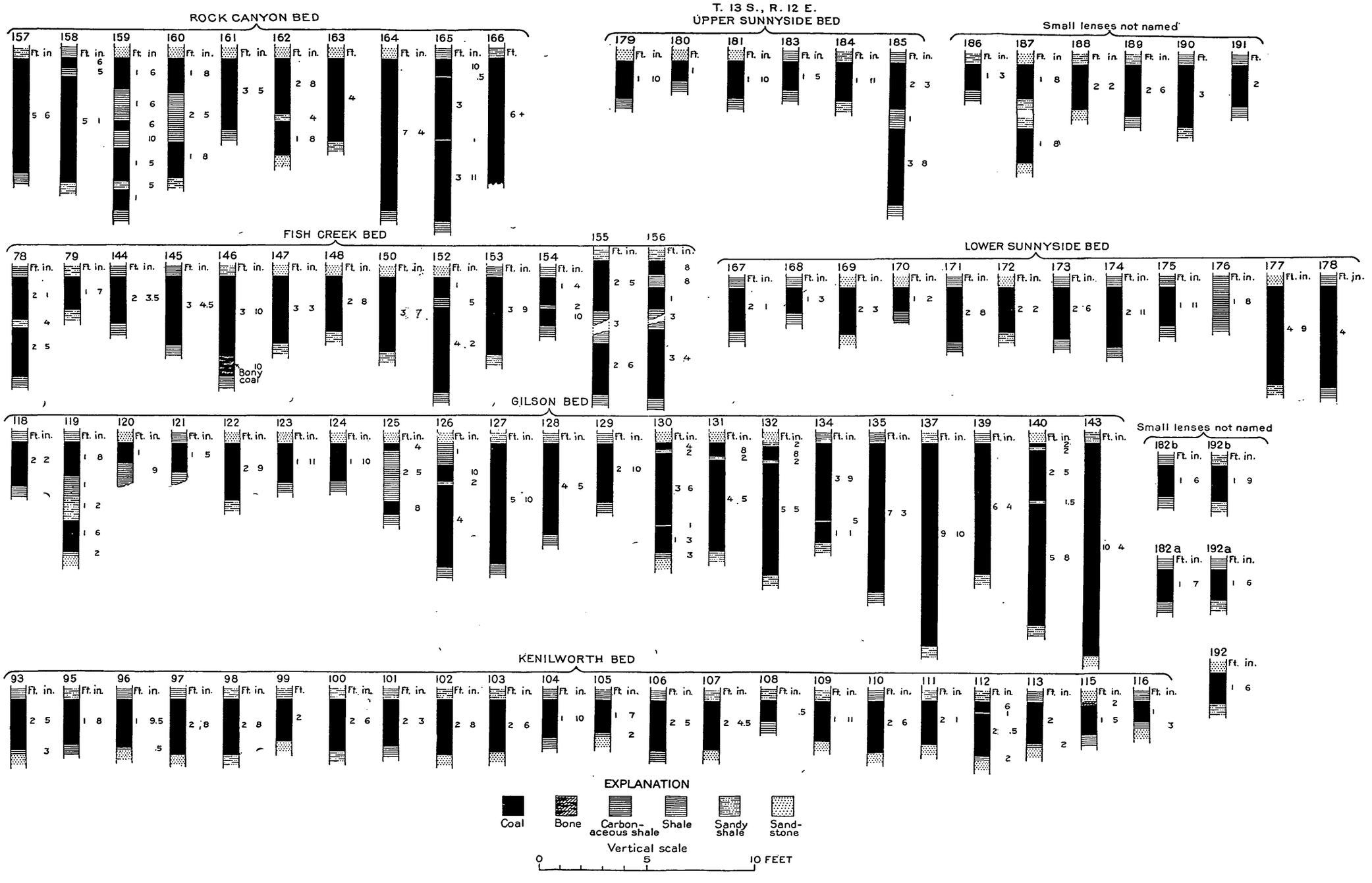
	Ft.	in.
Shale.		
Coal	1	
Shale and ash	1	
Sandstone	2	
Shale	1	3
Coal and ash	1	6
Shale and ash	6	
Sandstone.		
Total coal	2	6+

This coal had been extensively burned at the surface, and the exposures remaining furnish the only means of estimating its character and thickness under cover. These sections above indicate that the bed is continuous and persistent and that where not burned it contains more coal than is recorded in them. The coal bed back of the burned-out zone is probably continuous, persistent, and of good workable thickness, for the sections measured in each of the adjoining townships indicate these conditions.

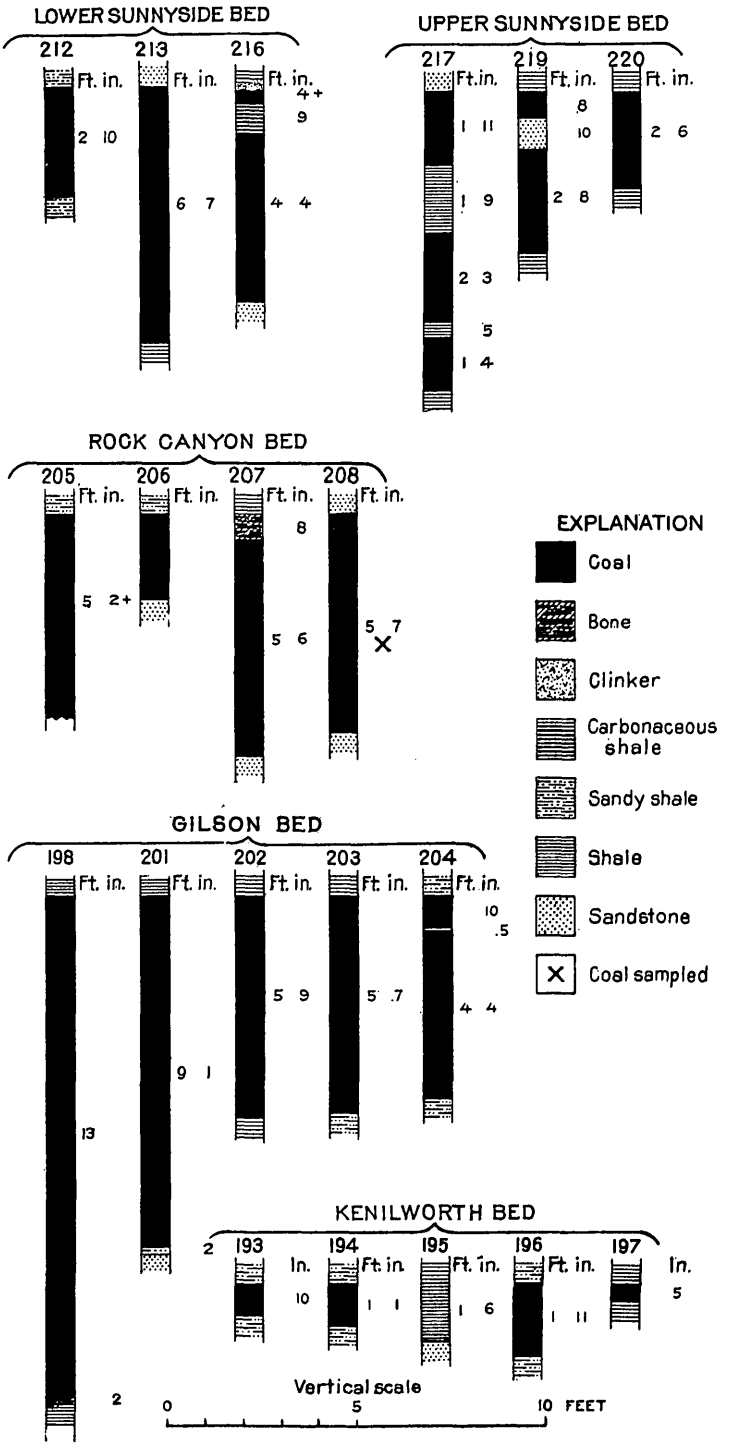
Upper Sunnyside coal bed.—The Upper Sunnyside bed in T. 13 S., R. 13 E., seems to be more irregular in its occurrence than the Lower Sunnyside bed. It is 25 to 30 feet above the Lower



SECTIONS OF THE PRINCIPAL COAL BEDS EXPOSED IN T. 13 S., R. 11 E.



SECTIONS OF THE PRINCIPAL COAL BEDS EXPOSED IN T. 13 S., R. 12 E.



SECTIONS OF THE PRINCIPAL COAL BEDS EXPOSED IN T. 13 S., R. 13 E.

Sunnyside bed, and its tracing and correlation were based principally upon the stratigraphic position and thickness of the coal. This bed, like most of the others and especially the Lower Sunnyside bed, is generally burned at the surface, and few exposures are left, so that exact mapping is difficult if not impossible. The few remaining exposures show the coal to be more or less "split" by rock partings. Four sections were measured in the township, three of which are shown in Plate 8. This bed at location 217, in sec. 30, is divided into three benches, whose total thickness amounts to 5 feet 6 inches of coal; at location 218, about half a mile to the southeast, the following section was measured:

Section at location 218, in sec. 30, T. 13 S., R. 13 E.

	Ft.	in.
Shale, sandy.		
Bone	1	2
Shale	5	
Bone	1	2
Sandstone.		
	7	4

The section at location 219, in sec. 3, also shows the bed divided into two benches. (See pl. 8.) A complete section of the beds exposed above the Lower Sunnyside bed at location 220, in sec. 32, shows five benches or beds, two of which exceed 2 feet in thickness. The thickest one of these five beds, 2 feet 6 inches thick, is believed to be equivalent to the Upper Sunnyside bed. (See pl. 5.)

The tentative correlations of the sections measured in this and the adjoining townships indicate a fairly persistent coal bed, which increases in thickness toward the south and east but decreases toward the west and is of little economic value in T. 13 S., R. 12 E. It is believed that this bed is continuous and of fair thickness and quality throughout a considerable portion of the southwestern part of the township.

Summary of coal beds.—Five coal beds were traced in T. 13 S., R. 13 E.; their stratigraphic relations are shown in Plate 5, and representative sections of them are shown in Plate 8.

The three principal beds—the Lower Sunnyside, Gilson, and Rock Canyon—according to sections measured on the outcrops, are of considerable value, for they contain coal of good quality and are thick enough to warrant exploitation at the present time.

The Gilson is the thickest bed at the outcrop but will not yield so great a tonnage as the Lower Sunnyside bed, because the area of thick coal is smaller. The Rock Canyon bed at the outcrop is probably the second thickest coal, but the Lower Sunnyside bed will yield a greater tonnage because it underlies a greater area. All

the coal beds are extensively burned at the surface, and from the few exposures remaining it is difficult to estimate the character and thickness of the beds under cover.

The Kenilworth bed is practically valueless in this township, being thin and irregular in occurrence. The Upper Sunnyside bed is of more value than the Kenilworth, but it is likely to be split by partings and is generally thin. Its tracing is also more uncertain than that of the three principal beds named above, and little is known of its character and thickness under cover.

Accessibility.—The most favorable point of access to the coal beds in this township is in Rock Canyon. A direct line of railroad would require prohibitive grades, but by using a circuitous route a road with practicable grades could be built up Rock Creek from the Sunnyside branch of the Denver & Rio Grande Western Railroad at the south end of Clark Valley to the mouth of the canyon.

Tonnage estimate.—It is estimated that a total of 342,000,000 short tons of coal underlies T. 13 S., R. 13 E. This relatively large tonnage, compared with that in neighboring townships, is primarily due to the larger area underlain by the Lower Sunnyside coal and to the greater thickness of the Gilson, Rock Canyon, and Lower Sunnyside coal beds. The average thickness here used for the Rock Canyon and Gilson coals is that for all exposures in Tps. 13 and 14 S., R. 13 E. It is considerably less than the average for the sections in T. 13 S., R. 13 E., but is believed to be nearer the average of the coal beds under cover. The average thickness used for the Lower Sunnyside coal is greater than the average of exposures in T. 13 S., R. 13 E., and was calculated from thickness contours drawn upon the bed. The details of the tonnage estimate by beds are given in the table on page 102.

T. 14 S., R. 13 E.

General features.—The coal in T. 14 S., R. 13 E., occurs in the bold southwestward-facing escarpment that trends diagonally across the center of the township. The coal is generally burned at the surface, and few exposures are left on which identifications of the several beds may be made. Five beds were fairly definitely mapped in the township—named in order of stratigraphic position, from the lowest upward, the Kenilworth, Gilson, Rock Canyon, Lower Sunnyside, and Upper Sunnyside.

Each of the Kenilworth, Rock Canyon, and Lower Sunnyside beds rests on a massive ledge-making sandstone or is separated from such a sandstone by a few inches to a few feet of sandy shale. The stratigraphic relations of the coal beds and associated rocks are shown in Plate 5, and detailed representative sections of the coal beds

are shown in Plate 9. The following list gives the names of coal beds exposed and the number by which each coal section is identified.

Coal beds exposed in T. 14 S., R. 13 E., and location numbers on each bed

Upper Sunnyside	271 to 286
Lower Sunnyside	255 to 270
Rock Canyon	243 to 254
Gilson	228 to 242
Kenilworth	221 to 227

Kenilworth coal bed.—Comparatively few sections were measured on the Kenilworth bed in T. 14 S., R. 13 E., owing in part to its lenticular character and in part to the burned condition of its outcrop. The coal generally rests on a massive ledge-making sandstone, which materially facilitated the traversing and accurate mapping of the coal bed. All the sections measured are shown in Plate 9. The bed varies in thickness and is split in many places by rock partings. On the outcrop in this township the coal occurs in two small and relatively thin lenses. One of these is probably confined to secs. 10, 11, 14, and 15, in which the coal ranges from 1 foot 3 inches to 2 feet 6 inches and averages about 2 feet in thickness, and the other is in sec. 25, in which the coal ranges from 2 feet 10 inches to 3 feet 3 inches and averages about 3 feet. The latter is a part of the lens extending into T. 14 S., R. 14 E. (See description of that township.) Outside these lenses no coal of economic value crops out at this horizon.

Gilson coal bed.—The Gilson bed in T. 14 S., R. 13 E., is 25 to 35 feet above the Kenilworth bed. The coal decreases in thickness toward the southeast from 13 feet at location 198, in sec. 30, T. 13 S., R. 13 E., to 1 foot 9 inches at location 235, in sec. 9 of this township.

The bed has been tentatively traced west to location 49, in sec. 7, T. 13 S., R. 11 E., and southeast to location 242, in sec. 25, T. 14 S., R. 13 E. These locations mark the edges of the coal swamp in which the Gilson bed was formed. The coal bed is thickest in T. 13 S., Rs. 12 and 13 E., an area which is roughly midway between the eastern and western limits of the swamp. Beyond these locations the coal is too thin for economic development or was never formed.

The coal is burned in places on the outcrop, but 15 sections were measured and are shown in Plate 9. The bed shows a steady decrease in thickness, except for local irregularities, toward the southeast. At location 228, in sec. 5, it is 3 feet 9 inches thick, and at location 236, in sec. 9, 1 foot 9 inches. The exposure at location 237, in the NW. ¼ sec. 15, shows only 10 inches of bone, but at location 238, in the center of sec. 15, there are two benches with 1 foot 2 inches

of coal in the upper and 1 foot 3 inches in the lower, separated by 6 feet of sandy shale. The extent of the valueless coal represented by the section at location 237 is believed to be slight. At location 239, in the NE. ¼ sec. 15, the bed is exposed in two benches, the upper 2 feet and the lower 1 foot 8 inches thick, separated by 6 inches of carbonaceous shale. It is believed that little coal of economic value will be found southeast of location 239, but thin coal is exposed in places between this point and location 242, sec. 25. (See pl. 5.)

Rock Canyon coal bed.—The Rock Canyon coal bed in T. 14 S., R. 13 E., is 70 to 95 feet above the Gilson bed, to which it is very similar. The greater part of the interval between these coal beds is filled with a massive ledge-making sandstone, on which the Rock Canyon coal bed generally rests. The relations of this sandstone and other associated rocks are shown in Plate 5.

The coal has been extensively burned at the surface throughout the greater part of the township, and few exposures of unburned coal remain. Twelve sections were measured in the northwest corner of the township, but no coal is exposed southeast of location 254, in sec. 9. The coal ranges from 1 foot 9 inches to 6 feet in thickness and averages about 4 feet. In most places the coal occurs in one bench, but locally it crops out in two benches separated by sandy shale. The details of the thickness and character of the coal are shown in Plate 9.

The Rock Canyon bed has been tentatively mapped from location 49, in sec. 7, T. 13 S., R. 11 E., to location 254, in sec. 10, T. 14 S., R. 13 E. These locations indicate the western and eastern edges of the coal swamp in which the coal bed was formed. The coal may be present for a considerable distance west of location 49, but it is known that no coal of economic value will be found on the outcrop east of sec. 10, T. 14 S., R. 13 E.

Lower Sunnyside coal bed.—The Lower Sunnyside bed in T. 14 S., R. 13 E., is 120 to 140 feet above the Rock Canyon bed. The interval between them is filled for the most part with a massive ledge-making sandstone, on which the Lower Sunnyside coal generally rests. The coal is extensively burned at the surface, and few exposures remain. The underlying sandstone was carefully traversed, and 16 sections were measured, which include all the exposed coal on this bed in the township. The relations of the several coal beds and the associated rocks are shown in Plate 5, and the detailed sections of the coal bed, which range from 5 feet 6 inches to 10 feet 7 inches in thickness, are shown in Plate 9. In places a part of the coal has been burned. These sections are given below but are not shown in Plate 9.

Sections of the Lower Sunnyside coal bed in T. 14 S., R. 13 E.

Location 247, sec. 5

	Ft.	in.
Talus-covered coal	5	10
Shale		6
Concealed	2	
Sandstone	50	
Total coal	5	10

Location 258, sec. 9

	Ft.	in.
Clay.		
Coal	4	
Shale.		

Location 259, sec. 15

	Ft.	in.
Shale containing some ash	3	
Coal	2	6
Sandstone	45	
Total coal	2	6+

Location 263, sec. 23 (unsurveyed)

	Ft.	in.
Shale containing some ash	3	1
Sandstone	1	
Shale containing some ash	2	11
Coal	3	9
Sandstone	45	
Total coal	3	9+

Location 265, sec. 23 (unsurveyed)

	Ft.	in.
Shale containing ash.		
Coal	4	8
Sandstone.		

Location 266, sec. 23 (unsurveyed)

	Ft.	in.
Shale and ash		7
Coal	5	
Sandstone	45	
Total coal	5+	

These sections show the continuity of the coal and indicate that it is probably thicker under cover than where it was measured. In places on the outcrop the burning of this bed has fused the rocks and is believed to extend several hundred feet back of the outcrop, especially at the points of the sharp ridges between the canyons.

Upper Sunnyside bed.—The Upper Sunnyside bed in T. 14 S., R. 13 E., is about 25 to 35 feet above the Lower Sunnyside bed. It is difficult to trace the bed between exposures because the coal is extensively burned at the surface in this zone. In places along the line of outcrop the burned rock extends from the Lower Sunnyside bed to and a considerable distance above the Upper Sunnyside bed, and the position and amount of coal originally present can not be determined. The tentative mapping is based in part on the position and in part on the thickness and character of the coal bed itself. As several beds of coal crop out in places above the Lower Sunnyside bed it is difficult to tell which of them is the Upper Sunnyside bed. The stratigraphic relations of these upper coals to the Lower Sunnyside bed are shown in Plate 5, and the details of sections referred to the Upper Sunnyside bed are shown in Plate 9. The following sections, not given in Plate 9, show only a part of the coal bed.

Sections of the Upper Sunnyside coal bed in T. 14 S., R. 13 E.

Location 271, sec. 5

	Ft.	in.
Shale containing ash.		
Coal	1	5
Shale, carbonaceous	1	
Sandstone.		
Total coal	1	5+

Location 271, sec. 5

	Ft.	in.
Shale containing ash.		
Coal	1	6
Shale, sandy	4	
Total coal	1	6+

Location 274, sec. 3

	Ft.	in.
Shale, sandy.		
Coal	2	
Shale containing ash	1	3
Total coal	2+	

Location 280, sec. 23 (unsurveyed)

	Ft.	in.
Shale containing ash		3
Coal	2	9
Shale containing ash	3	1
Total coal	2	9+

It is difficult to determine the character and thickness of the bed under cover, but it probably maintains a good thickness of coal in T. 14 S., R. 13 E.

Summary of coal beds.—Five coal beds exposed in T. 14 S., R. 13 E., have been fairly definitely mapped at the outcrop. The extensive burning of the coal beds added to the difficulties of mapping and of the determination of the character and thickness of the several beds, but the information obtained is sufficient to indicate the relative value of the several beds and to form a basis for an estimate of the amount of available coal.

The Lower Sunnyside bed is the thickest bed in this township. The Rock Canyon coal is the second thickest bed, but it is exposed only in the northwest corner of the township. Its tonnage yield is probably much less than that of the Upper Sunnyside bed and possibly less than that of the Gilson.

The Upper Sunnyside coal at the outcrop is third in thickness, but probably ranks second in value. The Gilson coal bed is probably third in economic importance, but, like the Rock Canyon bed, it is exposed only in the northwest corner of the township, and coal of economic value will not be found on the outcrop southeast of sec. 15. The Kenilworth bed is the least valuable bed in the township.

Tonnage estimate.—The potential coal tonnage in T. 14 S., R. 13 E., is small compared to that in adjoining townships, because only the northeast corner is underlain by coal-bearing rocks. Five beds contribute to the total estimated tonnage of 120,000,000 short tons. The Lower Sunnyside will yield more coal than any other bed, because it is thicker and underlies a greater area. The others in the order of their estimated tonnage yield are Upper Sunnyside, Gilson, Rock Canyon, and Kenilworth.

The tonnage of the Lower Sunnyside coal was calculated from its area in square miles and from its average thickness as determined from thickness contours. The average thickness used for the Upper Sunnyside, Gilson, and Rock Canyon beds is the average of all sections measured in Tps. 13 and 14 S., R. 13 E. All the beds except the Lower Sunnyside, according to surface evidence, are restricted in this township to small lenses. The Gilson and Rock Canyon beds do not extend southeastward beyond this township, as they appear to reach here the eastern limit of coal deposition at these horizons.

Accessibility.—The easiest and most economical places to mine the coal in T. 14 S., R. 13 E., are on the outcrop where it crosses the main canyons. (See pl. 22.) The coal can also be reached by shafts, and it is nearest the surface in sec. 1, in the Left Fork of Whitmore Canyon.

In order to reach a coal mine on the outcrop by a railroad it would probably be found most economical to build a branch up Clark Valley to the mouth of Rock Canyon or Bear Canyon and thence extend it along the slope, parallel to the coal-bearing escarpment but at a considerable distance from it. This would be expensive, because of the rough surface formed by the gravel-capped terraces with intervening shale valleys. A road might be built connecting with the Sunnyside branch at the mouth of Whitmore Canyon and running northwestward along the slope parallel with the coal-bearing escarpment, but such a road would be not only expensive to build but expensive to maintain, as floods from torrential storms in the hills would wash out the roadbed wherever it was exposed to their action.

In order to handle the coal mined from a shaft in sec. 1, the Sunnyside branch railroad would have to be extended up Whitmore Canyon. This would necessitate overcoming locally a grade as much as 200 feet to the mile, or about 4 per cent, which is considerably steeper than any part of the Sunnyside branch.

T. 12 S., R. 14 E.

General features.—That part of T. 12 S., R. 14 E., situated in the Sunnyside quadrangle is occupied by a high northeastward-sloping plateau deeply cut by canyons. The surface of the plateau roughly represents the structure of the surface rocks, being in general a dip slope. The township is drained by Sheep Canyon and Stone Cabin Creek, which flow north and northeast into Ninemile Creek.

The nearest outcropping coal is in the southwest corner of T. 13 S., R. 13 E., 7 miles to the southwest, where five beds are exposed. Two of these, the Kenilworth and Upper Sunnyside beds, are thin and apparently are not persistent on the outcrop, so that it is impossible to estimate the thickness of the coal 7 miles distant. The Gilson and Rock Canyon coal beds, both of good quality and thickness in T. 13 S., R. 13 E., reach the eastern margin of coal deposition near the center of T. 14 S., R. 13 E., and therefore these beds probably do not extend to T. 12 S., R. 14 E. This leaves only the Lower Sunnyside bed of those that crop out as a probable source of coal in this township. This bed wherever exposed is of workable thickness and is persistent across the Sunnyside quadrangle, and it is believed to be of workable thickness in T. 12 S., R. 14 E.

Tonnage estimate.—The available information indicates that only the Lower Sunnyside bed is present under cover in T. 12 S., R. 14 E. It is estimated that this bed will average about 4 feet in thickness throughout an area of 12 square miles, giving 55,000,000 short tons of coal in that part of the township situated in the Sunnyside quadrangle.

Accessibility.—The coal in T. 12 S., R. 14 E. is economically inaccessible at the present time because of its great distance from the outcrop and the difficulty, if not impossibility, of railroad approach. The coal can be mined only by shafts and in the most favorable places, the bottoms of canyons, it is 3,500 to 4,500 feet below the surface. It would be possible to transport the coal mined by shafts in this township to a railroad connection at the mouth of Rock Canyon by aerial tramway, but this would be so expensive an undertaking that a mine depending upon it could not compete with mines more favorably located.

T. 13 S., R. 14 E.

General features.—The surface of T. 13 S., R. 14 E. is rough and is deeply trenched by Whitmore Canyon and Dry Creek. The total relief is more than 3,100 feet, the altitude ranging from 7,150 feet in the bed of Dry Creek, in sec. 12, to 10,285 feet at Bruin Point, in sec. 33. The tops of the ridges in the northern and eastern parts slope northeast and correspond in a general way to the dip of the rocks. The high divide between the Price River and Green River drainage systems trends southeastward across the southwestern part of the township.

The nearest outcropping coal is in T. 14 S., R. 13 E., 3 miles southwest of the southwest corner of the township. There five beds crop out. Four of these—the Kenilworth, Gilson, Rock Canyon, and Upper Sunnyside—are so thin and lenticular that they are not likely to be present in this township, although it is possible that any one or all of them may here have a workable thickness. The coal swamps in which the Gilson and Rock Canyon coal beds were formed probably did not extend eastward to T. 13 S., R. 14 E., and the Kenilworth and Upper Sunnyside beds are thin, lenticular, and at many localities absent in this part of the Book Cliffs. The fact that the Lower Sunnyside bed in the Sunnyside and Wellington quadrangles is of good thickness on the outcrop supports the belief that it will be found under cover in the township and that it maintains a fair thickness.

Tonnage estimate.—The Lower Sunyside bed is the only one considered in making a tonnage estimate of the coal that underlies this township. The estimated thickness of the bed is more than 5 feet on the average throughout an area of about 33 square miles, which gives a total of 203,000,000 short tons of coal for T. 13 S., R. 14 E. The

average thickness was determined by drawing several more or less arbitrary lines of equal thickness, representing a known decreasing thickness of the bed on its outcrop north and west from the south edge of the Sunnyside quadrangle.

Accessibility.—The coal in T. 13 S., R. 14 E., is at present economically inaccessible compared with the coal in adjoining townships to the southwest. It must be mined by shafts and is 2,500 to 5,000 feet below the surface. The only route for railroad approach is up Whitmore Canyon, which has an ascent of about 200 feet to the mile from Sunnyside to the southwest corner of the township. A shaft sunk in sec. 32, in the bottom of the Right Fork of Whitmore Canyon, would probably reach the Lower Sunnyside bed at a depth of 2,500 feet. Several square miles of coal may be mined from a shaft at this point, but elsewhere in the township the coal is inaccessible to railroad transportation. It would be possible to construct aerial tramways from shaft mines in Dry Creek and other canyons over the Bruin Point-Mount Bartles divide to points in Whitmore Canyon, but this would entail great expenditures of money, which are unwarranted so long as vast coal deposits near the outcrop remain untouched.

T. 14 S., R. 14 E.

General features.—Three coal beds crop out in T. 14 S., R. 14 E., and have been correlated as shown in Plate 5, and detailed representative sections of each bed are shown in Plate 10. These beds are, in the order of their occurrence from the lowest upward, the Kenilworth, Lower Sunnyside, and Upper Sunnyside. The outcrops traverse the southwest corner of the township, passing through secs. 30, 31, and 32. The Kenilworth bed reaches its maximum thickness for the Sunnyside quadrangle in this township, but it is of small value compared with the Lower Sunnyside bed which is here from 6 to 12 feet thick. The Upper Sunnyside bed, according to measurements on its outcrop, is of small value, because it appears to consist of two or more thin benches of coal separated by relatively thick sandstone or shale partings. The scarcity of exposures on this bed is due to the extensive burning of the coal, and this scarcity makes it difficult to estimate the real value of the bed under cover.

The Lower Sunnyside and Kenilworth coal beds rest on heavy ledge-making sandstones which greatly facilitate the mapping of these beds. The identification of the Upper Sunnyside bed is based on its position relative to the Lower Sunnyside coal.

Coal beds exposed in T. 14 S., R. 14 E., and location numbers on each of the beds

Upper Sunnyside	322 to 330
Lower Sunnyside	306 to 321
Kenilworth	287 to 305

The rock beds in this township are broken by faults having a maximum vertical displacement of more than 100 feet, and this displacement must be considered in planning future developments. The faults are described in detail under "Structure" (pp. 24 and 25).

Kenilworth coal bed.—The Kenilworth bed was carefully traversed in T. 14 S., R. 14 E., but only 19 exposures were measured; the details of 17 are shown in Plate 10.

The coal generally rests on a heavy ledge-making sandstone and in most places crops out in one bench, but near the west edge of the township, at location 287, in sec. 30, and to the northwest in the adjoining township it is more or less split by rock partings. The thickest part of the bed is near the center of sec. 31, at location 292, where the coal is 4 feet 7 inches thick. The thickness decreases rather abruptly northward, and the coal is of little value in the adjoining township except within small areas. (See description of T. 14 S., R. 13 E.) Southward from location 292 the coal maintains a fair thickness to location 303, in the SW. ¼ SW. ¼ sec. 32, except at location 302, where there is only 1 foot of coal. Sections at locations 294 and 299 were omitted from Plate 10 and are given below.

Sections of Kenilworth coal bed in T. 14 S., R. 14 E.

Location 294, sec. 31

	Ft.	in.
Shale, gray.		
Coal	4	3
Shale, brown		4
Sandstone, gray	5	6
Shale	2	
Sandstone, gray.		
Total coal	4	3

Location 299, sec. 31

	Ft.	in.
Shale, sandy.		
Coal	3	6
Shale, sandy.		

No exposures were found for a considerable distance south of location 303, but it is believed that the coal thins rapidly in that direction, because near the center of sec. 5, T. 15 S., R. 14 E., there is less than 1 foot of coal. The information obtained indicates that a lens of coal, 14 inches or greater in thickness, underlies the SW. ¼ and the SW. ¼ NW. ¼ sec. 29, most of sec. 30 northwest of the outcrop, all of sec. 31 northeast of the outcrop, and the NW. ¼ and NW. ¼ SW. ¼ sec. 32, T. 14 S., R. 14 E., also part of the E. ½ NE. ¼ and part of the E. ½ SE. ¼ sec. 25, T. 14 S., R. 13 E., with the center of greatest thickness of the lens at location 292, near the center of sec. 31, T. 14 S., R. 14 E.

The Kenilworth coal is well exposed in the township, as there has been little or no burning at the surface, and the sections measured probably represent the true character of the bed for a short distance under cover.

Lower Sunnyside coal bed.—The Lower Sunnyside bed is 200 to 225 feet above the Kenilworth bed. The relations of the coal beds and the character of the associated rocks are shown in Plate 5.

The Lower Sunnyside is the thickest and most persistent coal bed in T. 14 S., R. 14 E. It ranges from 5 to 12 feet in thickness and generally crops out in one bench. The coal is reasonably well exposed in spite of the extensive burning of the coal at the surface. Sixteen sections were measured, and all but one are shown in Plate 10. At location 317, in the SE. ¼ SE. ¼ sec. 31, the greater part of the bed has been burned, leaving only 2 feet 11 inches of coal. The sections indicate a considerable variation in the thickness of the coal, although in places adjacent sections indicate that in general the thick or thin portions of the bed underlie considerable areas in which the changes in thickness are relatively slight. The bed ranges from 8 to 12 feet in thickness from location 270, in sec. 25, T. 14 S., R. 13 E., to location 310, in the NW. ¼ sec. 31, T. 14 S., R. 14 E., except at location 309, where less than 7 feet of coal crops out. Section 312 represents the thickness of coal at a point in the mine beneath Number Two Canyon, where a sample for analysis was cut from a fresh working face of the coal. The part of the bed included in the sample (No. 12632) is shown by brackets in Plate 10. Section 321 also shows this bed separated into two benches by a shale parting, which appears to continue for some distance southward into the next township. Such variations in the thickness and character of the Lower Sunnyside bed on the outcrop do not seem to be characteristic of this bed where it has been mined under cover. Personal observation in the mines and reports from mine officials and miners indicate a reasonably constant thickness of coal, which probably averages about 10 feet.

Upper Sunnyside coal bed.—The Upper Sunnyside coal in T. 14 S., R. 14 E., is of small economic value at the surface. It crops out in a zone in which the bed appears to be separated by rock partings into several benches, no one of which is more than 2 feet 9 inches thick. The Upper Sunnyside as well as the Lower Sunnyside coal has been extensively burned at the surface, so that few exposures are left, and the associated rocks are much disturbed. The only basis for tracing the Upper Sunnyside bed is its stratigraphic position with reference to the massive sandstone on which the Lower Sunnyside coal rests. This is a fairly satisfactory basis where the bed to be traced crops out in one bench and where the distance between the coal and the key rock is reasonably constant, but here several beds crop out in the zone of the Upper Sunnyside, and the distance between this zone and the key sandstone ranges from 20 to 50 feet.

The Upper Sunnyside coal bed, where it has been mined in this township and in T. 15 S., R. 14 E., on the south, is confined to one bench, but the distance between the two Sunnyside coal beds ranges from less than 6 feet to nearly 40 feet, decreasing toward the south. The "split-up" condition of the bed on the outcrop in this township, as shown in Plate 5 and in Figure 3, is therefore believed to be confined to a small area and is not typical of the coal under cover. All coal exposed in rocks above the Lower Sunnyside bed are shown in Figure 3. Broken lines connecting adjacent sections in the figure suggest possible correlations for some of these coal beds. These sections show the difficulties encountered in trying to trace accurately and identify the Upper Sunnyside bed.

Summary of coal beds.—As the three coal beds exposed in T. 14 S., R. 14 E., crop out only across the extreme southwest corner of

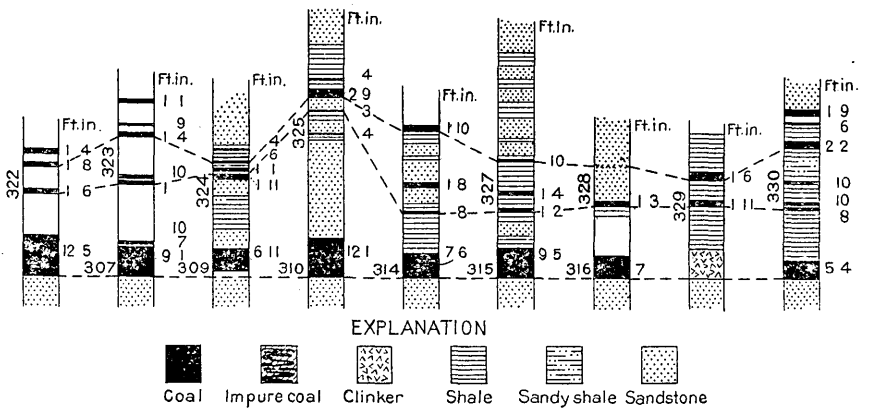


FIGURE 3.—Sections of coal on the Lower Sunnyside bed and in the zone of the Upper Sunnyside bed in T. 14 S., R. 14 E., showing tentative correlations

the township, in secs. 30, 31, and 32, they afford only a short outcrop distance for study. The Kenilworth and Upper Sunnyside beds are erratic and, compared with the Lower Sunnyside bed, are of small economic value. A total of 44 sections were measured on all three beds, and 37 of these sections are shown in Plate 10. The Lower Sunnyside bed shows a considerable variation on the outcrop but is everywhere of good workable thickness.

Tonnage estimate.—The tonnage estimate for T. 14 S., R. 14 E., exceeds by nearly 80,000,000 short tons that for any other township in these quadrangles. The estimate is large because the Lower Sunnyside bed, with an average thickness of nearly 10 feet, is considered to be present throughout the township. The Upper Sunnyside and Kenilworth beds are regarded as making up less than 10 per cent of the estimated total tonnage of 444,000,000 short tons. The tonnage of the Upper Sunnyside bed is believed to be somewhat under-

estimated, because where this bed has been mined, in secs. 32 and 33, it is confined to one bench, which is 4 to 5 feet thick, but the available information is not sufficient to warrant a greater estimate.

The Lower Sunnyside bed is thickest at the south edge of the township and gradually thins toward the northwest. In making the estimate this thinning was taken into account by drawing lines of equal thickness on the outcrop and extending these lines to indicate the probable thickness under cover.

Accessibility.—The most advantageous place for mining a part of the coal in T. 14 S., R. 14 E., is near the mouth of Whitmore Canyon, in sec. 32, where the two Sunnyside beds have been mined on a large scale for many years. (See pl. 1.) All the coal within a reasonable distance of the outcrop can be mined from the entries in Whitmore Canyon, but the greater part of the coal in the township will have to be mined by shafts. The coal dips to the northeast and therefore is deeper the farther from the outcrop it is tapped. Whitmore Canyon has deeply trenched the overlying rocks, and the coal lies nearer the surface here than elsewhere in the township. The Lower Sunnyside bed will be found at about the depths here given at the following places in T. 14 S., R. 14 E. At the confluence of Whitmore and Water Canyons in the NW.¼ sec. 20, 950 feet; at the junction of the left and right forks of Whitmore Canyon in the NW. ¼ sec. 7, 1,425 feet; near the northwest corner of sec. 5, 2,500 feet; on Range Creek in the NW ¼ sec. 13 (unsurveyed), 4,100 feet; and near the pumping station in the SW.¼ sec. 35, 2,900 feet. These depths are only approximate because they are based on surface altitudes determined from sketched contours and on the more or less indeterminate subsurface structure of the Lower Sunnyside coal bed. (See general discussion under "Structure.")

T. 15 S., R. 14 E.

General features.—The outcrops of three coal beds have been traversed and mapped in T. 15 S., R. 14 E. These beds, in the order of their stratigraphic position from the lowest upward are the Kenilworth, Lower Sunnyside, and Upper Sunnyside. The Sunnyside beds are extensively burned at the surface, and the burned-out area extends from several hundred to more than a thousand feet from the outcrop of slag and clinker, but the Kenilworth bed is unburned. As a result of the burning few exposures of coal could be found. Forty-nine coal sections were measured in this township, 37 of which are shown in Plate 11. The stratigraphic relations of the coal beds and the character of the associated rocks are shown in Plate 5.

Coal beds exposed in T. 15 S., R. 14 E., and location numbers of the sections measured on each bed

Upper Sunnyside	366 to 379
Lower Sunnyside	341 to 365
Kenilworth	331 to 340

Kenilworth coal bed.—The Kenilworth bed in T. 15 S., R. 14 E., is of little economic value, being thin and lenticular. Several exposures show that the coal is impure, and many sections of associated rocks show no coal. Ten sections were measured on the bed in the township, but the exposures of coal are confined to several small groups of locations, a fact which indicates that the coal lies in lenses on the outcrop. These sections are shown in detail in Plate 11.

The Kenilworth bed in some places rests directly on a massive sandstone, but in others it is separated from the sandstone by a few inches to a few feet of clay shale or sandy shale. It was accurately mapped by traversing this sandstone, which crops out continuously across the township. Six inches of coal was measured in the NE. ¼ NW. ¼ sec. 5, and south of this locality coal "bloom" (badly weathered and finely divided coal) was partly exposed at several places, but it is believed that these exposures represent coal less than 1 foot thick. At location 331, in the NW. ¼ sec. 8, 2 feet of impure coal crops out, which probably indicates the edge of a small coal lens in the N. ½ sec. 8, and 10 inches of bone at location 337, sec. 8, may indicate the opposite edge of this lens. Sections at locations 332 to 336 (pl. 11) show the thicknesses of this lens on the outcrop. Two other small lenses, one near the center of sec. 17 and the other near the center of sec. 20, were detected. Two sections (locations 338 and 339) were measured in sec. 17, and one in sec. 20 (location 340), all of which are shown in Plate 11. The horizon of this bed was traversed between these coal exposures, but no more coal was found.

Lower Sunnyside coal bed.—The Lower Sunnyside is the most valuable coal bed in T. 15 S., R. 14 E., where it has its greatest thickness in these quadrangles. The coal in complete sections ranges from 7 to 14 feet and averages about 11 feet in thickness. Twenty-five sections were measured on the bed in this township, 14 of which are shown in Plate 11.

The Lower Sunnyside bed crops out 220 to 240 feet above the Kenilworth bed. The stratigraphic positions of the several coal beds and the nature of the associated rocks are shown in Plate 5. The Lower Sunnyside bed generally rests on a massive ledge-making sandstone.

The following sections, not shown in Plate 11, each include a part of the thickness of the coal bed:

Sections of Lower Sunnyside coal bed in T. 15 S., R. 14 E.

Location 341, sec. 5

	Ft.	in.
Sandstone.		
Shale	3	
Shale, carbonaceous	1	
Shale, gray, sandy	4	6
Sandstone	1	6
Shale	4	
Sandstone	4	
Shale, brown	1	
Coal, bony	1	2
Shale	12	
Coal	2	2
Shale, brown	2	2
Coal (bottom not seen)	7	9+
Sandstone, massive.		
Total coal	11	1+

Location 345, sec. 8

	Ft.	in.
Sandstone, brick-red	5+	
Shale, baked	4+	
Shale, containing ash		5
Coal	7	2
Shale, brown		4
Shale, sandy	2	
Sandstone	50+	
Total coal	7	2+

Location 349, sec. 8

	Ft.	in.
Sandstone, baked.		
Shale and some ash.		
Coal	4	1
Shale	4	
Sandstone	50+	
Total coal	4	1+

Location 350, sec. 8

	Ft.	in.
Shale.		
Coal and ash.		
Coal	4	4
Shale.		
Total coal	4	4+

Location 351, sec. 9

	Ft.	in.
Top not exposed.		
Coal (sampled)	9	10+
Bottom not exposed.		

Location 353, sec. 8

	Ft.	in.
Shale; contains some ash.		
Coal	6	2
Shale, brown	2	
Sandstone	2	
Shale, brown	4	
Sandstone, massive	50+	
Total coal	6	2+

Location 354, sec. 8

	Ft.	in.
Shale; contains some ash.		
Coal	6	4
Shale, brown	3	
Sandstone	1	
Shale	4	
Sandstone, massive	50+	
Total coal	6	4+

Location 356, sec. 17

	Ft.	in.
Shale, sandy.		
Coal (sampled)	8+	
Bottom not exposed.		

Location 360, sec. 21

	Ft.	in.
Shale, sandy.		
Clay, containing ash	6	
Coal	5	
Shale, carbonaceous sandy	11	
Sandstone	75+	
Total coal	5+	

Location 362, sec. 20

	Ft.	in.
Shale, baked.		
Clay and ash	3	
Coal	4	2
Sandstone	50	
Total coal	4	2+

Location 364, sec. 20

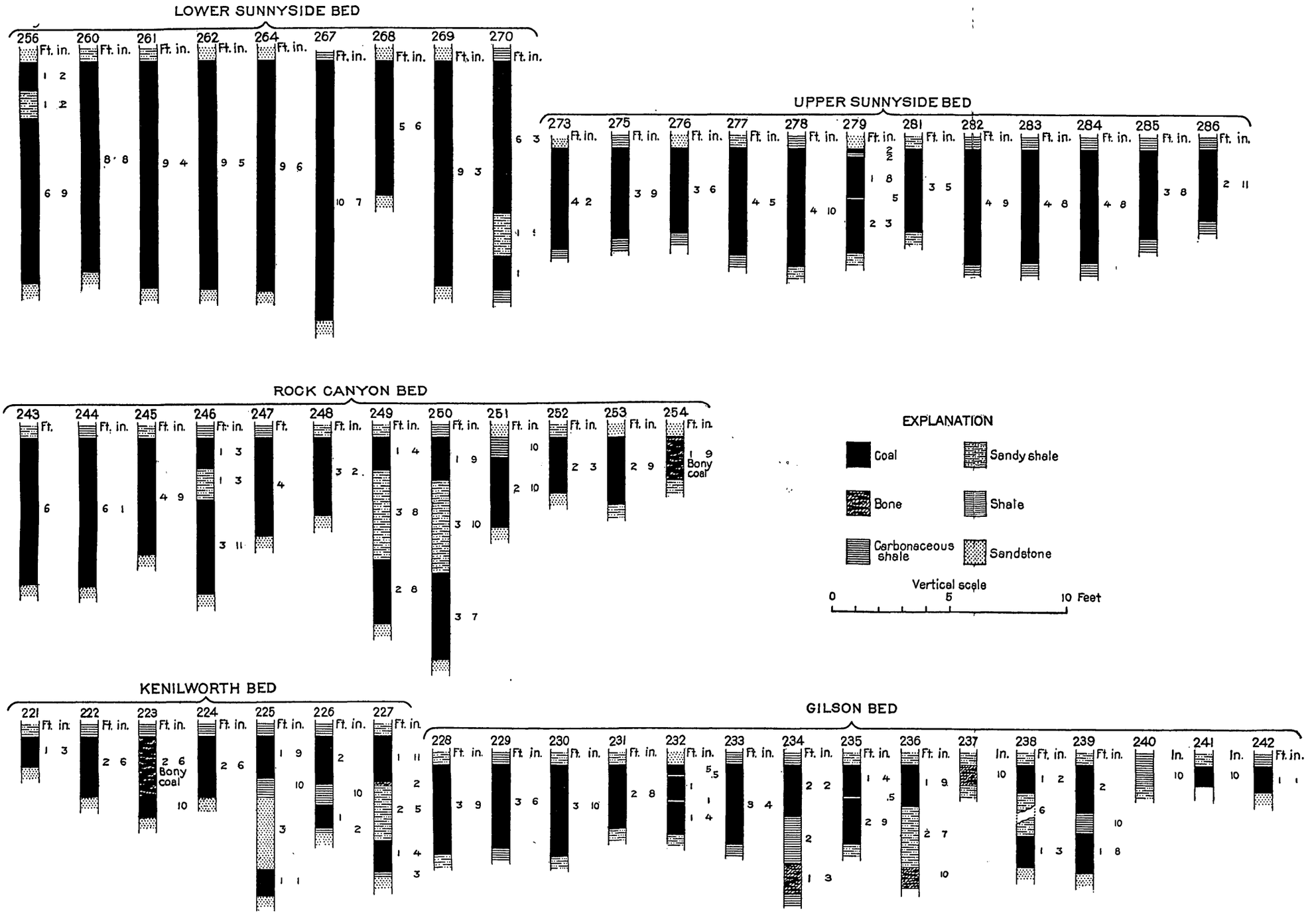
	Ft.	in.
Sandstone.		
Shale, gray, sandy	3	6
Coal (bottom not exposed)	11	7+
Sandstone, massive	75	
Total coal	11	7+

The sections given above are of little value in determining the true character and thickness of the coal bed, because the coal has been considerably altered by heat, and its full thickness was not exposed at any of these locations. They are important in showing the continuity of the bed and its minimum thickness at these places.

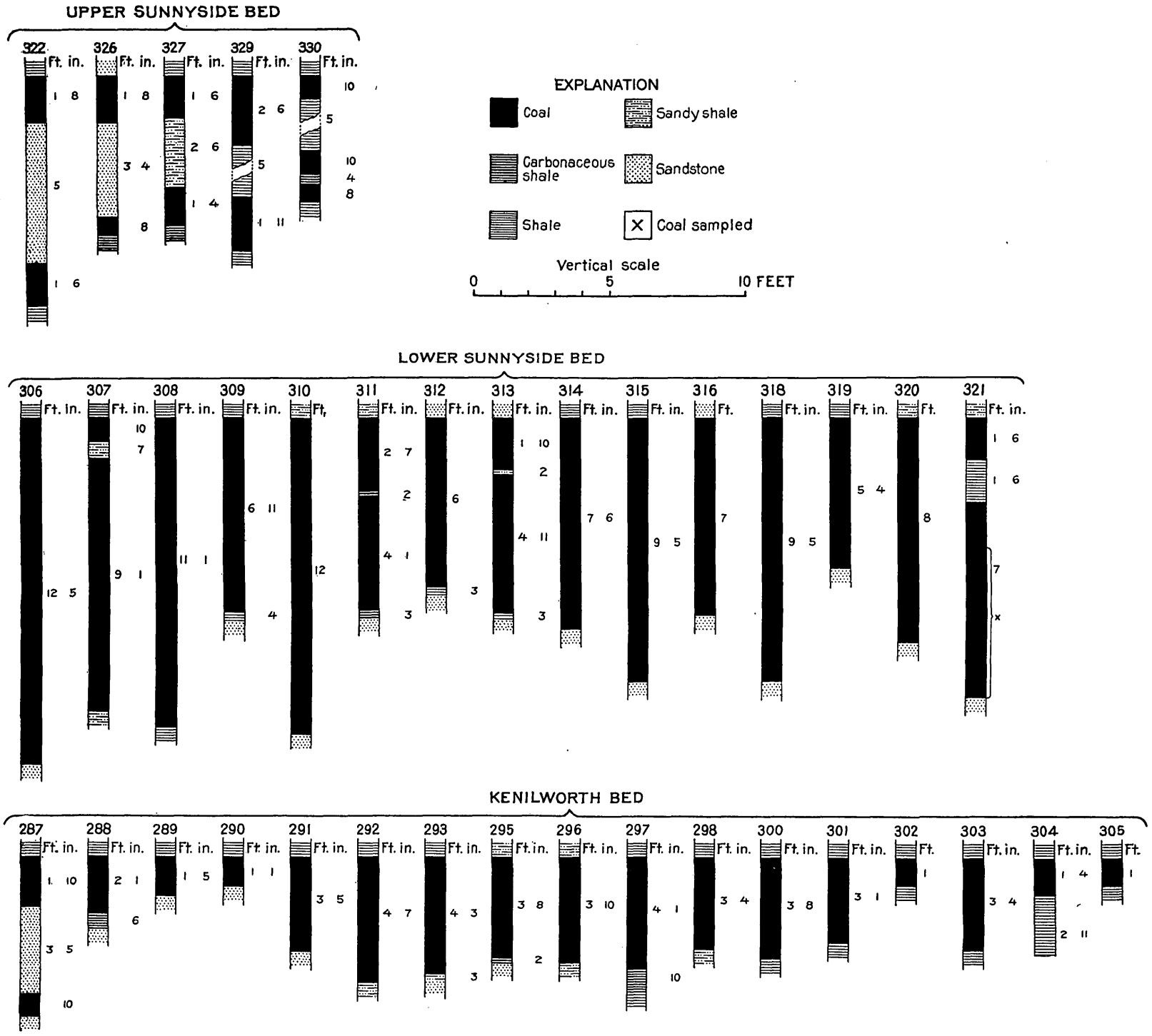
The Lower Sunnyside bed generally crops out in one bench, but in sec. 5 several exposures show a parting of sandy shale 1 foot 4 inches to 2 feet 2 inches thick. (See pl. 11.) One other section measured in the mine in the SW. ¼ sec. 33, T. 14 S., R. 14 E., shows a similar parting at the same relative position in the bed. The parting may be continuous between these two locations, but it probably does not extend throughout a wide area. The average thickness of 11 feet given above is slightly greater than the average thickness reported by mine officials and miners, who say that the coal bed ranges from 5 to 11 feet throughout the mines. The few sections measured by the writer in the mine show 8 feet or more of coal, but at no place examined was the total thickness mined. It is believed that the Lower Sunnyside bed is reasonably constant in thickness, but it has a maximum thickness in sec. 21, at the southern edge of the quadrangle, and in general it shows a slight decrease toward the north. Several sections on the outcrop show exceptional differences in thickness of the coal. At location 358, in sec. 17, for example, there is only 6 feet 10 inches, and unfortunately the extent of this thin coal can not be determined because in near-by exposures a part of the coal has been burned.

The coal-bearing rocks in T. 15 S., R. 14 E., are cut by several faults which interfere more or less with the normal mining of the coal but are not serious hindrances if taken into account in planning development. The details of these faults are described in the general discussion of structure (pp. 24 and 25).

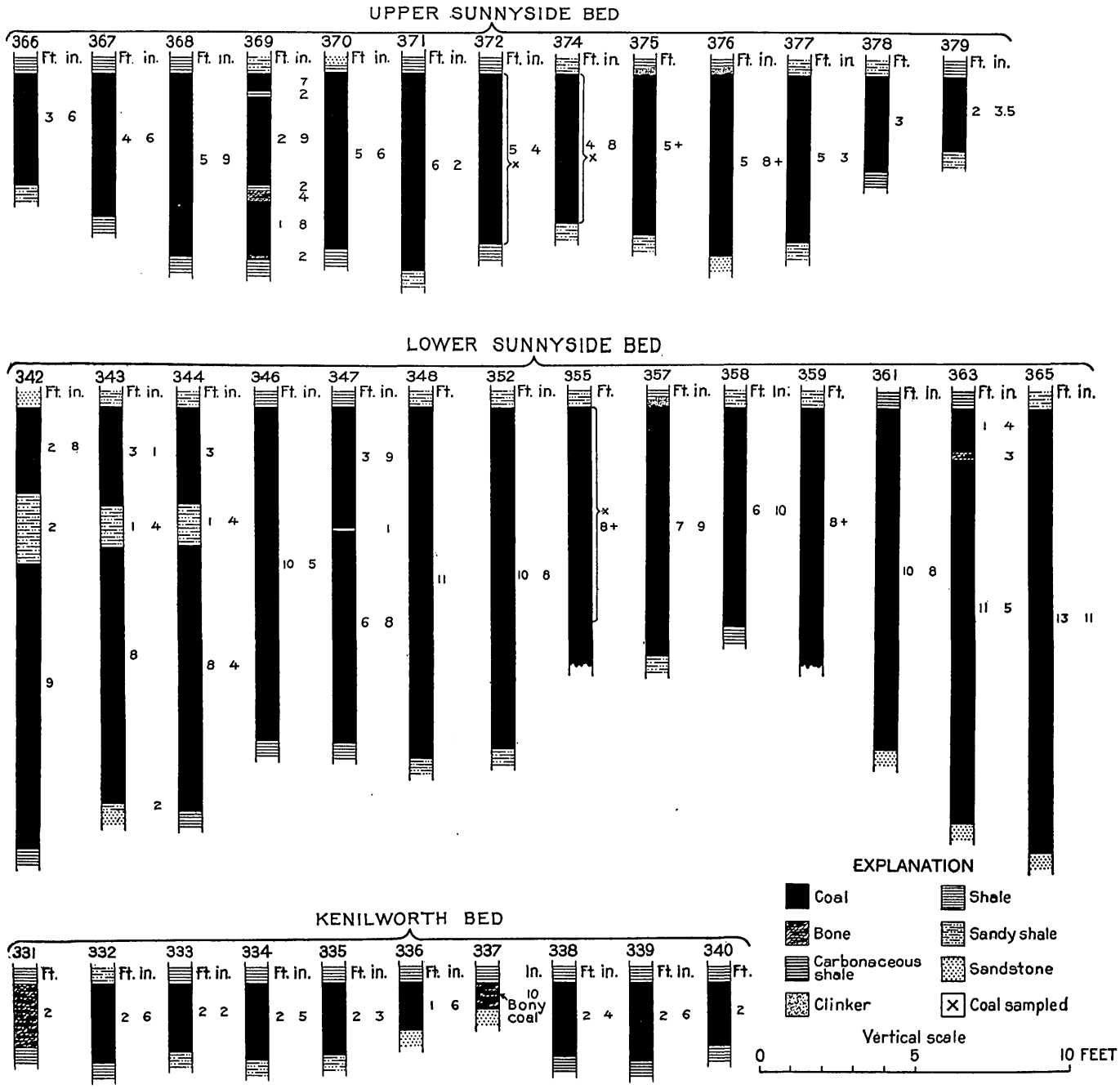
Upper Sunnyside coal bed.—The Upper Sunnyside bed is probably of greater economic importance in T. 15 S., R. 14 E., than it is in any other township in these quadrangles. It appears to be persistent and constant in thickness, ranging from 2 feet 3 inches to 6 feet 2 inches, and the coal at most places consists of a single bench. The Upper Sunnyside bed ranges from 3 feet to nearly 40 feet above the Lower Sunnyside bed. This range was noted both on the outcrop and in the mines. In mine No. 1, probably in sec. 32 or 33, the interval is reported to be 39 feet; in Water Canyon it is about 15 feet; near the Right Fork of Water Canyon it is about 8 feet; in the NE. ¼ sec. 16 it is about 6 feet; and the section near location 373 is as follows:



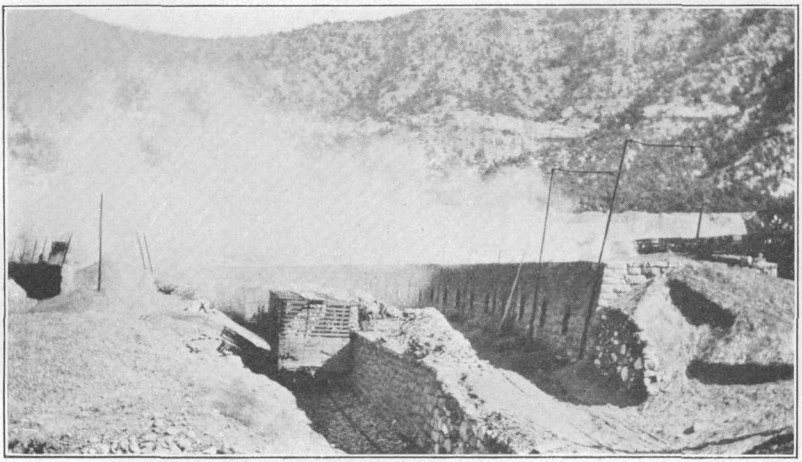
SECTIONS OF THE PRINCIPAL COAL BEDS EXPOSED IN T. 14 S., R. 13 E.



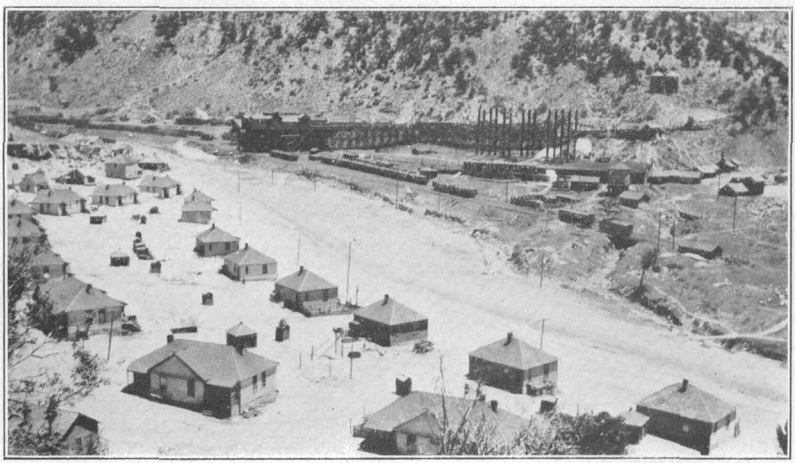
SECTIONS OF THE PRINCIPAL COAL BEDS EXPOSED IN T. 14 S., R. 14 E.



SECTIONS OF THE PRINCIPAL COAL BEDS EXPOSED IN T. 15 S., R. 14 E.



A. COKE OVENS AT SUNNYSIDE



B. TIPPLE AT MINE OF UTAH FUEL CO. AT SUNNYSIDE

Section of coal beds near location 373, in sec. 16, T. 15 S., R. 14 E.

	Ft.	in.
Coal, top not exposed (Upper Sunnyside)	4+	
Shale, sandy	3	9
Coal		6
Shale, brown, sandy	1	8
Coal, bottom not exposed (Lower Sunnyside)	8+	
Thickness of section	17	11
Thickness of coal	12	6+

In Horse Canyon, several miles south of this quadrangle, Richardson[14] observed the following section of what is probably the two Sunnyside coal beds, although these beds have not been traced by the writer as far as Horse Canyon:

Section of coal beds in Horse Canyon, in sec. 4, T. 16 S., R. 14 E. (unsurveyed)

[By G. B. Richardson]

Shale, carbonaceous:	Ft.	in.
Coal (Upper Sunnyside ?)	2	1
Bone		6
Sandstone and shale	1	6
Bone	1	
Coal (Lower Sunnyside ?)	13	5
Sandstone.		
Thickness of section	18	6
Thickness of coal	15	6

Considerable changes in the character and thickness of the Upper Sunnyside bed are apparent on the outcrop from T. 14 S., R. 15 E., southward (compare sections in pls. 10 and 11), but no such changes within the mines are reported. There are local minor variations in the thickness of the bed in the mine, but it is reported to be reasonably constant, ranging from 4 to 6 feet and probably averaging about 5 feet in thickness. This average corresponds closely with the average thickness of 4 feet 9 inches for the sections shown in Plate 11. The Upper Sunnyside bed in this township consists of a single bench both on the outcrop and throughout the mines. On the outcrop the bed decreases in thickness near the north and south sides of T. 15 S. and in Horse Canyon south of the Sunnyside quadrangle. It is believed that the bed is continuous and of economic importance throughout a considerable part of this township. The belief is based on exposures, on the extensive burning on the outcrop, and on the conditions and the thickness of the coal in the mines. Mining operations are extensive and have penetrated the coal bed 2 to 3 miles southeast of the tipple at Sunnyside.

[14] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, p. 41, pl. 8, 1909.

The stratigraphic sections in Plate 5 show several thin and probably local and economically unimportant coal beds above the Upper Sunnyside, none of which have been found to be of workable thickness or to extend laterally much beyond the exposures. These sections are probably characteristic of the rocks between the Sunnyside coal beds and the Castlegate sandstone in this township.

Summary of coal beds.—Three coal beds crop out in T. 15 S., R. 14 E. The Lower and Upper Sunnyside beds have been extensively burned at the surface and are being mined on a large scale by the Utah Fuel Co. The Kenilworth bed has not been burned at the surface and is not mined. The outcrops of all the beds have been carefully traversed and mapped, and the sections given probably contain all the available information on these beds.

The Upper and Lower Sunnyside coal beds are persistent and reasonably constant in thickness. The lower bed is the thicker.

Tonnage estimate.—The total tonnage of coal in all beds in the part of T. 15 S., R. 14 E., lying within the Sunnyside quadrangle is estimated to be 285,000,000 short tons. This township ranks fourth in potential coal resources in these quadrangles. It is estimated that the Lower Sunnyside bed contains about 75 per cent and the Upper Sunnyside about 25 per cent of the total tonnage. The area underlain by coal is small in this part of the township, but the two Sunnyside beds are relatively thick. The maximum thickness of the Lower Sunnyside bed, 13 feet 11 inches, is found in sec. 21, T. 15 S., R. 14 E., a few hundred feet south of the south edge of the Sunnyside quadrangle. The northward decrease in thickness of this bed was taken into account in the estimate of tonnage by drawing lines or arcs representing definite differences in thickness on the outcrop and extending these lines to indicate the probable thickness under cover.

The estimate for the Upper Sunnyside bed is based on a considerable lens which underlies most of T. 15 S., R. 14 E., and a small area in the southwestern part of T. 14 S., R. 14 E.

Accessibility.—The coal crops out near the west edge of T. 15 S., R. 14 E., and is easily accessible at Sunnyside, in Whitmore Canyon, where coal has been mined extensively by the Utah Fuel Co. for many years. The coal within 1 to 2 miles of the outcrop will probably be taken out from the mines now in operation at Sunnyside. The coal farther from the outcrop probably must be reached by shafts. The probable depths to the Lower Sunnyside bed at several places in the township are as follows: In Horse Canyon in the SW. ¼ sec. 22, 650 feet; in Horse Canyon in the SW. ¼ sec. 10, 1,450 feet; on the south end of Patmos Mountain, 3,950 feet; on Range Creek in the NE. ¼ sec. 1, 2,750 feet; in a tributary of Range Creek on the east side of sec. 13, 2,300 feet. Coal that might be mined by shafts in T. 15 S., R. 14 E., except possibly that in Horse

Canyon, would have to be transported out of the rough mountainous country to railroad connections by aerial tramways.

T. 12 S., R. 15 E.

General features.—Only about 4 square miles in the southwest corner of T. 12 S., R. 15 E., lies in the Sunnyside quadrangle. This area is about 11 miles northeast of the nearest coal outcrops. (See pl. 22.) The extension of any particular coal bed a distance of 10 to 15 miles from the outcrop is a matter of conjecture, but as it is almost certain that the coal-bearing rocks of the nearest outcrops extend under cover into this township one or more beds of coal are probably present.

Tonnage estimate.—The estimate of 18,000,000 short tons of coal in this area of 4 square miles is obviously a guess, but it is regarded as reasonable. It is based on the assumption that the Lower Sunnyside coal is 4 feet thick on the average throughout this area. This thickness was determined by drawing more or less arbitrary thickness contours which represent a decrease in thickness north and west from the maximum thickness at the south edge of the Sunnyside quadrangle.

Accessibility.—The coal lying under thick cover in T. 12 S., R. 15 E., is economically inaccessible, because it lies at depths of 4,000 feet or more below the surface, and because there is no easy railroad approach to this township. Two deeply intrenched streams, Stone Cabin and Dry Creeks, traverse the southeast and northwest corners of the area, and the divides between them are relatively flat on top and rise about 1,000 to 1,500 feet above the streams. The coal might be mined from shafts in the bottoms of the valleys and hoisted on inclined trams to the top of an adjacent ridge. Thence it could be transported by tram up the ridge to the Bruin Point divide and thence to some railroad connection beyond the coal-bearing escarpment. (See pl. 22.) Manifestly provision of this sort is out of the question at the present time, and it seems probable that the coal of this township will remain undisturbed until railroad connection is obtained for this county from some other direction.

T. 13 S., R. 15 E.

General features.—Only the two west tiers of sections in T. 13 S., R. 15 E., which aggregate about 11 square miles, are in the Sunnyside quadrangle. The highest known coal bed in this area is estimated to lie 4,000 feet or more below the present surface, and the nearest outcropping coal is 7 miles to the southwest, in the vicinity of Sunnyside, where three beds of workable thickness crop out. Two of these, the Kenilworth and Upper Sunnyside, are irregular in thickness, are lenticular on the outcrop, and are probably not

continuous between the outcrop and T. 13 S., R. 15 E. The Lower Sunnyside bed, however, is persistent and of workable thickness on the outcrop and is probably continuous and of workable thickness under cover in the whole of the Sunnyside quadrangle.

Tonnage estimate.—The estimate of tonnage of coal in the west two tiers of T. 13 S., R. 15 E., is based on a reasonable assumption and is probably not too high. Only the Lower Sunnyside coal bed has been considered in estimating a total of 76,000,000 short tons of coal in this area. This coal bed has its known maximum thickness of nearly 14 feet in sec. 21, T. 15 S., R. 14 E., and shows a gradual decrease in thickness along the outcrop to the west and north. The thickness of 6 feet here used in estimating tonnage was obtained by extending thickness contours based on the decreasing thickness to the north and west from the point of maximum thickness. It is probable that not only will the Lower Sunnyside bed prove to be of good workable thickness in this area but that other coal beds will also be found in drill holes or shafts.

Accessibility.—The coal underlying T. 13 S., R. 15 E., is inaccessible at the present time because of its great depth below the surface and because of the lack of easy approach by railroad. Dry Creek, Cold Spring Draw, and Cottonwood Canyon flow northeast and drain the township. These streams have cut canyons of considerable depth, which materially reduce the depth to the coal. Shafts or wells sunk at the following locations would probably reach the horizon of the Lower Sunnyside coal at the depths indicated: On Dry Creek, in the SW. ¼ sec. 7, 4,100 feet; in Cold Spring Draw, near the east quarter corner of sec. 18, 4,500 feet; on Cottonwood Creek, in the NE. ¼ sec. 29, 4,850 feet; and near the southeast corner of sec. 32, 4,750 feet. It will be many years before the demand will warrant exploitation of this coal. The most serious problem in the mining of coal in this township is the transportation of the coal after it is brought to the surface. It is almost impossible to build a railroad to the township, and the coal would have to be transported by one or more of the tramway methods to the nearest railroad.

T. 14 S., R. 15 E.

General features.—The two west tiers of sections in T. 14 S., R. 15 E., lie within the Sunnyside quadrangle. The coal possibilities of this small area are difficult to predict because the nearest outcropping coal is 5 miles to the west, and nothing can be known definitely of the thickness and continuity of the coal beds so far from the outcrop. Three beds of workable thickness crop out at Sunnyside. The Kenilworth and Upper Sunnyside beds are irregular in thickness and lenticular and probably are not continuous eastward to

T. 14 S., R. 15 E., but these or other beds may be present. The Lower Sunnyside coal bed is persistent and of good thickness on the outcrop and is probably continuous and of good thickness in this township.

Tonnage estimate.—An estimate of coal tonnage in an area 5 to 10 miles from the nearest outcrop is difficult to make, but if it is based on reasonable assumptions it is a valuable guide to those interested in the coal reserves of the area. It is estimated that the Lower Sunnyside bed, the only bed considered to be present in the two west tiers of sections in T. 14 S., R. 15 E., is 8 feet thick on the average and contains 111,000,000 short tons of coal. This thickness was determined by extending thickness contours based on the decreasing thickness northeast and north from the known place of maximum thickness in sec. 21, T. 15 S., R. 14 E.

Accessibility.—The coal which may underlie the western part of T. 14 S., R. 15 E., is inaccessible at the present time because it lies at depths of 4,700 feet or more, except near the southwest corner, on Range Creek, where, it is estimated, the Lower Sunnyside coal may be reached at 2,750 feet. The present surface is more or less rolling, being near the heads of several streams which lower in their courses have cut deep canyons in the underlying rocks. Any coal that might be mined in this township would have to be transported by one or more of the tramway methods to a place of easy railroad approach, such as Sunnyside. It is probable that a shaft on Range Creek near the pumping station would reach the coal at about 3,000 feet.

T. 15 S., R. 15 E.

General features.—The west edge of T. 15 S., R. 15 E., is from 3 to 4 miles east of the Book Cliffs, in which three beds of coal crop out. The Kenilworth and Upper Sunnyside beds are irregular in thickness and are known to be lenticular along the outcrop. The Lower Sunnyside bed is persistent on the outcrop but shows a gradual decrease in thickness from nearly 14 feet at the south edge of the Wellington quadrangle to less than 4 feet at the west edge. This coal is believed to underlie the Book Cliffs Plateau within the Wellington and Sunnyside quadrangles, but the other coal beds, with an ever-changing thickness, are confined to lenses of irregular size and shape, the limits of which are not definitely known. The Lower Sunnyside is the only coal bed considered to be present under cover in T. 15 S., R. 15 E., but other beds of workable thickness may be present.

Tonnage estimate.—It is estimated that the Lower Sunnyside bed contains about 10½ feet of coal on the average under cover in T. 15 S., R. 15 E., which would yield a total of 96,000,000 short tons for that part of the township situated in the Sunnyside quad-

rangle. The thickness was determined by assuming that the thickness of this coal is at its maximum in sec. 21, T. 15 S., R. 14 E., and that it decreases east and north at a definite rate, which is determined from sections measured on the outcrop. The Kenilworth and Upper Sunnyside beds, which crop out at Sunnyside and farther south, are irregular in thickness and are known to be lenticular on the outcrop, therefore no estimate was made for these beds in T. 15 S., R. 15 E. It is probable that they or other beds are present, and if so they will add much to the tonnage of the township.

Accessibility.—The coal that some day may be mined in T. 15 S., R. 15 E., is to-day inaccessible compared to the vast deposits which crop out on the west and can be reached by railroad. The coal will have to be mined by shafts and will be found at depths ranging from 2,250 to 5,300 feet below the surface. Near the south line of sec. 20 the Lower Sunnyside coal may be found at 2,250 feet, and in the NW. ¼ sec. 6 it may be reached at 2,750 feet below the bed of Range Creek. There is no easy railroad approach to this township, and the coal would have to be transported by aerial tramway over Patmos Mountain to Sunnyside or vicinity.

PHYSICAL CHARACTER OF THE COAL

The coal in these quadrangles is of bituminous rank; it is black, and its powder is brown to black. It is massive and blocky and shows little evidence of bedding, but in places alternations of dull and vitreous bands are common, and bedding planes are visible. Fresh faces have a semivitreous luster, but in many places the weathered outcrop is rusty and its surface is covered with small crystals of alkali salts. The beds are remarkably free from rock partings. The unweathered coal is brittle and hard to pick and has a metallic ring when struck with the hammer. While mining is going on the working faces are continually snapping and splintering. The coal weathers very slowly on exposure to the air and therefore makes a good stocking fuel; it may even be stored for several months in open bins without perceptible deterioration.

Physical tests have been made to determine the relative coking qualities of the coals from several beds. The Upper and Lower Sunnyside beds contain the best coking coal known in the Book Cliffs coal field in Utah and are here used as a standard or type for the field. In making these tests the Pishel coking test,[15] which consists in grinding the coal to a fine powder in an agate mortar, was employed. The stronger the coking tendency of the coal the tighter the powder sticks to the mortar and pestle, and a noncoking coal does not adhere to them at all.

[15] Pishel, M. A., The Pishel coking test; Colliery Engineer, vol. 33, pp. 674–679, 1913.

The Sunnyside beds appear to lose their coking qualities as they extend toward the north and west, samples from Coal Creek, in T. 13 S., R. 11 E., showing only slight coking tendencies. In tests on samples from the Rock Canyon bed very small amounts of the powder adhered to the mortar, indicating that here it is practically a noncoking coal. In a test of a sample of the Fish Creek bed from Coal Creek a thick film of fine dust adhered strongly to the mortar, which indicates that this coal here possesses strong coking tendencies. According to the physical tests made on samples from the Gilson bed the coking qualities differ from place to place. A sample from Coal Creek, at the old Gilson prospect, yielded a thick film of brown-black powder which stuck firmly to the mortar, but on coal from Deadman Creek, at the Knight prospect, the test indicated only medium coking qualities.

A test was made on only one sample of coal from the Kenilworth bed, from Coal Creek in T. 13 S., R. 11 E. A thick film of black powder adhered strongly to the mortar and indicated a coking tendency equal to that of the Sunnyside beds at Sunnyside.

The Pishel coking test indicates only the relative coking qualities of coals, but it is simple and serves well to distinguish between a noncoking coal and a good coking coal.

CHEMICAL COMPOSITION OF THE COAL

The tables of analyses on pages 83 to 86 give the chemical composition of many samples of coal from the Castlegate, Wellington, and Sunnyside quadrangles, as well as from other parts of the Book Cliffs and Wasatch Plateau fields in Utah, and from local fields in Colorado, Wyoming, Montana, and Canada, which are likely to compete with the fields of Carbon and Emery Counties, Utah.

Table 1 gives analyses of individual samples collected inside the mines and there sealed in air-tight cans, which were shipped to the Pittsburgh laboratory of the United States Bureau of Mines. These analyses show the condition of the coal in the mine away from the air and rapid changes in temperature.

Table 2 gives the results of yearly average analyses of coal from several fields, as delivered for Government use during the fiscal years 1908 to 1915, and is copied from Bureau of Mines Bulletin 119, 1916. These analyses were made from samples of the coal delivered at the place of consumption. The details regarding the place of delivery, contract guaranties, and price per ton are given on pages 98 and 99. The number of pounds in a ton is 2,240 unless otherwise stated.

In comparing analyses in Tables 1 and 2 due allowance should be made for the larger percentage of impurities that may be included in the commercial shipments, because the mined coal is necessarily

extracted without so great care as is used in taking samples from the face of a bed in the mine. In spite of the rigid inspection at the tipple enforced by all successful mine operators, the practice of miners will differ, and in mines in which the coal bed has friable partings or a soft flaky roof or floor it is impossible to load the coal free from these impurities. For these reasons the mine sample usually indicates a lower ash content and higher heating value than can be expected in commercial shipments, hence it represents coal that can be produced commercially only under the most favorable conditions. Furthermore, commercial shipments sampled at their destination are likely to contain either more or less moisture than the coal in the mine, depending on the amount of moisture in the bed, the size of the coal, and the weather conditions during transit.

Analyses representing many shipments and a large tonnage more truly indicate the practical value of a particular coal than a single analysis from a specially prepared shipment or analyses of carefully selected mine samples.

In Table 1 the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. This form is not well suited for determining the relative merits of a fuel, because the amount of moisture in a sample of coal as it comes from the mine is largely a matter of accident, and consequently analyses of the same coal expressed in this form may vary as widely as the analyses of coal from different beds or from different fields. Analysis B represents the sample after it has been dried at a temperature of 86° to 95° Fahrenheit until its weight becomes constant. This form of analysis probably represents the coal in the most stable form that it can be put by natural or artificial means and therefore is the one best adapted to general purposes of comparison in order to determine relative fuel values. Analysis C represents the coal after all moisture has been eliminated, and analysis D the coal after all moisture and ash have been theoretically removed. The latter is supposed to represent the true coal substance, free from the most significant impurities. Forms C and D are obtained from the others merely by recalculation. They are useful to the mechanical engineer who desires to reduce his fuel theoretically to a stable, unchanging form in order to test or check the performance of his apparatus and also in a study of the pure coal substance, free from all impurities, but as this substance is not the same as the coal that reaches the bin of the consumer neither Forms C nor D should be used in determining the relative practical fuel values of coals.

The analyses reported from the laboratory have been somewhat generalized, as it is commonly recognized that the figures representing the different percentages are not generally correct to the second decimal place or to the ultimate unit. This is particularly true of

the proximate analysis, and therefore the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only; and the ash (in the ultimate analysis), sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. The determination of the calorific value to individual units is not reliable, hence in the column headed "Calories" the values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest ten, as the value of a British thermal unit is about one-half that of a calorie.

TABLE 1.—*Analyses of coal samples from Carbon, Emery, and Grand Counties, Utah*

Carbon County

[Made by the Bureau of Mines; A. C. Fieldner, chemist in charge. For description of samples, see pp. 87-93]

Laboratory No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
			Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
a 2541	3.9	A	8.1	40.2	45.9	5.7	0.86	-------	-------	-------	-------	-------	-------
		B	4.4	41.8	47.8	6.0	.89	-------	-------	-------	-------	-------	-------
		C	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
		D	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
a 254[illegible]	3.1	A	7.0	41.9	45.8	5.3	.57	-------	-------	-------	-------	-------	-------
		B	4.0	43.2	47.3	5.5	.58	-------	-------	-------	-------	-------	-------
		C	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
		D	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
19680	3.2	A	6.2	40.8	48.5	4.55	.37	5.57	71.47	1.37	16.67	7,040	12,670
		B	3.1	42.1	50.1	4.70	.38	5.39	73.79	1.41	14.33	7,270	13,090
		C	-------	43.5	51.7	4.85	.39	5.21	76.16	1.46	11.93	7,505	13,510
		D	45.7	45.7	54.3	-------	.41	5.48	80.04	1.53	12.54	7,885	14,000
19711	2.2	A	6.0	38.8	49.1	6.1	.49	-------	-------	-------	-------	6,910	12,430
		B	3.9	39.7	50.2	6.2	.50	-------	-------	-------	-------	7,065	12,710
		C	-------	41.3	52.2	6.5	.52	-------	-------	-------	-------	7,350	13,230
		D	-------	44.2	55.8	-------	.56	-------	-------	-------	-------	7,855	14,140
19681	2.0	A	5.0	43.7	46.5	4.80	.41	5.83	71.93	1.31	15.72	7,125	12,820
		B	3.1	44.6	47.4	4.90	.42	5.72	73.39	1.34	14.23	7,270	13,080
		C	-------	46.0	49.0	5.05	.43	5.55	75.72	1.38	11.87	7,500	13,500
		D	-------	48.4	51.6	-------	.45	5.85	79.75	1.45	12.50	7,895	14,220
19712	.9	A	5.1	41.8	47.4	5.7	.55	-------	-------	-------	-------	7,080	12,740
		B	4.2	42.2	47.9	5.7	.56	-------	-------	-------	-------	7,145	12,860
		C	-------	44.1	49.9	6.0	.58	-------	-------	-------	-------	7,455	13,420
		D	-------	46.9	53.1	-------	.62	-------	-------	-------	-------	7,930	14,270
19682	1.5	A	4.4	44.1	46.6	4.94	.68	5.64	72.34	1.29	15.11	7,125	12,830
		B	3.0	44.8	47.2	5.01	.69	5.56	73.42	1.31	14.01	7,230	13,020
		C	-------	46.1	48.7	5.17	.71	5.39	75.68	1.35	11.70	7,455	13,420
		D	-------	48.6	51.4	-------	.75	5.68	79.80	1.42	12.35	7,860	14,150
19710	1.8	A	4.0	41.1	50.5	4.4	.65	-------	-------	-------	-------	7,250	13,050
		B	2.3	41.8	51.4	4.5	.65	-------	-------	-------	-------	7,385	13,290
		C	-------	42.8	52.6	4.6	.68	-------	-------	-------	-------	7,555	13,600
		D	-------	44.9	55.1	-------	.71	-------	-------	-------	-------	7,925	14,260
19702	.7	A	4.7	41.3	47.6	6.4	.41	-------	-------	-------	-------	7,015	12,630
		B	4.0	41.6	48.0	6.4	.41	-------	-------	-------	-------	7,060	12,710
		C	-------	43.4	49.9	6.7	.43	-------	-------	-------	-------	7,360	13,240
		D	-------	46.5	53.5	-------	.46	-------	-------	-------	-------	7,885	14,190
19706	.7	A	4.0	45.7	44.7	5.6	.54	-------	-------	-------	-------	7,175	12,920
		B	3.3	46.0	45.0	5.7	.54	-------	-------	-------	-------	7,225	13,000
		C	-------	47.6	46.5	5.9	.56	-------	-------	-------	-------	7,475	13,460
		D	-------	50.6	49.4	-------	.59	-------	-------	-------	-------	7,940	14,290

TABLE 1.—*Analyses of coal samples from Carbon, Emery, and Grand Counties, Utah*—Continued

Carbon County—Continued

Laboratory No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
			Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
19843	1.3	A	3.7	42.8	48.2	5.31	0.33	5.78	73.94	1.26	13.38	7,325	13,190
		B	2.4	43.4	48.8	5.38	.33	5.71	74.94	1.28	12.36	7,425	13,360
		C	-------	44.4	50.1	5.51	.34	5.58	76.78	1.31	10.48	7,605	13,690
		D	-------	47.0	53.0	-------	.36	5.91	81.26	1.39	11.08	8,050	14,490
19845	2.6	A	4.8	40.3	45.9	8.99	.65	5.61	69.62	1.35	13.78	6,945	12,500
		B	2.2	41.4	47.2	9.23	.67	5.46	71.48	1.39	11.77	7,130	12,830
		C	-------	42.3	48.3	9.44	.68	5.33	73.11	1.42	10.02	7,290	13,130
		D	-------	46.7	53.3	-------	.75	5.89	80.73	1.57	11.06	8,050	14,490
19844	1.3	A	3.8	44.7	44.4	7.09	.61	5.88	71.86	1.39	13.17	7,195	12,950
		B	2.6	45.2	45.0	7.18	.62	5.81	72.78	1.41	12.20	7,290	13,120
		C	-------	46.4	46.2	7.37	.63	5.68	74.71	1.45	10.16	7,480	13,470
		D	-------	50.1	49.9	-------	.68	6.13	80.66	1.57	10.96	8,075	14,540
19846	2.2	A	5.0	41.8	48.4	4.77	.47	5.76	73.10	1.38	14.52	7,255	13,060
		B	2.8	42.8	49.5	4.88	.48	5.63	74.75	1.41	12.85	7,420	13,360
		C	-------	44.0	51.0	5.02	.49	5.48	76.93	1.45	10.63	7,635	13,750
		D	-------	46.3	53.7	-------	.52	5.77	81.00	1.53	11.18	8,040	14,470
19847	1.9	A	4.6	42.3	46.9	6.16	.49	5.72	71.80	1.37	14.46	7,150	12,870
		B	2.8	43.1	47.8	6.28	.50	5.62	73.17	1.40	13.03	7,285	13,120
		C	-------	44.3	49.2	6.46	.51	5.46	75.24	1.44	10.89	7,495	13,490
		D	-------	47.4	52.6	-------	.55	5.84	80.44	1.54	11.63	8,010	14,420
19880	1.0	A	3.3	42.5	48.0	6.19	.40	5.60	73.22	1.35	13.24	7,260	13,060
		B	2.3	43.0	48.5	6.25	.40	5.54	73.99	1.36	12.46	7,335	13,200
		C	-------	44.0	49.6	6.40	.41	5.41	75.72	1.40	10.66	7,505	13,510
		D	-------	47.0	53.0	-------	.44	5.78	80.90	1.50	11.38	8,020	14,430
19879	.9	A	3.0	43.5	46.9	6.57	.47	5.67	73.25	1.41	12.63	7,290	13,120
		B	2.1	43.9	47.4	6.63	.47	5.62	73.93	1.42	11.93	7,360	13,240
		C	-------	44.8	48.4	6.78	.48	5.50	75.56	1.45	10.23	7,520	13,540
		D	-------	48.1	51.9	-------	.51	5.90	81.05	1.56	10.98	8,065	14,520
19881	1.3	A	3.6	45.6	45.4	5.38	.58	6.06	74.33	1.42	12.23	7,410	13,340
		B	2.3	46.2	46.0	5.45	.59	6.00	75.28	1.44	11.24	7,505	13,510
		C	-------	47.3	47.1	5.58	.60	5.87	77.07	1.47	9.41	7,685	13,840
		D	-------	50.1	49.9	-------	.64	6.22	81.62	1.56	9.96	8,140	14,650
19837	2.2	A	4.6	43.3	44.6	7.5	.76	-------	-------	-------	-------	7,065	12,710
		B	2.5	44.2	45.7	7.6	.78	-------	-------	-------	-------	7,220	12,990
		C	-------	45.4	46.8	7.8	.80	-------	-------	-------	-------	7,400	13,320
		D	-------	49.2	50.8	-------	.87	-------	-------	-------	-------	8,035	14,460
19838	1.8	A	4.1	41.3	45.9	8.7	.69	-------	-------	-------	-------	6,990	12,580
		A	2.3	42.1	46.7	8.9	.70	-------	-------	-------	-------	7,120	12,810
		C	-------	43.1	47.8	9.1	.72	-------	-------	-------	-------	7,285	13,110
		D	-------	47.4	52.6	-------	.79	-------	-------	-------	-------	8,015	14,430
19986	2.4	A	4.4	42.9	44.3	8.43	.55	5.78	70.43	1.42	13.39	7,050	12,690
		B	2.1	43.9	45.4	8.63	.56	5.65	72.13	1.45	11.58	7,220	13,000
		C	-------	44.9	46.3	8.82	.58	5.54	73.70	1.49	9.87	7,380	13,280
		D	-------	49.2	50.8	-------	.64	6.08	80.83	1.63	10.82	8,090	14,560
19987	3.9	A	6.0	42.9	46.2	4.93	.85	6.03	71.80	1.52	14.87	7,190	12,940
		B	2.2	44.7	48.0	5.13	.88	5.82	74.72	1.58	11.87	7,485	13,470
		C	-------	45.7	49.1	5.25	.90	5.70	76.39	1.62	10.14	7,650	13,770
		D	-------	48.2	51.8	-------	.95	6.02	80.62	1.71	10.70	8,075	14,540
19990	2.8	A	4.9	42.2	44.7	8.15	.39	5.71	70.19	1.36	14.20	6,960	12,530
		B	2.2	43.4	46.0	8.38	.40	5.55	72.17	1.40	12.10	7,160	12,890
		C	-------	44.4	47.0	8.57	.41	5.44	73.80	1.43	10.35	7,320	13,180
		D	-------	48.5	51.5	-------	.45	5.95	80.72	1.56	11.32	8,005	14,410
19988	1.6	A	3.8	45.7	44.5	6.00	.36	5.88	73.12	1.35	13.29	7,260	13,070
		B	2.2	46.5	45.2	6.10	.37	5.79	74.33	1.37	12.04	7,380	13,290
		C	-------	47.6	46.2	6.24	.37	5.67	75.99	1.40	10.33	7,545	13,580
		D	-------	50.7	49.3	-------	.39	6.05	81.05	1.49	11.02	8,050	14,490

TABLE 1.—*Analyses of coal samples from Carbon, Emery, and Grand Counties, Utah*—Continued

Carbon County—Continued

Laboratory No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
			Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
19989	2.8	A	4.9	42.8	46.2	6.07	0.41	5.80	71.80	1.37	14.55	7,140	12,850
		B	2.1	44.1	47.5	6.25	.42	5.65	73.89	1.41	12.38	7,345	13,220
		C	-------	45.1	48.5	6.38	.43	5.53	75.50	1.44	10.72	7,505	13,510
		D	-------	48.1	51.9	-------	.46	5.91	80.64	1.54	11.45	8,015	14,430
14678	.3	A	5.7	41.9	47.7	4.7	.58	-------	-------	-------	-------	7,020	12,640
		B	5.4	42.0	47.8	4.8	.58	-------	-------	-------	-------	7,040	12,680
		C	-------	44.4	50.6	5.0	.61	-------	-------	-------	-------	7,445	13,400
		D	-------	46.8	53.2	-------	.64	-------	-------	-------	-------	7,840	14,110
14801	5.3	A	8.5	39.8	47.9	3.8	.48	-------	-------	-------	-------	7,115	12,810
		B	3.4	42.0	50.5	4.1	.51	-------	-------	-------	-------	7,515	13,520
		C	-------	43.5	52.3	4.2	.52	-------	-------	-------	-------	7,780	14,000
		D	-------	45.4	54.6	-------	.54	-------	-------	-------	-------	8,120	14,620
12631	2.1	A	5.1	39.9	47.7	7.3	1.37	-------	-------	-------	-------	7,095	12,770
		B	3.0	40.8	48.7	7.5	1.40	-------	-------	-------	-------	7,245	13,040
		C	-------	42.1	50.2	7.7	1.44	-------	-------	-------	-------	7,475	13,450
		D	-------	45.6	54.4	-------	1.56	-------	-------	-------	-------	8,095	14,570
17604	1.1	A	4.1	38.0	49.9	8.0	1.15	5.66	71.91	1.47	11.75	7,130	12,840
		B	3.0	38.4	50.5	8.1	1.16	5.59	72.74	1.49	10.87	7,215	12,980
		C	-------	39.6	52.0	8.4	1.20	5.43	74.95	1.53	8.49	7,435	13,380
		D	-------	43.2	56.8	-------	1.31	5.93	81.82	1.67	9.27	8,115	14,610
17605	1.2	A	4.4	38.2	50.5	6.9	.82	-------	-------	-------	-------	-------	-------
		B	3.3	38.6	51.1	7.0	.83	-------	-------	-------	-------	-------	-------
		C	-------	39.9	52.8	7.3	.86	-------	-------	-------	-------	-------	-------
		D	-------	43.0	57.0	-------	.93	-------	-------	-------	-------	-------	-------
12632	3.40	A	5.9	38.7	48.8	6.6	1.73	5.43	71.28	1.52	13.45	7,135	12,840
		B	2.7	40.0	50.5	6.8	1.79	5.23	73.79	1.57	10.80	7,385	13,290
		C	-------	41.1	51.9	7.0	1.84	5.07	75.80	1.62	8.66	7,585	13,660
		D	-------	44.2	55.8	-------	1.98	5.45	81.52	1.74	9.31	8,160	14,680
12546	1.0	A	6.0	38.1	48.8	7.1	.56	-------	-------	-------	-------	6,665	11,990
		B	5.0	38.5	49.3	7.2	.57	-------	-------	-------	-------	6,730	12,110
		C	-------	40.5	51.9	7.6	.60	-------	-------	-------	-------	7,085	12,750
		D	-------	43.8	56.2	-------	.65	-------	-------	-------	-------	7,665	13,800
12630	1.5	A	5.1	38.4	48.7	7.8	.51	5.54	70.72	1.58	13.84	7,010	12,620
		B	3.6	39.1	49.4	7.9	.52	5.45	71.80	1.60	12.70	7,120	12,810
		C	-------	40.5	51.3	8.2	.54	5.25	74.49	1.66	9.83	7,385	13,290
		D	-------	44.1	55.9	-------	.59	5.72	81.17	1.81	10.71	8,045	14,490
12545	2.50	A	15.2	33.9	46.2	4.7	.60	-------	-------	-------	-------	5,295	9,530
		B	13.0	34.7	47.4	4.9	.62	-------	-------	-------	-------	5,430	9,770
		C	-------	39.9	54.5	5.6	.71	-------	-------	-------	-------	6,240	11,230
		D	-------	42.3	57.7	-------	.75	-------	-------	-------	-------	6,610	11,900
12792	2.90	A	6.7	38.6	49.5	5.2	1.04	-------	-------	-------	-------	6,730	12,110
		B	3.9	39.7	51.0	5.4	1.07	-------	-------	-------	-------	6,930	12,470
		C	-------	41.3	53.1	5.6	1.11	-------	-------	-------	-------	7,210	12,980
		D	-------	43.8	56.2	-------	1.18	-------	-------	-------	-------	7,635	13,740
Emery County													
4015	2.9	A	5.2	36.0	52.7	6.1	0.83	5.26	71.22	1.29	15.32	7,240	13,030
		B	2.4	37.1	54.3	6.3	.85	5.09	73.35	1.34	13.12	7,455	13,420
		C	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
		D	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
4013	4.1	A	9.0	31.8	51.0	8.2	.46	4.97	62.22	1.25	22.92	6,035	10,860
		B	5.1	33.2	53.2	8.5	.47	4.71	64.88	1.30	20.11	6,295	11,330
		C	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
		D	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

TABLE 1.—*Analyses of coal samples from Carbon, Emery, and Grand Counties, Utah*—Continued

Emery County—Continued

Laboratory No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
			Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
2613	0.9	A	4.0	41.8	42.6	11.6	4.7	-------	-------	-------	-------	6,660	11,990
		B	3.1	42.2	43.0	11.7	4.7	-------	-------	-------	-------	6,720	12,100
		C	-------	43.6	44.3	12.1	4.9	-------	-------	-------	-------	6,935	12,480
		D	-------	49.6	50.4	-------	5.5	-------	-------	-------	-------	7,890	14,200
12627	.3	A	4.0	40.9	49.2	5.93	.39	5.52	73.02	1.25	13.89	7,205	12,960
		B	3.6	41.0	49.4	5.95	.39	5.51	73.24	1.25	13.66	7,225	13,000
		C	-------	42.6	51.2	6.17	.41	5.29	76.01	1.30	10.82	7,500	13,500
		D	-------	45.4	54.6	-------	.44	5.64	81.01	1.39	11.52	7,990	14,380
12652	1.8	A	5.2	39.1	41.6	14.1	.8	-------	-------	-------	-------	6,265	11,270
		B	3.5	39.8	42.4	14.3	.8	-------	-------	-------	-------	6,380	11,480
		C	-------	41.2	43.9	14.9	.9	-------	-------	-------	-------	6,605	11,890
		D	-------	48.4	51.6	-------	1.0	-------	-------	-------	-------	7,765	13,970
22350	4.4	A	7.5	43.0	43.4	6.0	.63	-------	-------	-------	-------	6,935	12,480
		B	3.3	45.0	45.4	6.3	.66	-------	-------	-------	-------	7,255	13,055
		C	-------	46.5	47.0	6.5	.68	-------	-------	-------	-------	7,500	13,500
		D	-------	49.8	50.2	-------	.73	-------	-------	-------	-------	8,025	14,440
22351	4.1	A	7.5	41.9	45.1	5.6	.60	-------	-------	-------	-------	6,980	12,560
		B	3.5	43.7	47.0	5.8	.63	-------	-------	-------	-------	7,280	13,100
		C	-------	45.3	48.7	6.0	.65	-------	-------	-------	-------	7,540	13,580
		D	-------	48.2	51.8	-------	.69	-------	-------	-------	-------	8,025	14,440
22352	2.2	A	6.5	42.1	44.0	7.5	.95	-------	-------	-------	-------	6,895	12,410
		B	4.4	43.1	44.9	7.6	.97	-------	-------	-------	-------	7,045	12,680
		C	-------	45.0	47.0	8.0	1.02	-------	-------	-------	-------	7,370	13,260
		D	-------	49.0	51.1	-------	1.11	-------	-------	-------	-------	8,005	14,410
22353	3.4	A	7.1	42.1	45.7	5.1	.70	-------	-------	-------	-------	6,990	12,580
		B	3.8	43.6	47.4	5.2	.72	-------	-------	-------	-------	7,240	13,030
		C	-------	45.3	49.2	5.5	.75	-------	-------	-------	-------	7,525	13,540
		D	-------	48.0	52.1	-------	.79	-------	-------	-------	-------	7,955	14,320
22354	3.0	A	6.6	43.4	44.3	5.7	.76	-------	-------	-------	-------	7,045	12,680
		B	3.7	44.7	45.7	5.9	.78	-------	-------	-------	-------	7,260	13,070
		C	-------	46.5	47.5	6.1	.81	-------	-------	-------	-------	7,545	13,580
		D	-------	49.5	50.5	-------	.86	-------	-------	-------	-------	8,030	14,460
22355	3.7	A	7.4	41.0	46.9	4.8	.72	-------	-------	-------	-------	6,985	12,580
		B	3.9	42.5	48.7	4.9	.75	-------	-------	-------	-------	7,255	13,060
		C	-------	44.2	50.6	5.1	.78	-------	-------	-------	-------	7,545	13,580
		D	-------	46.6	53.4	-------	.82	-------	-------	-------	-------	7,955	14,320
22356	4.0	A	7.5	43.0	43.8	5.7	.63	-------	-------	-------	-------	6,955	12,520
		B	3.6	44.8	45.6	5.9	.66	-------	-------	-------	-------	7,245	13,040
		C	-------	46.5	47.3	6.2	.68	-------	-------	-------	-------	7,515	13,530
		D	-------	49.6	50.4	-------	.72	-------	-------	-------	-------	8,010	14,420
22357	3.5	A	7.2	42.2	44.8	5.8	.68	5.71	69.85	1.43	16.48	6,965	12,540
		B	3.8	43.7	46.5	6.1	.70	5.52	72.41	1.48	13.83	7,220	13,000
		C	-------	45.4	48.3	6.3	.73	5.29	75.26	1.54	10.88	7,505	13,510
		D	-------	48.5	51.5	-------	.78	5.65	80.32	1.64	11.61	8,010	14,410
22414	3.5	A	7.6	41.7	44.2	6.5	.71	-------	-------	-------	-------	6,840	12,310
		B	4.3	43.2	45.8	6.7	.74	-------	-------	-------	-------	7,085	12,750
		C	-------	45.2	47.9	7.0	.77	-------	-------	-------	-------	7,405	13,330
		D	-------	48.6	51.4	-------	.83	-------	-------	-------	-------	7,960	14,320
17577F	2.0	A	7.1	37.1	45.4	10.4	.66	5.59	65.98	1.45	15.88	6,510	11,720
		B	5.3	37.8	46.3	10.6	.67	5.48	67.29	1.48	14.43	6,640	11,950
		C	-------	39.9	48.9	11.2	.71	5.17	71.05	1.56	10.27	7,010	12,620
		D	-------	44.9	55.1	-------	.80	5.82	80.04	1.76	11.58	7,895	14,210

2541. Bituminous coal from No. 1 mine of Utah Fuel Co., in Pleasant Valley district of Wasatch Plateau coal field, in the N. ½ sec. 7, T. 13 S., R. 7 E., on a branch of the Denver & Rio Grande Western Railroad. Coal bed, Winterquarters; Upper Cretaceous age; Blackhawk formation. Roof and floor are sandstone. Coal ranges from 9 to 16 feet in thickness. Sample was taken from southeastern part of mine, 6,000 feet from mine mouth, in 1905, by J. A. Taff, and included the full thickness of 16 feet.

2542. Bituminous coal from Clear Creek mine of Utah Fuel Co. at the terminus of the Pleasant Valley branch of the Denver & Rio Grande Western Railroad, in sec. 33, T. 13 S., R. 7 E., in the Pleasant Valley district of the Wasatch Plateau field. Coal bed, Clear Creek; Upper Cretaceous age; Blackhawk formation. Sample was taken from southern part of the mine, 3,000 feet from mine mouth, in 1905, by J. A. Taff, and represents 13 feet 5 inches of good, clean coal.

19680. Bituminous coal from Kenilworth (slope) mine of Independent Coal & Coke Co., in NW. ¼ sec. 16, T. 13 S., R. 10 E., three-quarters of a mile north of Kenilworth, at terminus of Kenilworth & Helper Railroad. Coal bed, Castlegate "A"; Upper Cretaceous age; Blackhawk formation. Roof and floor are coal. Sample cut from face of No. 10 right entry, 2,260 feet N. 30° W., 1,700 feet west, and 790 feet east from mine mouth, July 16, 1914, by F. R. Clark; represents 6 feet 10 inches of coal, only part of thickness of bed.

19711. Bituminous coal from same mine as No. 19680. Coal bed, Castlegate "A"; Upper Cretaceous age; Blackhawk formation. Roof and floor are coal. Sample dry; cut in room 7 off No. 9 left entry, 2,200 feet N. 30° W., 1,200 feet north, 530 feet west, and 100 feet S. 37° W. from mine mouth, July 24, 1914, by F. R. Clark; represents 16 feet 2 inches of coal, only part of thickness of bed.

19681. Bituminous coal from same mine as No. 19680. Coal bed, Kenilworth; Upper Cretaceous age; Blackhawk formation. Roof is sandstone and floor is coal. Sample dry; cut from face of main slope, 1,950 feet N. 33° W., 140 feet N. 19° E., 510 feet north, 165 feet west, and 165 feet north from mine mouth, July 16, 1914, by F. R. Clark.

19712. Bituminous coal from same mine as No. 19680. Coal bed, Kenilworth; Upper Cretaceous age; Mesaverde formation. Roof and floor are coal. Sample dry; cut at face of No. 1 left back entry, 1,930 feet N. 33° W., 150 feet N. 19° E., 455 feet north, 165 feet west, and 300 feet S. 70° W. from mine mouth; July 24, 1914, by F. R. Clark; represents 7 feet of coal, partial thickness of bed. Coal left as floor about 1 foot; thickness of roof coal not determined.

19682. Bituminous coal from same mine as No. 19680. Coal bed, Royal Blue; Upper Cretaceous age; Mesaverde formation. Roof is sandstone and floor is shale. Sample dry; cut from face of No. 1 right entry up new tunnel, 1,930 feet N. 33° W., 140 feet N. 19° W., 290 feet north, and 100 feet east from mine mouth, July 16, 1914, by F. R. Clark; represents 5 feet 7 inches of coal, entire thickness of bed.

19710. Bituminous coal from same mine as No. 19680. Coal bed, Royal Blue; Upper Cretaceous age; Mesaverde formation. Roof and floor are sandstone. Sample wet; cut in room 3 off No. 2 west entry, 350 feet N. 7° W., 250 feet N. 81° W., and 250 feet S. 57° W. from mine mouth, July 24, 1914, by F. R. Clark; represents entire bed. Section at point sampled is as follows:

	Ft.	in.
Coal, soft		8
Coal, dull, hard		2
Coal, bright, hard	1	8
Bone		½
Coal, bright, hard	1	8
Bone		1
Coal, very hard	2	3
	6	6½

19702. Bituminous coal from Aberdeen (wagon drift) mine, in SW. ¼ sec. 10, T. 13 S., R. 10 E., 1½ miles northeast of Kenilworth, at terminus of Kenilworth & Helper Railroad. Coal bed, Aberdeen; Upper Cretaceous age; Mesaverde formation. Roof is sandstone and floor is coal. Sample dry; cut 460 feet west of mine mouth July 23, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal (sampled)	10	10
Coal	3	4
	14	2

19706. Bituminous coal from Milburn (wagon drift) mine, in SW. ¼ sec. 11, T. 13 S., R. 10 E., 2¼ miles northeast of Kenilworth, at terminus of Kenilworth & Helper Railroad. Coal bed, Kenilworth; Upper Cretaceous age; Mesaverde formation. Sample cut 100 feet N. 55° W. and 90 feet north from mine mouth July 23, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Shale, brown		9
Coal (sampled)	6	4
Coal	4	10
	11	11

19843. Bituminous coal from Castlegate No. 2 (drift) mine of Utah Fuel Co., in NW. ¼ sec. 6, T. 13 S., R. 10 E., three-fourths of a mile northeast of Castlegate, on Denver & Rio Grande Western Railroad. Coal bed, "D"; Upper Cretaceous age; Mesaverde formation. Roof and floor are coal. Sample cut in No. 1 left main entry off No. 1 rise, 3,200 feet south of mine mouth, September 23, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal	Thickness unknown.	
Bone		½
Coal (sampled)	3	3
Bone		1
Coal (sampled)		3
Bone		½
Coal (sampled)	3	4
Coal, cut by machine		6
Coal	Thickness unknown.	
	7	6+

19845. Bituminous coal from same mine as No. 19843. Coal bed, "B"; Upper Cretaceous age; Mesaverde formation. Roof and floor are sandstone. Sample cut at face of No. 4 right entry off No. 1 rise, 1,700 feet S. 30° E. of mine mouth, September 23, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal		6
Bone		3
Coal (sampled)		6
Bone		3
Coal (sampled)		7
Bone		2
Coal (sampled)	3	5
Bone		5
Coal (sampled)		8
Coal	Thickness unknown.	
	6	9+

19844. Bituminous coal from Castlegate No. 1 (slope) mine of Utah Fuel Co., in NW. ¼ sec. 1, T. 13 S., R. 9 E., at Castlegate, on Denver & Rio Grande Western Railroad. Coal bed, Castlegate "D." Upper Cretaceous age; Blackhawk formation. Roof and floor are sandstone. Sample cut in mine in No. 1 right entry off No. 1 dip, 5,400 feet S. 66° W. and 1,400 feet N. 45° W. from mine mouth, September 22, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal (sampled)	4	10
Coal		2
	5	

19846. Bituminous coal from same mine as No. 19844. Coal bed, Castlegate "C"; Upper Cretaceous age; Blackhawk formation. Roof and floor are sandstone. Sample cut in room 18 off No. 4 right entry off No. 1 rise, 5,400 feet S. 66° W. and 1,900 feet S.

45° W. from mine mouth, September 22, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Bone		3
Coal (sampled)	5	7
	5	10

19847. Bituminous coal from same mine as No. 19844. Coal bed, Castlegate "A"; Upper Cretaceous age; Blackhawk formation. Roof is coal and floor is sandstone. Sample dry; cut at entry stump on No. 12 level off No. 10 rise, 4,000 feet S. 66° W., 4,650 feet S. 4° W., and 200 feet S. 80° E. from mine mouth, September 22, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal		8±
Coal (sampled)	7	4½
Bone		3
	8	3½±

19880. Bituminous coal from No. 1 (slope) mine of Cameron Coal Co., in sec. 35, T. 12 S., R. 9 E., 1½ miles northwest of Castlegate, on Denver & Rio Grande Western Railroad. Coal Bed No. 1; Upper Cretaceous age; Blackhawk formation. Sample cut in second left main entry 800 feet south and 50 feet west from slope mouth. September 24, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal (mine roof)		8
Coal (sampled)	5	6½
Coal (mine floor)		6
	6	8½

19879. Bituminous coal from No. 2 (slope) mine of Cameron Coal Co., in NE. ¼ sec. 35, T. 12 S., R. 9 E., 1½ miles northwest of Castlegate, on Denver & Rio Grande Western Railroad. Coal bed No. 2; Upper Cretaceous age; Blackhawk formation. Roof and floor are shale. Sample cut at face of main rise entry, 900 feet S. 85° W. of mine mouth, September 24, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal, not mined	2±	
Bone, mine roof		4
Coal (sampled)	5	
Coal, cut by machine		6½
Coal, mine floor		9
	8	7½±

19881. Bituminous coal from Panther (slope) mine of Panther Coal Co., in sec. 1, T. 13 S., R. 9 E., 1¼ miles north of Carbon post office, on Denver & Rio Grande Western Railroad. Coal bed, Castlegate; Upper Cretaceous age; Blackhawk formation. Roof and floor shale. Sample cut at face of No. 2 east entry off main slope, 1,000 feet N. 45° E. and 500 feet east from mouth, September 25, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal		4
Bone		5
Coal (sampled)	6	2½
	6	11½

19837. Bituminous coal from drift prospect in Hardscrabble Canyon, in SW. ¼ NE. ¼ sec. 10, T. 13 S., R. 9 E., 3 miles northwest of Helper, on Denver & Rio Grande Western Railroad. Coal bed, Spring Canyon No. 1; Upper Cretaceous age; Mesaverde formation. Roof is sandy shale and floor is sandstone. Sample dry and possibly slightly weathered; cut at face of main entry, 350 feet S. 35° W. of opening. September 19, 1914, by F. R. Clark; represents 4 feet ½ inch of coal, entire thickness of bed.

19838. Bituminous coal from drift prospect near same prospect and from same bed as No. 19837. Sample dry and perhaps slightly weathered; cut at face of main entry, 400 feet S. 70° W. of mine mouth, September 19, 1914, by F. R. Clark; represents 4 feet of coal, entire thickness of bed.

19986. Bituminous coal from No. 1 (slope) mine of Spring Canyon Coal Co., in sec. 9, T. 13 S., R. 9 E., at

Storrs, on Spring Canyon Railroad. Coal bed, Spring Canyon No. 1; Upper Cretaceous age; Mesaverde formation. Roof is shale and floor is sandstone. Sample wet; cut at face of No. 4 right entry off main entry, 1,720 feet N. [illegible] W. of mine mouth, October 16, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal (sampled)	6	4
Bone		2
Coal (sampled)	2	2
Coal		4
	9	0

19987. Bituminous coal from No. 2 (drift) mine of Spring Canyon Coal Co., in sec. 9, T. 13 S., R. 9 E., at Storrs, on Spring Canyon Railroad. Coal bed, Spring Canyon No. 2; Upper Cretaceous age; Mesaverde formation. Roof and floor are shale. Sample cut at face of main entry, 810 feet east of mine mouth, October 17, 1914, by F. R. Clark; represents 4 feet 2½ inches of coal, entire thickness of bed.

19990. Bituminous coal from No. 3 (drift) mine of Spring Canyon Coal Co., in sec. 9, T. 13 S., R. 9 E., at Storrs, on Spring Canyon Railroad. Coal bed, Spring Canyon No. 3 (Aberdeen); Upper Cretaceous age; Mesaverde formation. Roof and floor are sandstone. Sample dry; cut at face of main entry October 17, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal (sampled)	3	10
Bone		½
Coal (sampled)	3	10
Coal		8
	8	4½

19988. Bituminous coal from Standard (drift) mine of Standard Coal Co., in sec. 8, T. 13 S., R. 9 E., at Standardville, terminus of Spring Canyon Railroad. Coal bed, Castlegate; Upper Cretaceous age; Mesaverde formation. Roof and floor are sandstone. Sample dry; taken in crosscut 200 feet S. 50° E. of face of fan way or 1,450 feet N. 50° W. of mine mouth, October 17, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal (on roof)	1	
Coal (sampled)	8	2
Coal, cannel (sampled)		1
Bone		1½
Coal (lower bench)	5	8
	15	½

19989. Bituminous coal from same mine as No. 19988. Coal bed, Castlegate; Upper Cretaceous age; Mesaverde formation. Roof and floor are sandstone. Sample dry; cut 150 feet from face of fan way or 1,550 feet N. 50° W. of mine mouth October 17, 1914, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal	8±	
Coal, cannel		1
Bone		8
Coal (sampled)	1	8
Bone		1
Coal (sampled)	3	4
Coal		10
	14	8

14678. Bituminous coal from Jesse Knight prospect, in Deadman Canyon, sec. 7, T. 13 S., R. 11 E., 11 miles due north of Wellington, on Denver & Rio Grande Western Railroad. Position of this prospect is shown on Plate 12, at location 49. Coal bed, Gilson; Upper Cretaceous age; Blackhawk formation. Roof and floor are sandy shale. Sample cut from face 90 feet west of opening, August 28, 1912, by F. R. Clark; represents slightly weathered coal. Section of the bed at point sampled is as follows:

	Ft.	in.
Coal (sampled)	2	2½
Shale, sandy brown		3
Coal (sampled)	5	3
	7	8½

14801. Bituminous coal from Branch Bros.' prospect, 14 miles north-

east of Wellington, on main line of Denver & Rio Grande Western Railroad, in the SE. ¼ NW. ¼ sec. 23, T. 13 S., R. 12 E. (location 140, pls. 7 and 12), in Dugout Canyon. Coal bed, Gilson; Upper Cretaceous age; Blackhawk formation. Roof is sandstone and floor is sandy shale. Sample cut from the face 500 feet east of opening, September 29, 1912, by F. R. Clark; represents slightly weathered coal. Section at point sampled is as follows:

	Ft.	in.
Coal, bony		2
Shale, sandy		1½
Coal (sampled)	2	5
Shale, sandy		1½
Coal (sampled)	5	8
	8	6

12631. Bituminous coal from No. 3 (drift) mine of Utah Fuel Co., at Sunnyside. Coal bed, Lower Sunnyside; Upper Cretaceous age; Blackhawk formation. Roof is sandy shale and floor is sandstone. Sample cut in the "dips" near location of sample 12630; represents upper 6 feet 10 inches of the 8-foot coal bed. Sample collected September 13, 1911, by F. R. Clark.

17604. Bituminous coal from No. 3 (drift) mine of the Utah Fuel Co., at Sunnyside. Coal bed, Lower Sunnyside. Sample dry; cut from face of second left entry in "dips," 150 feet in room No. 1, about 1 mile northeast of mine mouth, August 5, 1913, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal	1	
Coal (sampled)	6	10
Coal	2	
	9	10

17605. Bituminous coal from same mine as sample 17604. Coal bed, Upper Sunnyside. Sample dry; cut from room No. 5 off second right entry, about 1 mile from mine mouth, August 5, 1913, by F. R. Clark; includes total thickness of 5 feet 4 inches of good clean coal.

12632. Bituminous coal from No. 1 (slope) mine of Utah Fuel Co., at Sunnyside. Coal bed, Lower Sunnyside. Upper Cretaceous age; Blackhawk formation. Sample wet; cut from face of Fowler slope September 14, 1911, by F. R. Clark. Section at point sampled is as follows:

	Ft.	in.
Coal	1	7
Coal (sampled)	5	5
	7	

12546. Bituminous coal from airway in No. 3 (drift) mine of Utah Fuel Co., Sunnyside. Coal bed, Upper Sunnyside; Upper Cretaceous age; Blackhawk formation. Roof and floor are brown shale. Sample cut 50 feet north of mouth of air tunnel, at location 371, in sec. 9, T. 15 S., R. 14 E., August 7, 1911, by F. R. Clark; represents total thickness of 6 feet 2 inches.

12630. Bituminous coal from No. 3 (drift) mine of Utah Fuel Co., at Sunnyside, near mine No. 1. Coal bed, Upper Sunnyside; Upper Cretaceous age; Blackhawk formation. Roof and floor are sandy shale. Sample cut from face of second crosscut off first right of No. 1 rise, 2¾ miles southeast of mine mouth, September 13, 1911, by F. R. Clark; included full thickness of 56 inches of coal.

12545. Bituminous coal from prospect pit at location 341, 1 mile south of Sunnyside, at terminus of Sunnyside branch of Denver & Rio Grande Western Railroad. Coal bed, Lower Sunnyside; Upper Cretaceous age; Blackhawk formation. Roof and floor are sandstone. Sample cut 85 feet northeast of opening August 3, 1911, by F. R. Clark. Section at point sampled is as follows:

Sandstone.	Ft.	in.
Coal	2	8
Shale, sandy	2	2
Coal (lower 6 feet sampled)	9	
Sandstone.		
	13	10

12792. Bituminous coal from Rock Canyon prospect (location 208, pls.

8 and 12), about 15 miles northeast of Wellington on main line of Denver & Rio Grande Western Railroad; no railroad connection. Coal bed, Rock Canyon; Upper Cretaceous age; Blackhawk formation. Roof and floor are sandstone. Sample cut from face of drift 200 feet north of opening; represents full thickness of coal, 5 feet 7 inches. The coal was slightly weathered.

4015. Bituminous coal from a prospect in Horse Canyon, sec. 4, T. 16 S., R. 14 E. Coal bed, Lower Sunnyside (?); Upper Cretaceous age; Blackhawk formation. Sample taken 400 feet from opening, in the autumn of 1906, by G. B. Richardson; represents 13 feet 5 inches of coal.

4013. Bituminous coal from Prentiss prospect, about 9 miles south of Sunnyside, Carbon County, at terminus of Sunnyside branch of Denver & Rio Grande Western Railroad. Coal bed, Lower Sunnyside (?); Upper Cretaceous age; Blackhawk formation. Roof and floor are sandstone. Coal measured and sampled October 18, 1906, by G. B. Richardson. Section of bed at point sampled as follows:

	Ft.	in.
Coal	2	
Shale and sandstone	4	
Coal (sampled)	14	11
	20	11

12613. Bituminous coal, slightly weathered, from Williams mine, a drift prospect, in sec. 12, T. 22 S., R. 5 E., 3½ miles southeast of Emery; no railroad connection. Coal bed, I (Williams), Upper Cretaceous age; Ferron sandstone member of Mancos shale. Coal measured and sampled 100 feet from opening, September 14, 1911, by C. T. Lupton; sample represents 5 feet 9½ inches of coal.

12627. Bituminous coal from Browning mine (drift prospect), in sec. 33, T. 22 S., R. 6 E., 4 miles south of Emery. No railroad connection. Coal bed, I (Pugsley); Upper Cretaceous age; Ferron sandstone member of Mancos shale. Sample taken 165 feet from opening, September 19, 1911, by C. T. Lupton; represents lower 12 feet of a 20-foot bed of clean coal.

12652. Bituminous coal from Casper mine (drift prospect), in sec. 22, T. 22 S., R. 6 E., 4 miles southeast of Emery. No railroad connection. Coal bed, C (Grassy Valley); Upper Cretaceous age; Ferron sandstone member of Mancos shale. Sample taken at end of right entry, 250 feet from opening, September 23, 1911, by C. T. Lupton. Section of bed at point sampled is as follows:

	Ft.	in.
Coal	1	3
Sandstone and shale	1	3½
Bone		2
Coal (sampled)	1	6
Bone	1	1½
Coal (sampled)	4	6
	9	10

22350–22357, 22414. Bituminous semicoking coal from Black Hawk mine, a slope mine in Book Cliffs field, Castle Valley district, in sec. 4, T. 16 S., R. 8 E., three-fourths of a mile from Black Hawk, on Utah Railway. Coal bed, Hiawatha; Upper Cretaceous age, Blackhawk formation. Thickness, 13 to 25 feet. Roof and floor are hard feldspathic sandstone; dip, 2° SW. Bed sampled by J. C. Roberts March 2, 1915, as described below.

Sections of coal bed in Black Hawk mine

	22350	22351	22352	22353
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal (left up)	8 6	4 6	5	5
Coal (sampled)	12	12	12 6	12 6
Coal (not mined)				
	20 6	16 6	17 6	17 6

	22354	22355	22356	22414
	Feet	*Feet*	*Feet*	*Feet*
Coal (left up)	4	4	4	5
Coal (sampled)	10	13	10	12
Coal (not mined)	4	5	4	
	18	22	18	17

Section 22350 was measured at face of No. 3 west main entry; 22351, at face of Carbon entry; 22352, at face of room 13, No. 1 east main entry; 22353, at face of room 16, No. 1 east entry, back entry; 22354, at face of No. 3 east entry; 22355, at face of main entry in Mexico entry; 22356, at face of No. 2 west entry; 22414, from No. 4 pillar in Carbon entry. The ultimate analysis of a composite sample made by combining face samples 22350 to 22356, is given under laboratory No. 22357.

17577 F. Coal from mine No. 1 A of American Fuel Co., near Thompson. Sample unweathered; taken by F. R. Clark from bed B (middle seam Bear coal), at point 1,200 feet east of mine opening; represents entire bed, containing 5 feet 8½ inches of coal.

TABLE 2.—*Coals analyzed for the United States Government during the fiscal years 1908–1915*

Foreign coals

[Adapted from U. S. Bur. Mines Bull. 119, 1916]

Where mined			Commercial name of coal	Size of coal	Tons delivered	Number of analyses averaged	Index No.	Form of analysis	Proximate analysis					Heating value	
Town	Mine	Bed							Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Calories	British thermal units
BRITISH COLUMBIA															
Michel and Fernie	Michel and Coal Creek.		Crows Nest Pass	Lump, over 2-inch screen.	2,210	19	21	A	1.73					7,165	12,900
								B		24.38	61.10	14.52	0.47	7,290	13,130
								D						8,530	15,350
Cumberland	Comox		Comox	Run of mine	3,113	45	23	A	2.91					6,780	12,210
								B		32.91	51.27	15.82	1.43	6,985	12,570
								D						8,300	14,940
Ladysmith	Dunsmuir-Wellington.		Dunsmuir-Wellington.	Lump, over ¾ inch screen.	2,369	15	27	A	2.92					6,765	12,180
								B		39.55	46.67	13.78	1.12	6,965	12,540
								D						8,080	14,550
Nanaimo	Nanaimo			Lump, over 3 inch bar screen.	2,157	21	31	A	3.09					6,880	12,390
								B		40.45	47.30	12.25	1.09	7,100	12,780
								D						8,090	14,570
Nanaimo	Wellington		Wellington	Lump, over 3½ inch screen.	2,100	21	35	A	2.70					6,870	12,370
								B		39.87	47.53	12.60	1.13	7,060	12,710
								D						8,080	14,540
South Wellington	South Wellington		Wellington	Lump, over 1-inch round-hole shaking.	838	12	41	A	2.64					6,790	12,230
								B		40.14	45.70	14.16	1.72	6,975	12,560
								D						8,130	14,630

COLOBADO															
Las Animas County															
Aguilar	Royal		Royal	Lump, over 1¼-inch screen.	761	10	100	A	2.07					7,040	12,670
								B		36.02	50.24	13.74	.60	7,190	12,940
								D						8,330	15,000
Primero	North and East Primero.	Primero	Primero	Lump over 1¾-inch bar screen.	749	12	107	A	1.47					7,265	13,080
								B		30.91	56.03	13.06	.53	7,375	13,280
								D						8,485	15,270
Do	Primero	do	do	Mixture of lump over 1¾ inch and 2½-inch screens.	9,034	62	111	A	2.91					7,145	12,860
								B		36.65	53.48	9.87	.48	7,355	13,240
								D						8,165	14,690
Rugby	do		do	Lump, over 1¼-inch round-hole shaking screen.	4,324	38	112	A	2.90					7,065	12,710
								B		37.06	52.42	10.52	.48	7,275	13,090
								D						8,130	14,630
Mesa County															
Grand Junction	Book Cliff	Cameo	Book Cliff	Run of mine	319	2	114	A	7.50					6,545	11,790
								B		36.38	53.42	10.20	.57	7,080	12,740
								D						7,880	14,190
Routt County															
Oak Creek	Pinnacle	Mammoth	Pinnacle	Run of mine	1,441	41	115	A	8.12					6,775	12,200
								B		40.07	54.39	5.54	.71	7,375	13,270
								D						7,805	14,050
MONTANA															
Carbon County															
Bear Creek	Bear Creek	Nos. 2 and 3	Original Bear Creek.	Slack	130	16	257	A	9.71					5,925	10,660
								B		38.49	49.09	12.42	1.49	6,560	11,810
								D						7,490	13,480
Do	do	do	do	Lump	1,815	24	258	A	9.55					6,085	10,950
								B		42.97	46.84	10.19	1.60	6,725	12,110
								D						7,490	13,480
Do	do	do	do	Lump, over 2-inch round hole shaking screen.	1,496	9	263	A	9.04					6,220	11,200
								B		42.53	48.74	8.73	1.54	6,840	12,310
								D						7,490	13,490
Do	International	No. 3	Peerless Bear Creek.	Slack forkings	209	13	266	A	9.63					5,980	10,770
								B		41.30	47.37	11.33	1.70	6,620	11,910
								D						7,465	13,440

TABLE 2.—*Coals analyzed for the United States Government during the fiscal years 1908–1915*—Continued

United States coals—Continued

Where mined			Commercial name of coal	Size of coal	Tons delivered	Number of analyses averaged	Index No.	Form of analysis	Proximate analysis					Heating value	
Town	Mine	Bed							Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Calories	British thermal units
MONTANA—contd.															
Carbon County—Continued															
Washoe	Nos. 2 and 3	No. 2	Faultless	Lump, over 2-inch screen.	2,940	51	267	A	9.73					6,140	11,050
								B		41.53	49.06	9.41	1.54	6,805	12,250
								D						7,510	13,520
Cascade County															
Sand Coulee	Nelson	Nelson	Nelson	Lump	150	12	268	A	5.73					5,855	10,540
								B		30.21	51.81	17.98	2.90	6,210	11,180
								D						7,575	13,633
Do	Sand Coulee		Sand Coulee	do	638	10	269	A	5.50					5,925	10,670
								B		29.23	52.56	18.21	2.50	6,270	11,290
								D						7,665	13,800
Park County															
Chimney Rock	Maxey		Maxey	Lump	1,856	12	271	A	16.85					5,530	9,960
								B		41.89	48.42	9.69	.47	6,650	11,970
								D						7,370	13,260
UTAH															
Carbon County															
Black Hawk	Black Hawk	Book Cliff	Black Hawk	do	1,300	12	496	A	4.57					7,215	12,985
								B		46.76	46.88	6.36	.61	7,560	13,610
								D						8,075	14,530
Castlegate	Castlegate	Castlegate	Castlegate	Lump, over 4¼-inch round-hole screen.	3,750	28	497	A	3.83					7,250	13,050
								B		43.50	50.68	5.82	.52	7,540	13,570
								D						8,005	14,410
Hiawatha	Hiawatha	Book Cliff	Hiawatha	Lump	300	2	498	A	5.13					7,200	12,960
								B		45.17	48.96	5.87	.65	7,590	13,660
								D						8,060	14,510

Kenilworth		Aberdeen	Aberdeen	Lump, over 4-inch shaking screen.	939	8	499	A	4.94					7,050	12,690
								B		42.39	51.32	6.29	.58	7,415	13,350
								D						7,910	14,240
Emery County															
Mohrland	Mohrland	Book Cliff	King	Lump, over 3-inch round-hole screen.	3,510	35	500	A	4.65					7,230	13,010
								B		45.53	48.21	6.26	.64	7,580	13,650
								D						8,085	14,560
WYOMING															
Lincoln County															
Sublet	No. 5	Willow Creek.	Kemmerer	Run of mine	1,002	9	714	A	2.73					7,455	13,420
								B		38.19	56.29	5.52	.94	7,665	13,800
								D						8,110	14,600
Sheridan County															
Carneyville	Carney	Carney	Carney	do	1,788	25	727	A	22.59					4,950	8,910
								B		43.76	45.15	11.09	.63	6,395	11,510
								D						7,195	12,950
Sweetwater County															
Rock Springs	Blairtown	No. 1	Star lump	Lump, over 3-inch screen.	3,260	17	733	A	7.90					6,930	12,470
								B		43.56	52.55	3.89	.85	7,525	13,540
								D						7,825	14,090
Do	do	do	do	do	1,783	6	734	A	7.35					6,805	12,250
								B		42.08	52.07	5.85	.93	7,345	13,220
								D						7,805	14,050

ESSENTIAL DATA IN REGARD TO COAL CONTRACTS TO SUPPLY FUEL TO THE UNITED STATES GOVERNMENT [16]

In the following pages are given the essential data in regard to the place, date of delivery, purchaser, price, and contract guaranties for the coals that were sampled and analyzed as shown in Table 2. The numbers refer to the index numbers in Table 2. Prices given are per ton of 2,240 pounds, delivered, except where otherwise stated. The year given as date of delivery is the fiscal year—for example, 1910–11 refers to the fiscal year beginning July 1, 1910, and ending June 30, 1911.

21. Bituminous coal delivered to Fort George Wright, Wash., Quartermaster Corps, War Department, 1913–14. Contract guaranties: 6.5 per cent moisture, "as received"; 16 per cent volatile matter, 0.35 per cent sulphur, 10 per cent ash, 14,200 B. t. u., "dry coal." Price, $6.214 per ton.

24. Bituminous coal delivered to the depot quartermaster, United States Army, Seattle, Wash., Quartermaster Corps, War Department, 1914–15. Contract guaranties: 1.38 per cent moisture, "as received"; 29.34 per cent volatile matter, 1.01 per cent sulphur, 14.47 per cent ash, and 12,500 B. t. u., "dry coal." Price, $3.40 per ton in vessels at West Seattle, Wash.

27. Bituminous coal delivered to Presidio of San Francisco, Calif., Quartermaster Corps, War Department, 1911–12. Contract guaranties: 6.61 per cent ash, "dry coal"; 13,906 B. t. u., "as received." Price, $9.50 per ton.

31. Bituminous coal delivered to Fort Worden, Wash., Quartermaster Corps, War Department, 1912–13. Contract guaranties: 1.75 per cent moisture, "as received"; 10 per cent ash; 13,600 B. t. u., "dry coal." Price, $9.50 per ton.

35. Bituminous coal delivered to Fort McDowell, Calif., Quartermaster Corps, War Department, 1914–15. Contract guaranties: 2.5 per cent moisture, "as received"; 40 per cent volatile matter, 1.75 per cent sulphur, 10 per cent ash, and 12,800 B. t. u., "dry coal." Price, $9 per ton for delivery at San Francisco, Calif.

100. Bituminous coal delivered to Fort Meade, S. Dak., Quartermaster Corps, War Department, 1913–14. Contract guaranties: 3 per cent moisture, "as received."; 14 per cent ash, 12,500 B. t. u., "dry coal." Price, $7.056 per ton f. o. b. Sturgis, S. Dak.

107. Bituminous coal delivered to the Navy Department in May, 1912. No further information available.

111. Bituminous coal delivered to Fort D. A. Russell, Wyo., Quartermaster Corps, War Department, 1912–13. Contract guaranties: 4 per cent moisture, "as received"; 11.5 per cent ash, 12,550 B. t. u., "dry coal." Price, $5.32 per ton.

112. Bituminous coal delivered to Fort Logan, Colo., Quartermaster Corps, War Department, 1912–13. Contract guaranties same as No. 111. Price, $4.368 per ton.

115. Bituminous coal delivered to the mint building, Denver, Colo., Treasury Department, 1910–11. Contract guaranties: 5 per cent ash, "dry coal"; 12,320 B. t. u., "as received." Price, $4.35 per ton.

257. Subbituminous coal delivered to the post office, Helena, Mont., Treasury Department, 1910–11. Contract guaranties: 10 per cent ash, "dry coal"; 10,940 B. t. u., "as received." Price, $3.36 per ton.

258. Subbituminous coal delivered to Fort Missoula, Mont., Quartermaster Corps, War Department, 1911–12. Contract guaranties: 10.49 per cent ash,

[16] Pope, G. S., Analyses of coals purchased by the Government: Bur. Mines Bull. 119, pp. 52–101, 1916.

"dry coal"; 10,922 B. t. u., "as received." Price, $2.80 and $3.08 per ton f. o. b. mines (according to months of delivery).

263. Subbituminous coal delivered to Fort William Henry Harrison, Mont., Quartermaster Corps, War Department, 1912–13. Contract guaranties: 8.62 per cent moisture, "as received"; 8.25 per cent ash, 12,980 B. t. u., "dry coal." Price, $2.856 per ton for March to August, inclusive, and $3.136 per ton for September to February, inclusive, f. o. b. mines.

266. Subbituminous coal delivered to the post office, Helena, Mont., Treasury Department, 1911–12. Contract guaranties: 9.9 per cent ash, "dry coal"; 10,960 B. t. u., "as received." Price, $3.10 per ton.

267. Subbituminous coal delivered to Fort George Wright, Wash., Quartermaster Corps, War Department, 1911–12. Contract guaranties: 7.5 per cent ash "dry coal"; 11,500 B. t. u., "as received." Price, $3.50 per ton f. o. b. Washoe, Mont.

268. Bituminous coal delivered to the post office, Helena, Mont., Treasury Department, 1910–11. Contract guaranties: 14.7 per cent ash, "dry coal"; 11,190 B. t. u., "as received." Price, $5.90 per ton.

269. Bituminous coal delivered to the Fort Peck Indian School, Poplar, Mont., Office of Indian Affairs, Department of the Interior, 1910–11. Contract guaranties: 13.47 per cent ash, "dry coal"; 11,675 B. t. u., "as received." Price, $6.25 per ton (2,000 pounds).

271. Bituminous coal delivered to Fort Yellowstone, Wyo., Quartermaster Corps, War Department, 1911–12. Contract guaranties: 12 per cent ash, "dry coal"; 10,500 B. t. u., "as received." Price, $6.60 per ton.

496. Bituminous coal delivered to Fort Douglas, Utah, Quartermaster Corps, War Department, 1913–14. Contract guaranties: 4.7 per cent moisture, "as received"; 6.8 per cent ash, 13,480 B. t. u., "dry coal." Price, $5.26 per ton.

497. Bituminous coal delivered to Fort Douglas, Utah, Quartermaster Corps, War Department, 1912–13. Contract guaranties: 3 per cent moisture, "as received"; 5 per cent ash, 13,000 B. t. u., "dry coal." Price, $6.22 per ton.

498. Bituminous coal delivered to Fort Douglas, Utah, Quartermaster Corps, War Department, 1913–14. Contract guaranties: 4.7 per cent moisture, "as received"; 6.3 per cent ash, 13,610 B. t. u., "dry coal." Price, $5.26 per ton.

499. Bituminous coal delivered to the Presidio of Monterey, Cal., Quartermaster Corps, War Department, 1914–15. Contract guaranties: 2.5 per cent moisture, "as received"; 3.5 per cent ash, and 13,810 B. t. u., "dry coal." Price, $2.44 per ton for delivery in July to September, 1914, inclusive; $2.72 per ton for delivery in October to December, 1914, incl., and $3.28 per ton for delivery in January to June, 1915, inclusive.

714. Bituminous coal delivered to Boise Barracks, Idaho, Quartermaster Corps War Department, 1911–12. Contract guaranties: 10 per cent ash, "dry coal"; 12,500 B. t. u., "as received." Price, $8.40 per ton before September 1, 1911, and $8.96 per ton after September 1, 1911.

733. Bituminous coal delivered to Fort D. A. Russell, Wyo., Quartermaster Corps, War Department, 1913–14. Contract guaranties: 5 per cent moisture, "as received"; 40 per cent volatile matter, 0.8 per cent sulphur, 3.55 per cent ash, 13,500 B. t. u., "dry coal." Price, $5.91 per ton.

734. Bituminous coal delivered to Fort D. A. Russell, Wyo., Quartermaster Corps, War Department, 1914–15. Contract guaranties: 8 per cent moisture, "as received"; 43 per cent volatile matter, 0.85 per cent sulphur, 3.72 per cent ash 13,500 B. t. u., "dry coal." Price, $5.91 per ton.

ORIGINAL COAL CONTENT OF SUNNYSIDE AND WELLINGTON QUADRANGLES

General features.—It is obvious that the coal tonnage of any field is hard to ascertain and may be very differently estimated, even by geologists and engineers using the same data. The estimate here given is based on a detailed study of the coal along the outcrop in the field and on an interpretation of the probabilities of the coal under cover. It is believed that before mining was begun at least 2,629,000,000 short tons of coal was present in the area of 237 square miles north and east of the present outcrop of the lowest coal bed. In a considerable part of the area five or more coal beds contribute to the tonnage, but in other parts only one bed has been considered, although it is likely that more than one bed of workable thickness is present at all places. If the total estimated tonnage were confined to one bed spread out evenly over the 237 square miles, it would make a solid bed of coal 9 feet 7 inches thick.

Method of computation.—Individual beds could be studied and mapped in the field, and therefore estimates are made of each traceable bed and given in the table in township units. All the beds are irregular in thickness, and some of them are limited to small lenses, the outline of which is difficult to determine. The general assumption made in estimating tonnage is that a coal bed will extend under cover at right angles to the outcrop the same distance as it is known to be present on the outcrop and that the average thickness will be approximately the same as on the outcrop.

The shore line of the Cretaceous sea along which this coal was formed was west of this area, and the sediments with which the coal is interbedded came from a land mass on the west. For this reason the Castlegate "A," Gilson, and Rock Canyon coal beds thin to a feather edge eastward, where coal deposition presumably was limited either by deep water or by sand bars between the swamp and the open sea. In computing the tonnage of these beds it was therefore assumed that they did not extend eastward under cover a greater distance than the known limits of coal that is workable on the outcrop. The average thickness of these beds for each unit of area was determined from exposures in the same township and in adjoining sections in other townships.

The Kenilworth and Upper Sunnyside beds are believed to have the form of thin lenses, which cover small areas and therefore do not contribute greatly to the tonnage. The limits of each lens were determined by drawing an arc with a radius equal to the distance from the maximum to the minimum thickness of that lens on the outcrop.

The Lower Sunnyside bed is the most persistent and at places is the thickest bed exposed in these quadrangles. The tonnage esti-

mate for this bed is based on the assumption that its thickness of nearly 14 feet in sec. 21, T. 15 S., R. 14 E., at the south edge of the Sunnyside quadrangle, is its maximum and that it thins to the east and north under cover at the same rate as it thins along the outcrop to the north and west. A series of thickness contours was drawn with the point of maximum thickness as a center and radii equal to the distances between this point and the points at which the coal successively decreased 1 foot in thickness on the outcrop. By this method the tonnage was computed for the area between each two thickness contours, but the table of tonnage estimates (given below) shows only the total tonnage for each township.

The estimates.—The following table gives the tonnage by beds and townships. It shows the tonnage of five coal beds that could be traced in the field and several other relatively unimportant beds, all contributing more or less to the fuel supply of Carbon County. One or more beds are considered to be present in parts of 15 townships in the Sunnyside and Wellington quadrangles.

Estimated coal tonnage of Sunnyside and Wellington quadrangles, by beds and townships

Name of bed	Calculated average thickness	Estimated area	Tonnage	
			Per square mile	Total (rounded)
T. 12 S., R. 11 E.:	*Ft. in.*	*Sq. miles*		
Lower Sunnyside	4 0	12	2,304,000	28,000,000
Rock Canyon	3 0	5	3,456,000	17,000,000
Gilson	4 0	10	4,608,000	46,000,000
Kenilworth	2 0	10	2,304,000	23,000,000
Castlegate "A"	3 0	8	3,456,000	28,000,000
				142,000,000
T. 12 S., R. 10 E				13,000,000
T. 13 S., R. 11 E.:				
Lower Sunnyside	3 9	8.5	4,320,000	37,000,000
Rock Canyon	3 2	9	3,480,000	33,000,000
Gilson	4 2	10.5	4,800,000	50,000,000
Kenilworth	2 4	9.7	2,688,000	26,000,000
Castlegate "A"	3 2	6.6	3,648,000	24,000,000
All others	5 0	.7	5,760,000	40,000,000
				210,000,000
T. 13 S., R. 10 E				31,000,000
T. 12 S., R. 12 E.:				
Lower Sunnyside	2 0	10	2,304,000	23,000,000
Rock Canyon and Fish Creek	6 0	10	6,912,000	69,000,000
Gilson	4 0	10	4,608,000	46,000,000
Kenilworth	1 6	10	1,728,000	17,000,000
				155,000,000
T. 13 S., R. 12 E.:				
Lower Sunnyside	2 6	18	2,880,000	52,000,000
Rock Canyon	4 0	17	4,608,000	78,000,000
Fish Creek	3 4	9	3,840,000	35,000,000
Gilson	4 8	19	5,376,000	102,000,000
Kenilworth	2 0	19	2,304,000	44,000,000
				311,000,000

Estimated coal tonnage of Sunnyside and Wellington quadrangles, by beds and townships—Continued

Name of bed	Calculated average thickness	Estimated area	Tonnage	
			Per square mile	Total (rounded)
T. 12 S., R. 13 E.:	*Ft. in.*	*Sq. miles*		
Lower Sunnyside	2 10	12	3,264,000	39,000,000
Rock Canyon	3 0	3	3,456,000	10,000,000
Gilson	2 6	4	2,880,000	12,000,000
				61,000,000
T. 13 S., R. 13 E.:				
Upper Sunnyside	2 0	4	2,304,000	9,000,000
Lower Sunnyside	4 9	34	5,472,000	186,000,000
Rock Canyon	4 0	14	4,608,000	65,000,000
Gilson	3 9	19	4,320,000	82,000,000
				342,000,000
T. 14 S., R. 13 E.:				
Upper Sunnyside	2 2	8.5	2,496,000	21,000,000
Lower Sunnyside	7 9	9	8,928,000	80,000,000
Rock Canyon	3 0	2	3,456,000	7,000,000
Gilson	3 0	3	3,456,000	10,000,000
Kenilworth	2 0	1	2,304,000	2,000,000
				120,000,000
T. 12 S., R. 14 E.:				
Lower Sunnyside	4 0	12	4,608,000	55,000,000
T. 13 S., R. 14 E.:				
Lower Sunnyside	5 4	33	6,144,000	203,000,000
T. 14 S., R. 14 E.:				
Upper Sunnyside	3 0	12	3,456,000	41,000,000
Lower Sunnyside	9 10	35	11,328,000	396,000,000
Kenilworth	2 7	2.5	2,976,000	7,000,000
				444,000,000
T. 15 S., R. 14 E.:				
Upper Sunnyside	4 0	14	4,608,000	65,000,000
Lower Sunnyside	12 0	15.5	13,824,000	214,000,000
Kenilworth	2 0	2.5	2,304,000	6,000,000
				285,000,000
T. 12 S., R. 15 E.:				
Lower Sunnyside	4 0	4	4,608,000	18,000,000
T. 13 S., R. 15 E.:				
Lower Sunnyside	6 0	11	6,912,000	76,000,000
T. 14 S., R. 15 E.:				
Lower Sunnyside	8 0	12	9,216,000	111,000,000
T. 15 S., R. 15 E.:				
Lower Sunnyside	10 5	8	12,000,000	96,000,000

	Short tons
Total original tonnage of all beds in the Sunnyside and Wellington quadrangles	2,629,000,000
Total coal mined, wasted in mining, or rendered useless	19,000,000
Total coal remaining	2,610,000,000
Total recoverable coal	1,566,000,000

Summary of tonnage estimate.—The principal part of the coal, according to this estimate, is contained in four beds—the Lower Sunnyside, 1,614,000,000 tons; Rock Canyon and Fish Creek taken together, 340,000,000 tons; Gilson, 348,000,000 tons. The combined tonnage of these beds is 2,302,000,000 tons, or more than 87 per cent of the original total for the quadrangles, and the Lower Sunnyside

has more than 61 per cent of the total for all beds. In townships in the northeastern part of the area the estimates have been based on Lower Sunnyside bed alone, but it is probable that other beds of workable thickness are present in these townships.

The percentages of coal recovered from different fields differ materially and depend on the thickness of the coal, character of roof, vertical distances between coal beds, care and skill used in mining, and character of the coal bed itself. The highest percentage of recovery possible can probably be made in coal beds from 5 to 10 feet thick, free from partings, over which the roof material stands up well in entries and rooms. In mining beds that are more than 5 or 6 feet thick, where the roof does not stand up well, it is common practice to leave some coal for a mine roof, and this coal is never recovered. Where two or more beds occur within a relatively small stratigraphic distance, it is the too common practice to mine the thickest and most easily accessible one first without regard to the future mining of thinner beds that may overlie the thick bed.

Before mining the coal from an area where more than one bed is present, a detailed study of all the beds should be made, with a view to making the greatest possible recovery. Wherever the distance between two workable beds is from about 25 feet to 100 feet, depending on the thickness of the coal and the character of the intervening rocks, the upper one should be mined first, the lower one being left for later working. Where the stratigraphic distance between two beds is 25 feet or less it may be found advisable to mine the beds simultaneously from the same entries and haulage ways.

The estimate of 1,566,000,000 tons of recoverable coal is based on a 60 per cent recovery, which probably can be realized if the beds are mined simultaneously in groups as follows: The Gilson and Kenilworth beds in places where they are both of workable thickness, the Fish Creek and Rock Canyon beds, and the Upper and Lower Sunnyside beds. The Castlegate "A" bed could probably be mined without damaging any of the overlying beds, but in the group from the Kenilworth to the Rock Canyon, inclusive, the upper beds should be mined first, as the mining of this group would probably not disturb the Sunnyside coal beds above.

HISTORY OF DEVELOPMENT

General features.—The vast potential coal reserves of the Book Cliffs, of which these quadrangles contain a part, are comparatively untouched by the mine operator. There are few large mines, and between them the coal lies undisturbed for many miles. The coal in these quadrangles has been extensively mined only at Sunnyside, at the terminus of the Sunnyside branch of the Denver & Rio Grande Western Railroad. The town, mine tipple, and coke ovens are situ-

ated in the mouth of Whitmore Canyon, in the southeastern part of the area. (See pls. 1, *A* and 12.) Outside of the Sunnyside district little prospecting has been done, but a few small drifts have been opened from which coal has been mined to supply the demands of near-by ranches and small towns. These small mines are on Rock Canyon, Dugout, Coal, and Deadman Creeks. The coal beds have been opened and "faced up" also at many places, but no coal has been mined.

Mines and prospects.—The only large mines in this area are at Sunnyside, where more than 10,000,000 tons of coal has been taken from the ground. The No. 1 mine at Sunnyside was opened in 1899 by the original locators with Robert Forrester as agent. The good coking qualities of the coal were recognized at once, and by the end of 1899 10 cars of coal a day were being shipped to the coke ovens at Castlegate. During this year 72 men worked 183 days and produced 11,179 short tons of coal. According to the Utah State mine inspector's report for 1900 the Sunnyside mines were owned and operated in that year by the Pleasant Valley Coal Co. and produced 132,222 short tons of coal, making a substantial increase over the production for 1899. The report for 1901 shows that the mine was operated by the Utah Fuel Co., which still operates it and which has extended the development and increased the production. A part of the coal mined at Sunnyside during the first three years was shipped to Castlegate and there converted into coke. The coking plant at Sunnyside was put in operation in 1902, and 53,674 tons of coke was produced in 200 beehive ovens during that year. The capacity of the coking plant was steadily increased until during the year 1914 the ovens in operation averaged 726 and produced 348,806 short tons of coke. The total amount of coke produced from 1902 to 1914 was 2,535,504 short tons.

The No. 1 mine is a slope which follows the coal bed down the dip to the northeast. In the mine the coal is gathered by mules and electric motors to the main slope, and thence it is raised to the tipple on the surface by a steam hoist. The main haulage ways and entries are electrically lighted. This mine is somewhat wet, and the water is pumped out by compressed-air pumps. Coal is mined from the Upper and Lower Sunnyside beds, which are here separated in places by 30 to 40 feet of rocks. The coal from both beds is hoisted through the main slope. The workings are artificially ventilated by a large fan placed at the mouth of the mine.

The Nos. 2 and 3 mines are drifts that enter the Lower Sunnyside coal in Number Two Canyon. The main haulage way extends southeast along the strike of the Sunnyside fault on the west and down through the side of it. The coal is gathered by mules, electric

motors, and electric hoists and then hauled by electric motors through the main haulage way to the tipple. These mines are dry, and dust is kept down by means of sprinkling from an elaborate water system. They are ventilated by fans at the mine mouth. Coal is mined from both beds, which in the south end of the workings are separated by about 3 to 6 feet of sandy shale and sandstone. In 1913 the total daily production was reported to be 2,500 short tons, about 80 per cent of which was crushed and converted into coke. The total coal mined up to the end of 1914 was 7,878,462 short tons and the total coke produced was 2,535,504 short tons. If as much coal was mined in the four years 1915 to 1918 as was produced in the four years preceding, a total of 10,700,000 short tons was mined up to December 31, 1918.

At several places in this area a few hundred tons of coal has been mined from small drift mines, which are here briefly described.

The Rock Canyon coal bed has been prospected in Rock Canyon, and traces of an old wagon road leading to the prospect suggest that some coal was hauled away. An entry was driven about 50 or 60 feet into the coal bed and probably penetrated the zone of surface weathering. A sample was collected for analysis (laboratory No. 12792), but the coal has weathered slightly since the opening was made.

The Gilson coal has been mined in a small way in Dugout Creek by Branch Bros., and hauled to Wellington for domestic use. The mine is a short drift into which the wagon is driven for loading. No rooms have been turned off, and no timbering has been done except at the mouth. A sample was collected from this prospect for analysis (laboratory No. 14801, p. 85), but the coal may be slightly weathered.

Many years ago the Gilson coal bed was mined by Sam Gilson, from whom it takes its name, in the bed of Coal Creek, but in 1912 the prospect was caved at the mouth and it could not be entered. It is reported that Gilson hauled the coal mined here up Coal Creek through Emma Park by way of Soldier Summit to Provo, Utah, but this long haul would seem to render such an undertaking unprofitable even in the days before railroads came.

The Gilson coal bed is mined in a small way during the winter by S. S. Young, of Price, who hauls coal from this prospect to Price for domestic use. A sample was collected for analysis (laboratory No. 14678, p. 85), but the coal may be slightly weathered.

CHAPTER II.—CASTLEGATE QUADRANGLE

INTRODUCTION

General features.—The Castlegate quadrangle lies in the west-central part of Carbon County, Utah, and embraces an area of 230 square miles, adjoining the Wellington quadrangle on the west. About 40 square miles of its area along its northern boundary is underlain by workable coal beds and forms a small portion of the Book Cliffs coal field. The country is sparsely settled, the only inhabited parts being the irrigated lands and small towns along Price River and the small coal-mining towns. Price, the county seat of Carbon County, is a thriving town on Price River, on the main line of the Denver & Rio Grande Western Railroad. Castlegate, from which the quadrangle takes its name, is one of the principal coal-mining towns and one of the first established by the Utah Fuel Co. in this region. It is in Price River canyon on the same railroad.

The field work that forms the basis for this report was done during the summer of 1914 and was undertaken as a part of a general plan of the United States Geological Survey to make a detailed study of the Book Cliffs and Wasatch Plateau coal fields in Utah. This work was designed to satisfy the increasing demand for more detailed information regarding the coal, to collect data upon which a competent classification and valuation of the land might be based, and to supply to operators additional facts to aid them in developing the field. The field work was carried on in the manner described in Chapter I of this report.

The coal, which is of bituminous rank, crops out in the bold southward-facing escarpment that traverses the north end of the quadrangle trending east. This escarpment, having a maximum relief of 1,500 feet, is the most conspicuous land form, and it has been cut through by Price River halfway between the east and west sides of the quadrangle. The rocks strike northwest or west and dip 4°–6° N. (See pl. 22.) It is estimated that before mining was begun approximately 1,000,000,000 short tons of coal was present in the coal-bearing portion of this quadrangle in beds exceeding 1 foot 2 inches in thickness, which is considered by the United States Geological Survey to be the minimum workable thickness for coal of this rank. The coal beds here are lenticular and vary greatly in thickness considered over large areas, but over relatively small areas most of them

are persistent and fairly regular in thickness. The ordinary uncertainty as to the character and thickness of a particular coal bed under cover is increased in this quadrangle by extensive burning of the coal at the outcrop, which reduces the number of exposures. From the available data it appears that a minimum of six workable coal beds crop out at the east edge of the quadrangle and a maximum of twelve workable coal beds near the west edge.

Several of the principal coal beds are associated with massive cliff-making sandstones, whose presence facilitates the field mapping of the coal beds. The coal beds that are not associated with sandstones are difficult to trace, and definite correlations with them can not be made. The Castlegate "A" coal bed, which is the lowest coal mined at Castlegate and at Kenilworth, is probably the most persistent coal in this quadrangle and will, it is believed, yield the greatest tonnage. It is traceable by means of the underlying Aberdeen sandstone from Coal Creek, in the Wellington quadrangle to the west edge of the Castlegate quadrangle, a distance by air line of 18 miles.

The Kenilworth coal bed, perhaps the next most valuable bed, is the uppermost coal mined at Kenilworth and has been traced by means of the underlying sandstone from a locality near the south edge of the Sunnyside quadrangle northwestward to Hardscrabble Canyon, in the Castlegate quadrangle, a distance of 33 miles by air line. It varies in thickness throughout this distance and in places seems to be absent, but it generally exceeds 14 inches and attains a maximum thickness of 18 feet. Coal mining in the Castlegate quadrangle has been active for several years, and there are shipping mines at Standardville, Storrs, and other places in Spring Canyon; at Panther, Castlegate, and Cameron, in Price River Canyon; and at Kenilworth, on the face of the escarpment 3 miles east of Price River. At several places small wagon mines supply a part of the local demand for domestic fuel.

The Book Cliffs coal field, of which the Castlegate quadrangle is a small part, extends from Grand Junction, Colo., in a northwesterly direction to the western edge of the Castlegate quadrangle, a distance of about 175 miles. The field as defined by the United States Geological Survey forms the southern rim of the Uinta Basin and lies north of the Denver & Rio Grande Western Railroad and east of Price River. The Wasatch Plateau coal field extends westward from the western border of the Castlegate quadrangle to Pleasant Valley and southward to Mount Hilgard, Utah. The two fields are continuous and structually similar and the coal occurs in rocks of the same age in both fields.

Previous geologic work.—The early explorations in this region and the later work by Taff are mentioned on page 3.

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A guidebook of the Denver & Rio Grande Western Route,[1] which passes through the Castlegate quadrangle, was published in 1922. This book describes the main geologic features and gives the history of the settlements within a short distance on either side of the railroad.

GEOGRAPHY

Accessibility.—The coal of the Castlegate quadrangle is as accessible as the coal in any other part of the Book Cliffs field and in the Wasatch Plateau field, because it is exposed in several deep canyons and the railroad facilities are excellent. Branches or spurs could be built from the main line of the Denver & Rio Grande Western Railroad, which traverses the central part of the coal field, up most of the main canyons or along the base of the escarpment. The coal may be brought to the end of such a branch by any one of the common types of tramways—cable, incline, or aerial—as in the operations at Storrs, Panther, and Kenilworth. The beds dip gently into the face of the escarpment, and the most economical points of access for mining the coal are where the outcrop crosses the main canyons, as from these points down grade in favor of loads may be had for all coal above drainage level. Furthermore, very little coal has been burned near the bottoms of canyons, whereas on the points of ridges entries might have to be driven from 1,000 to 2,000 feet from the outcrop before reaching marketable coal.

Settlement.—The region is sparsely settled except the irrigated lands along Price River valley and the vicinity of some railroad stations and of the operating coal mines. Price, the county seat of Carbon County, is the largest town in the region and has a population of 2,364. It is on the main line of the Denver & Rio Grande Western Railroad and is the main distributing point for mail and supplies to Castle Valley on the south and to the Uinta Basin on the north. At the mouth of Price River canyon 7 miles northwest of Price, is the railroad town of Helper, which was so named because here are kept the locomotives that serve as "helpers" in drawing trains up the heavy grade from Helper to Soldier Summit. Its population is about 1,600. Three miles above Helper, in Price River canyon, is Castlegate, one of the first coal-mining towns established by the Utah Fuel Co. in this region. Its present population is 1,120, and it takes its name from the peculiar gatelike passage 2 miles above the town, formed by vertical projecting cliffs of the Castlegate sandstone. Between Helper and Castlegate, in Price River canyon, is the coal mining town of Panther, established by the United States

[1] Campbell, M. R., Guidebook of the western United States, Part E, The Denver & Rio Grande Western Route: U. S. Geol. Survey Bull. 707, 1922.

Fuel Co., which operates a cable tramway from the railroad to the coal mine on the escarpment in Panther Canyon. Coal mining has developed rapidly in recent years in Spring Canyon, northwest of Helper. Much of the development in Spring Canyon has taken place since the field work for this report was done, and the features disclosed by the mine workings have doubtless added much to the fund of information concerning the coal. The attendant development above ground has also added to the region many details not shown on the map. Unfortunately it has been impossible to do the additional field work necessary to bring the information on the Spring Canyon district up to date, and it should be understood that the map and geologic information given in this report show the conditions existing in 1914, when the field work was done. In addition to the towns shown on the map, the towns of Rains, Latuda, and Liberty have been established. The coal mines in Spring Canyon are supplied from a branch railroad that leaves the main line half a mile above Helper.

Kenilworth, 3 miles east of Helper, is a typical coal-mining town and is served by a branch railroad that leaves the main line about half a mile south of Helper. The Utah Railway branches off from the main line of the Denver & Rio Grande Western Railroad 2 miles above Helper and extends south to serve the mines at Wattis, Mohrland, and Hiawatha, which are south of the Castlegate quadrangle. This railroad was built to replace the railroad which formerly ran from Price to Hiawatha and had an almost prohibitive grade.

Roads and trails.—The principal roads in the Castlegate quadrangle radiate from Price as a center, because this town is the main supply point for a large section of country in southeastern Utah. The most traveled roads out of Price are the Midland Trail and the Pikes Peak Ocean to Ocean Highway. The Midland Trail connects Price with Denver and other principal cities in Colorado on the east and with Salt Lake City and the Pacific coast on the west. The Pikes Peak Ocean to Ocean Highway extends southward from Price and connects it with all points in Castle Valley, Rabbit Valley, and Sevier Valley, and with southwestern Utah. The main road to the Uinta Basin branches off from the Midland Trail at Castlegate and follows Willow Creek and Indian Canyon to Duchesne, where it joins the Victory Highway. A well-traveled and fairly good road runs north from Price to Kenilworth. Secondary roads intersect the main roads at various places and connect farms or the small towns with the wooded part of the gravel-capped terraces and mountains or with the small coal mines. The scrub cedar and piñon which grow on the upper surface of the dissected gravel terraces are used for fence posts and firewood. Coal is hauled from the Aberdeen

and Milburn mines, in Cordingly Canyon, during the fall and winter for the local market in Price.

In the rugged country along the north side of the quadrangle there are no roads except along the main creeks or canyons, such as Spring Canyon, Price River, and Willow Creek. Trails used by range stock and horsemen traverse this rough country at places and render it partly accessible. One such trail goes up Cordingly Canyon, over the divide, and down Deep Canyon and Mathes Canyon to the head of Willow Creek, from which a good road leads into the Duchesne country. Another main trail of this quadrangle goes from the road in Price River canyon up Crandall Canyon, which is just north of the quadrangle, crosses the divide, and goes down Sowbelly Gulch, joining the road that traverses Spring Canyon. Several other trails traverse the branches of Spring Canyon and lead to the high country on the west.

Surface water.—The Castlegate quadrangle is drained by Price River and its tributaries. The perennial streams are Price River, Willow Creek, and Spring Canyon, which are fed by springs and by snow and rainfall. Many springs issue from the rocks back of the coal-bearing escarpment and supply water for stock, but not enough to form running streams. Price River, which cuts through the escarpment at about the center of the north margin of the quadrangle, flows southeastward across the quadrangle. Its discharge at Helper for the period between March, 1904, and December, 1908, except May and June, 1904, and April to June, 1907, had a maximum of 1,740 second-feet, a minimum of 4 second-feet, and a mean of 124 second-feet. The water is diverted for irrigation during the summer, and most of it is used on lands within the Castlegate and Wellington quadrangles.

Agriculture and stock raising.—Next to the coal mining at the places mentioned above, agriculture and stock raising are the principal industries. The climate and natural vegetation of the Castlegate quadrangle are similar to those of the Sunnyside and Wellington quadrangles, described in Chapter I. Farming in this arid country is mostly confined to irrigated lands. Small grains and hay are the staple crops, but some truck gardening is done, and the produce is hauled by team or truck to the coal-mining towns, where it finds a ready market. This is not a fruit country, but small quantities of apples, prunes, and plums are raised. The irrigated lands are confined mainly to the valley of Price River. They extend along both sides of the river from the mouth of Price River canyon to a point several miles below Wellington and form an area about 17 miles long and from half a mile to 5 miles wide. The soil, when properly worked and irrigated, is fertile and produces abundant crops of grains and alfalfa. It seems unlikely that water sufficient

to irrigate all land suitably located can ever be obtained, yet with proper conservation of the winter and spring run-off and economical use of the present water supply, much more land might be utilized.

Surface features.—The Castlegate quadrangle is a small part of a large dissected plateau, the present surface of which is rough and even rugged in places. The total relief in this quadrangle is about 3,900 feet; the lowest point, on Price River, being about 5,400 feet above sea level, and the highest point, on the divide between Spring Canyon and Crandall Canyon, in the northwest corner of the quadrangle, 9,300 feet. The land forms here represented are the result of erosion modified by the character of the rocks, being little affected by structure. The most conspicuous and striking land form in this quadrangle as viewed from the Price River valley is the bold southward-facing escarpment (see pl. 22) which traverses the north end of the quadrangle in an easterly direction. It rises 1,500 feet from the relatively flat country that it faces like a great wall. It has been deeply trenched by streams, which have cut more or less steep-sided canyons from 1 to 5 or 6 miles in length, leaving long finger-like ridges between them. Back of the coal-bearing escarpment is a second wall, formed by the Castlegate sandstone, which produces rugged land forms and nearly vertical cliffs. In the northeast corner of the quadrangle is a part of Emma Park, which is less dissected and whose gently sloping surface roughly represents the structure of the underlying rocks, being in general a dip slope. West of Price River and back of the coal-bearing escarpment the surface is steep, but the country is smoother and more accessible than the country east of Price River.

South of the coal-bearing escarpment the land forms comprise broad valleys, gravel-capped terraces, shale badlands around the front of the terraces, and gorgelike canyons eroded by streams through beds of sandstone that now form the walls of these canyons.

The gravel-capped terraces are remnants of alluvial fans which slope gently away from the coal-bearing escarpment. The land forms here would afford a very interesting physiographic study, but time did not permit studies on other subjects than the economic resources.

The total relief in the southern part of the quadrangle is about 1,850 feet, the altitude above sea level ranging from 5,400 feet on Price River to 7,250 feet on a gravel terrace west of Haley siding.

Drainage.—The Castlegate quadrangle is drained by Price River and its tributaries, as shown on Plate 22. The only tributaries that supply water to Price River, except during heavy rains or the melting of snows, are Spring Canyon and Willow Creek. At times the usually dry channels of these streams are filled with roaring masses

of water loaded with mud and rocks, which are very efficient agents of erosion.

GEOLOGY

STRATIGRAPHY

GENERAL FEATURES

The rocks exposed in this quadrangle belong to the Cretaceous, Tertiary, and Quaternary periods. There is an unconformity between the Upper Cretaceous and the Tertiary. The exposed Cretaceous beds (here all Upper Cretaceous) are the Mancos shale and the Mesaverde group; the Tertiary beds are the Wasatch formation, and the Quaternary beds are the terrace gravel and alluvium. The general character of these formations is shown in the columnar section (pl. 15) measured along Price River canyon. Some details in addition to the descriptions in Chapter I are given below.

UPPER CRETACEOUS ROCKS

MANCOS SHALE

About 3,500 feet (the upper part) of the Mancos shale is exposed in the Castlegate quadrangle. It is marine and is composed of dark bluish-gray to drab shale, in part sandy, and with two prominent sandstone members—the Garley Canyon sandstone member and the Emery sandstone member, described below. The uppermost part of the Mancos shale in this area is interfingered with tongues of sandstone belonging to the lower part of the Mesaverde group. (See pl. 15.) These tongues of sandstone thin eastward, so that 480 feet of coal-bearing Mesaverde sandstones at the west edge of the Castlegate quadrangle is represented in the Sunnyside quadrangle, 25 miles to the southeast, by typical Mancos shale.

Garley Canyon sandstone member.—The lower exposed sandstone member of the Mancos shale in the Castlegate quadrangle is the Garley Canyon sandstone, herein so named because it is prominently exposed in the walls of Garley Canyon. It extends in outcrop from the bench north of Price westward to Garley Canyon, and thence southward to sec. 10, T. 15 S., R. 9 E., where it thins out and disappears, merging with the inclosing shale of the Mancos formation. The sandstone is a lens in the cross section represented by exposures of it, but it probably represents a peninsula of sandy beaches extending out into the Mancos sea from the mainland on the west. Its eastern limit is somewhere under the bench north of Price; it is exposed on the west side of the bench, but the east side shows a long stretch of marine shale where the sandstone would appear if it

were present. At the south end of its exposure, in the broad benches east of North Spring Canyon, it changes gradually to shale.

The Garley Canyon sandstone consists uniformly of two beds of massive sandstone separated by a layer of shale. The following section shows its character in the valley of Price River about 1 mile northwest of the Carbonville School.

Section of Garley Canyon sandstone member on Price River at cut of Denver & Rio Grande Western Railroad in NW. ¼ sec. 1, T. 14 S., R. 9 E.

	Feet
Shale, gray, marine.	
Sandstone, buff, medium grained, massive	35
Shale, gray, with many sandy layers	80
Sandstone, buff-gray, thin bedded	10
Sandstone, buff, medium grained, massive	25
Shale, blue-gray, marine.	
	160

The two beds of sandstone are comparatively hard and resistant, and they form cliffs throughout the area in which they are exposed. The steplike character of the cliff is shown in Plate 13. Toward the west both beds of sandstone thicken, and toward the south they maintain their thickness almost to the place where they disappear. The member as a whole forms a series of broad benches with abrupt fronts, into which have been cut four narrow steep-walled canyons. Of these Pinnacle and Horse Canyons show on a small scale the type of erosion common in the Grand Canyon country, and they present many bits of rugged scenery not suggested by a general view of the region. The Pinnacle, a narrow shaft of sandstone 300 feet high, standing at the mouth of Pinnacle Canyon, is carved out of the upper bench of the Garley Canyon sandstone and is a striking landmark of the region. It is easily visible at distances greater than 10 miles from a surprising number of directions.

Fossils collected from the Garley Canyon sandstone in the railroad cut shown in Plate 13 are all species common in the Niobrara fauna, and they indicate clearly that the sandstone is of Niobrara age.

Emery sandstone member.—About 400 feet above the upper bed of the Garley Canyon sandstone is the Emery sandstone member of the Mancos shale.[2] It includes near the town of Spring Glen three thin beds of sandstone, each separated from the next by about 50 feet of bluish-gray to drab shale. The outcrop of the sandstone in the butte east of Spring Glen is shown on Plate 14, *A*. The lowest bed of sandstone is about 25 feet thick, the middle one about 15 feet, and the top one 5 feet. The beds are composed of massive sandstone at the top, grading downward through thin-bedded sandstone and sandy shale into shale at the base. They are gray to buff and con-

[2] Spieker, E. M., and Reeside, J. B., jr., Cretaceous and Tertiary formations of the Wasatch Plateau, Utah: Geol. Soc. America Bull., vol. 36, p. 439, 1925.

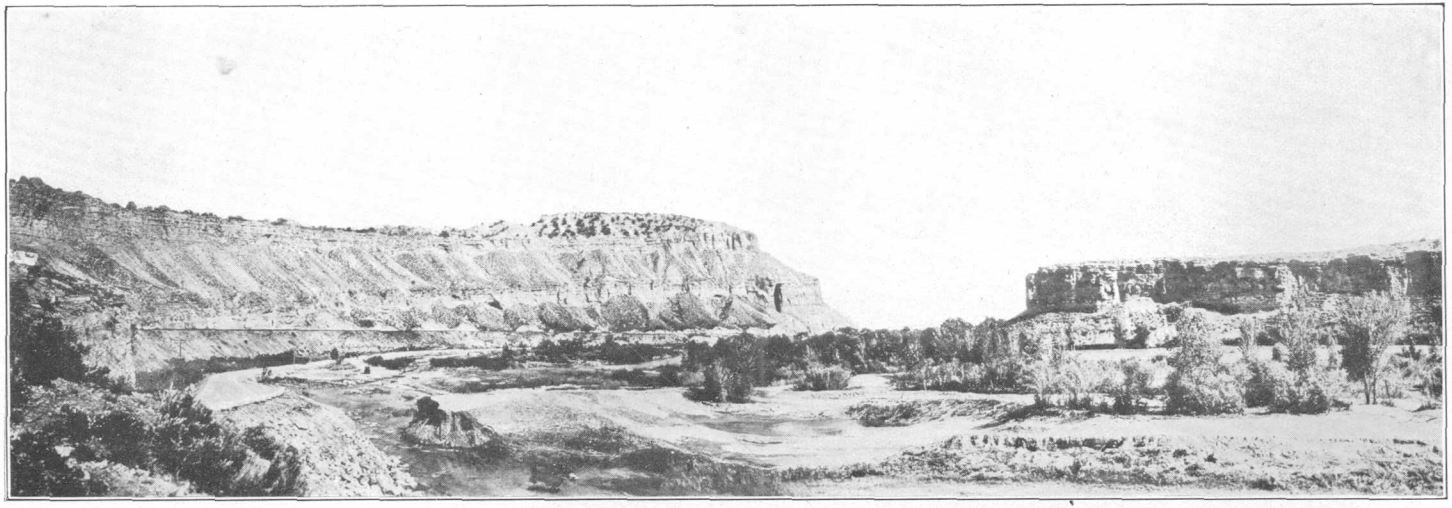
tain many stem casts and many lenses and concretions of impure limestone. These three sandstone beds thin rapidly toward the east and disappear before reaching the east edge of the quadrangle.

The Emery sandstone forms a second bench above and behind that of the Garley Canyon sandstone but normally less prominent. Near Price River the most conspicuous exposures are in the butte east of Spring Glen and near the closure of the sandstone across the river. West of Spring Glen the sandstone is inconspicuous as far as Wildcat siding, but farther south, in the canyons tributary to Gordon Creek and in the benches south of Haley siding, it becomes thicker. Southward toward Emery, near the south end of Castle Valley and beyond the limits of the Castlegate quadrangle, the thickening and increase in prominence proceed to such a degree that the member becomes a very conspicuous unit in the section. Near Emery it is 800 feet thick.

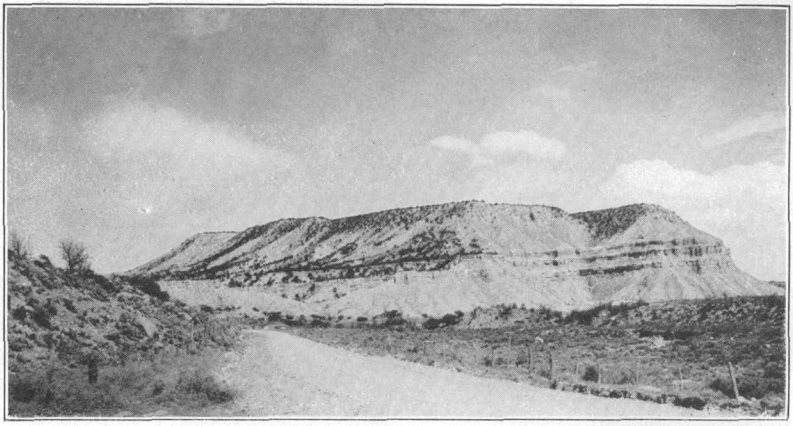
The Emery sandstone member has not yielded significant fossils in the Castlegate quadrangle, but it surely represents the much thicker sandstone at Emery in which fossils of Eagle age have been collected.

Other sandstones and their relations to the Garley Canyon and Emery sandstone members.—West of the escarpment formed by the Garley Canyon sandstone the part of the Mancos shale between that sandstone and the overlying Mesaverde group contains many subsidiary beds of sandstone which thicken toward the west until at the western edge of the quadrangle it is in places difficult to delimit exactly the Garley Canyon and Emery sandstones. In Haley Canyon a sandstone bed about 20 feet thick appears about 200 feet beneath the base of the Emery sandstone, and several other thin layers of sandstone subdivide the shale as far down as the Garley Canyon sandstone. On Gordon Creek the sandstones are still more numerous and the Garley Canyon sandstone is materially thicker. The interval between the Garley Canyon and Emery sandstones is barely 300 feet, and it is broken by many thin layers of sandstone that become visibly more prominent in westward progression.

The interval between the Emery sandstone member and the overlying Mesaverde likewise contains minor sandstones. About 300 feet beneath the Mesaverde group in the slopes at the mouth of Wildcat Canyon three sandstone beds appear, 10 to 20 feet thick, separated by 40 to 50 feet of shale. These sandstones all decrease in thickness eastward and finally disappear; conversely they increase in thickness toward the west and south, and the shale units decrease. In the Price River Canyon the shale unit above the Emery sandstone member is 700 feet thick. Farther south, near Emery, the shale is 600 feet thick, and the underlying sandstone member is 800 feet thick.

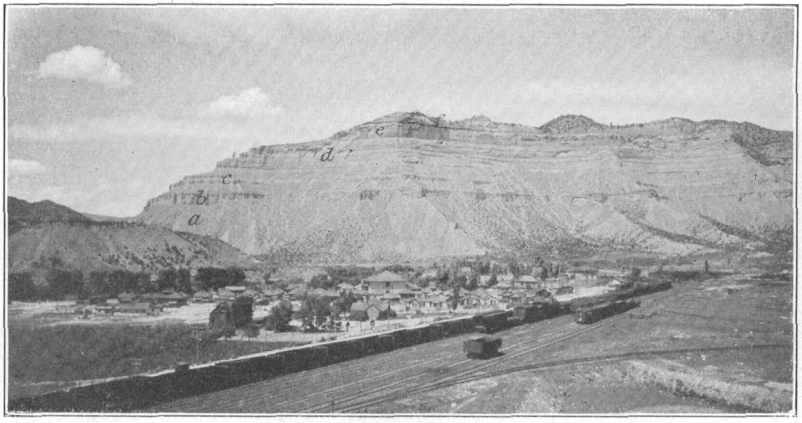


CLIFFS FORMED BY GARLEY CANYON SANDSTONE ON PRICE RIVER, IN SEC. 1, T. 14 S., R. 9 E.



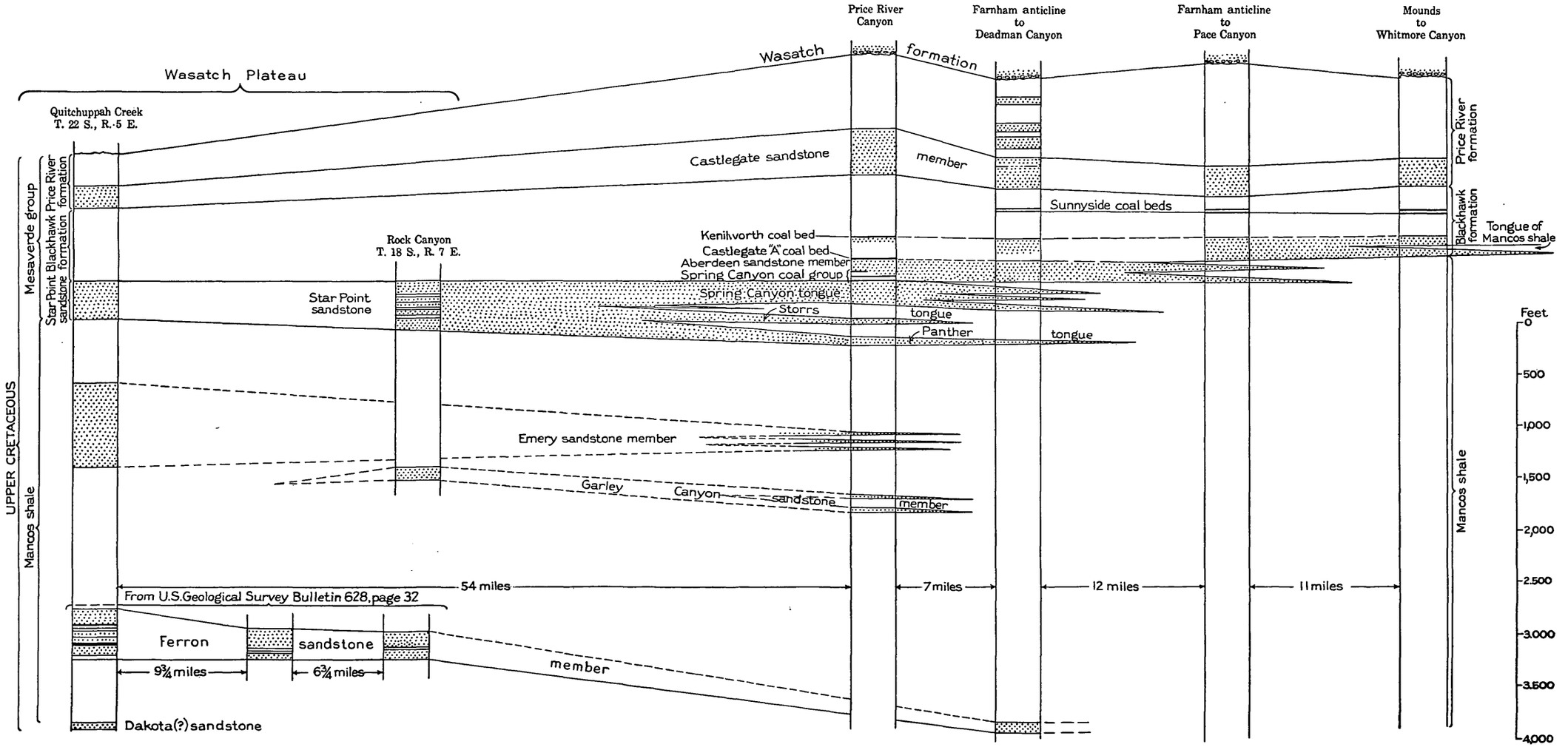
A. REMNANT OF TERRACE EAST OF SPRING GLEN

Showing sandstone and inclosing Mancos shale

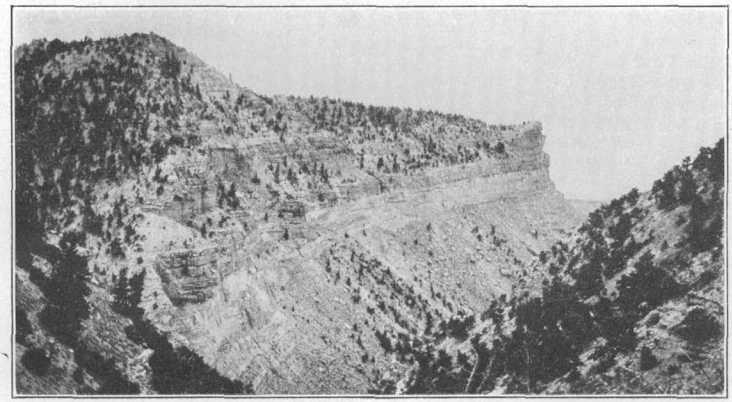


B. CLIFFS OF LOWER PART OF MESAVERDE GROUP AT MOUTH OF PRICE RIVER CANYON

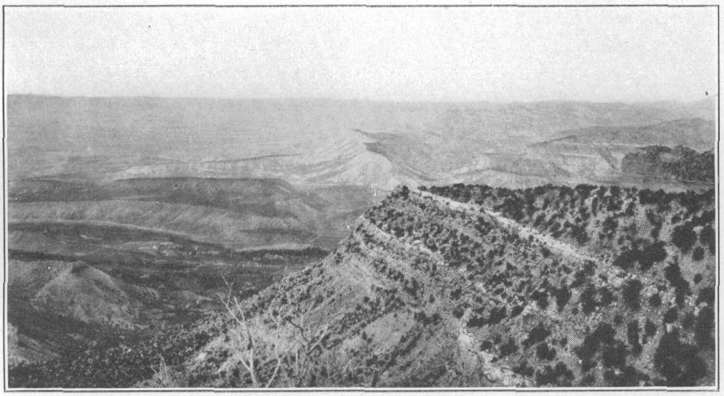
Town of Helper and yards of Denver & Rio Grande Western Railroad in the foreground. *a*, Mancos shale; *b*, Panther tongue of Star Point sandstone member; *c*, Storrs tongue of Star Point sandstone; *d*, Spring Canyon tongue of Star Point sandstone; *e*, Aberdeen sandstone member; *f*, Castlegate "A" coal bed



GENERALIZED SECTIONS OF ROCKS EXPOSED IN THE CASTLEGATE, WELLINGTON, AND SUNNYSIDE QUADRANGLES, CARBON COUNTY, UTAH

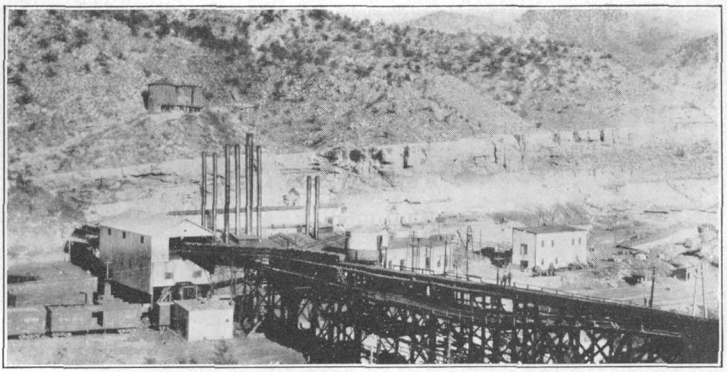


A. VERTICAL CLIFFS OF COAL-BEARING MESAVERDE ROCKS (BLACKHAWK FORMATION) IN HELPER CANYON



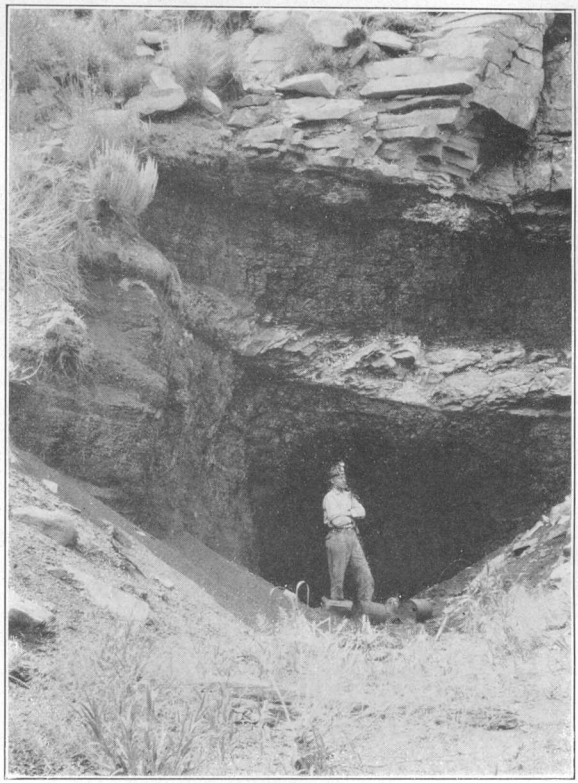
B. COAL-BEARING ROCKS (BLACKHAWK FORMATION) AT MOUTH OF PRICE RIVER CANYON AND SPRING CANYON

View from sec. 16, T. 13 S., R. 10 E.

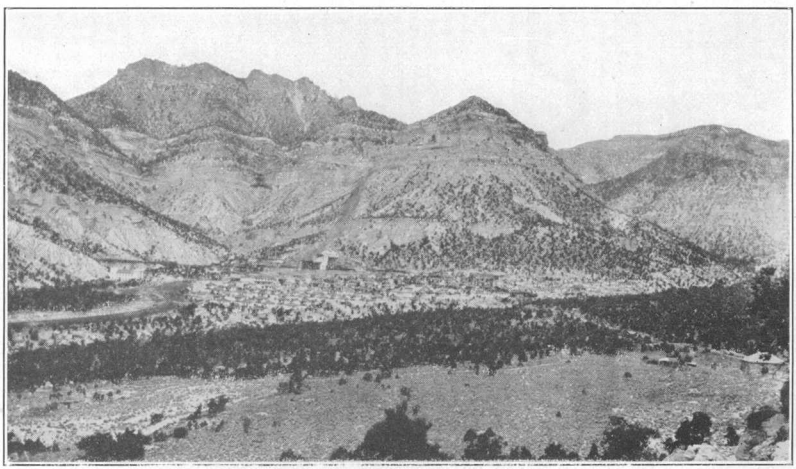


C. TIPPLE AT CASTLEGATE

Aberdeen sandstone crops out between the tipple and the water tanks



A. ENTRANCE TO MILBURN PROSPECT IN CASTLEGATE "A" COAL BED, SEC. 11, T. 13 S., R. 10 E.



B. COAL-BEARING BLACKHAWK FORMATION AT KENILWORTH

Panther tongue of Star Point sandstone just above tipple. Castlegate sandstone member caps high hill in left background

According to Spieker and Reeside [3] the sandstone beds herein designated the Emery sandstone member are equivalent to the 800-foot sandstone near Emery, and the Garley Canyon sandstone thins out and is not present in the Emery section.

At the south end of Castle Valley, 90 miles south and west of Price, the part of the Mancos formation above the Ferron sandstone member is about half sandstone. The Ferron sandstone at Farnham, in the northern part of Castle Valley, as described in Chapter I, is about 30 feet thick and is the only sandstone in the Mancos shale. At the south end of Castle Valley it is 800 feet thick and is coal bearing. Sections studied in Huntington Canyon,[4] west of the front of the Wasatch Plateau, show a greatly increased proportion of sandstone in the Mancos shale, and in the Colob Plateau,[5] about 170 miles southwest of Price River, the rocks of Colorado age, which there represent most of the Mancos shale, are chiefly sandstone. All this evidence suggests the union southward and westward of the sandstones of the Mancos shale exposed in the Castlegate quadrangle to form a succession, preponderantly sandstone, which may be coal bearing west of the known outcrops here discussed. It should be noted, however, that the rocks equivalent to these sandstones are buried so deep under most of the Wasatch Plateau that any coal they might contain would not be recoverable under present economic conditions.

The upper part of the Mancos shale is interfingered with tongues of sandstone belonging to the Mesaverde group described below.

MESAVERDE GROUP

GENERAL CHARACTER

The Mesaverde group crops out in a relatively narrow belt, which crosses the north end of the Castlegate quadrangle in an easterly direction and here forms the bold southward-facing escarpment known as the Book Cliffs and the front of the Wasatch Plateau. In this quadrangle its thickness ranges from 2,240 to 2,750 feet, the differences being due to the erosion of its upper surface before the deposition of the overlying Tertiary and to the sandstone tongues at the base of this group, which increase in thickness westward. The Mesaverde is essentially of fresh or brackish water origin, except possibly the sandstone tongues and the basal sandstone, which may have been laid down in marine waters.

The Mesaverde rocks in this area are separated into three formations by Spieker and Reeside, on the basis of lithologic and economic

[3] Idem, p. 439.
[4] Spieker, E. M., personal communication.
[5] Richardson, G. B., The Harmony, Colob, and Kanab coal fields: U. S. Geol. Survey Bull. 341, pp. 381–382, 1909.

differences in the character of the rocks. The basal formation is the Star Point sandstone; the second is the coal-bearing Blackhawk formation, with the Aberdeen sandstone member at its base; the third is the non coal-bearing Price River formation, with the Castlegate sandstone member at its base.

STAR POINT SANDSTONE

In Rock Canyon,[6] northwest of Ferron, Spieker observed that the sandstone formation now called the Star Point sandstone, 450 to 500 feet thick, splits toward the east into the three sandstones which the writer had proposed to name the Spring Canyon, Storrs, and Panther. These three sandstones are therefore now considered tongues of the Star Point sandstone. The upper 100 feet of the Star Point, which represents the Spring Canyon tongue, is a massive sandstone, white at the top, and buff at the base; the middle part, 270 feet thick, is composed of thinner-bedded sandstone, divided into two or three massive bench-forming sandstones, one of which is the Storrs tongue; and below is a massive persistent basal sandstone of a buff color, about 50 to 100 feet thick, which is continuous with the Panther tongue.

The contact between the Mancos and the Mesaverde as here drawn is a transition zone from marine shale into sandstone. In places this transition zone is as much as 25 feet thick, and any part of it might be taken as the contact. In addition to this simple transition zone, the lower part of the Mesaverde is composed of eastward-projecting sandstone tongues sandwiched between westward-projecting tongues of Mancos shale, which give a zigzag boundary line between these two divisions. The relation of these sandstone and shale tongues is well shown in Plates 4 and 15. The sandstone tongues present in the Mesaverde of the Castlegate quadrangle are, in ascending order, the Panther tongue, Storrs tongue, and Spring Canyon tongue, all tongues of the Star Point sandstone. These tongues are described in Chapter I of this report.

The contact as here drawn between the Mancos shale and Mesaverde group is 460 feet stratigraphically lower in the Price River Canyon and 700 feet lower in Rock Canyon, near Ferron, 30 to 35 miles southwest of Price, than it is in Sunnyside, 30 miles southeast of the Price River Canyon. The Aberdeen sandstone member of the Blackhawk formation in the Castlegate quadrangle and in the east face of Wasatch Plateau is the time equivalent of marine shale on the east and probably corresponds to the final stages of the Mancos sea in this region.

Panther tongue.—The Panther tongue of the Star Point sandstone is the most prominent sandstone which interfingers with the upper

[6] Spieker, E. M., personal communication.

part of the Mancos shale. It forms a conspicuous cliff near the coal-mining town of Kenilworth and is well exposed in Panther Canyon, southeast of Castlegate. It is traceable and has been mapped from Soldier Creek, in the Wellington quadrangle, westward to the west edge of the Castlegate quadrangle, a total distance of about 20 miles. At the easternmost exposure it consists of a band of impure limestone concretions and thin beds of sandstone and sandy shale. It gradually increases in thickness and the material gets coarser and more indurated toward the west. Wherever exposed in the Castlegate quadrangle it forms a cliff, and at the west edge of the quadrangle it reaches a thickness of 100 to 125 feet. The top surface is cross-bedded and well indurated, and the beds of sandstone range in thickness from 1 to 10 feet. The lower half of the bed is generally thin-bedded sandstone grading downward into sandy shale and shale at the base.

Storrs tongue.—About 150 feet above the top of the Panther tongue is the Storrs tongue of the Star Point sandstone, which forms a prominent cliff at Storrs, a mining town in Spring Canyon. This cliff extends for several miles from the mouth of the canyon, and here the Storrs tongue is composed of thick-bedded sandstone at the top and thin-bedded sandstone and sandy shale grading into shale at the base. It gradually thins toward the east and disappears before it reaches the east edge of the Castlegate quadrangle. In the vicinity of Kenilworth it is a soft or friable sandstone, sugary in appearance, and about 10 or 15 feet thick.

Spring Canyon tongue.—The Spring Canyon tongue of the Star Point sandstone underlies the Spring Canyon coal group in the western part of the Castlegate quadrangle. At the east edge of the quadrangle this tongue is split into three parts by interfingering tongues of Mancos shale. (See pl. 15.) The lowest part or extension occupies an interval of about 50 feet and lies about 225 feet below the top of the Mancos shale on the east. The upper extension is about 50 feet thick and occurs about 125 feet below the top of the Mancos shale. These two sandstone extensions increase in thickness toward the west at the expense of the intervening shale tongues, and between Kenilworth and Price River they unite and form one massive sandstone, called the Spring Canyon tongue.

BLACKHAWK FORMATION

Aberdeen sandstone member.—The Aberdeen sandstone, more fully defined in Chapter I of this report (p. 18), in this quadrangle consists of a massive medium-grained buff sandstone and ranges in thickness from 100 to 200 feet. It underlies the Castlegate "A" coal bed, and in some places it rests on the Spring Canyon coal group; in

others on the Spring Canyon tongue of the Star Point sandstone; and in still others on a tongue of Mancos shale. (See pl. 15.)

Coal-bearing strata.—The coal-bearing member of the Blackhawk formation ranges through a thickness of 900 to 1,300 feet of strata, consisting of massive gray to buff sandstone, sandy shale, shale, and coal beds, with the sandstone in excess of the other rocks. The sandstone is composed mainly of semirounded fine and coarse quartz grains cemented in most places by carbonate of lime. It is reasonably well consolidated, but not highly indurated, except in some of the fine-grained and highly calcareous beds. The shale is generally more or less sandy, but in places thinly laminated shale occurs, and adjacent to the coal beds much of it contains some carbonaceous material. The coal, which is bituminous in rank, occurs in beds reasonably free from bone and shale partings, and the beds range in thickness from a few inches to 18 or 20 feet. The minimum number of beds that exceed 1 foot 2 inches in thickness at any place is six and the maximum is twelve; there are also many lenses that are less than 1 foot 2 inches thick.

The lower half of the coal-bearing division of the Blackhawk formation contains three economically important coals or coal groups, each of which has a thick cliff-making sandstone at its base. The basal coal group in the west half of the quadrangle is the Spring Canyon coal group, which is usually underlain by the massive white sandstone forming the Spring Canyon tongue of the Star Point sandstone. The basal coal group at the east edge of the quadrangle is the Castlegate, which is underlain by the Aberdeen sandstone member, a cliff-forming bed ranging in thickness from 100 to 200 feet. The Castlegate coal group includes the Royal Blue coal, mined at Kenilworth, and the Castlegate "A," "B," and "C" beds, mined at Castlegate and other places in the western part of the quadrangle. These beds are confined mainly to the area west of Price River and occur within a stratigraphic distance of 100 to 125 feet.

The third prominent coal bed is the Kenilworth, which at the east edge of the quadrangle rests on a well-developed and easily traced sandstone 75 feet thick, but west of Price River this sandstone decreases in thickness and can not be definitely mapped. It is the basal sandstone of the Mesaverde group in the Sunnyside quadrangle, but in the Price River canyon it occurs more than 600 feet above the base of the Mesaverde, this 600-foot interval being farther east replaced by Mancos shale. The Kenilworth coal at Kenilworth is the equivalent of the Castlegate "D" coal bed, mined at Castlegate. The underlying sandstone has been traced as far west as Hardscrabble Canyon, but could not be traced with certainty beyond that locality.

That part of the coal-bearing division of the Blackhawk formation above the Kenilworth coal bed is composed of lenticular beds

of sandstone and shale, thin coal beds, and in places some carbonaceous shale. At the east edge of the quadrangle the Lower Sunnyside coal bed and the sandstone beneath it are traceable, but both the coal and the sandstone decrease in thickness westward and can not be traced.

The coal beds have been extensively burned at the outcrop, and the burning of the coal has greatly altered the associated rocks. At many places these rocks have been fused into slag, and elsewhere adjacent to the burned coal the heat has been sufficient to oxidize the iron in the rocks, thus changing their color from gray or buff to a brick-red.

PRICE RIVER FORMATION

Castlegate sandstone member.—The Castlegate sandstone, the basal member of the Price River formation, is composed of a single bed of massive sandstone, which is exposed continuously across the Sunnyside, Wellington, and Castlegate quadrangles and thence southward along the east face of the Wasatch Plateau.[7] It forms, in most places, a nearly vertical cliff from 100 to 300 or 400 feet high and in the Castlegate quadrangle ranges in thickness from 250 or 300 feet at the east edge to about 450 or 500 feet at the west edge. (See pl. 17, *B*.) It is made up of semirounded quartz grains of medium size and is gray to white or buff. It appears to mark the end of coal-forming conditions during Mesaverde time in this region, for no evidences of coal have been noted above the base of this sandstone. The Castlegate sandstone takes its name from its exposures in Price River Canyon, about 2 miles above the town of Castlegate, where the gatelike passage in the canyon, formed by vertical cliffs of this sandstone, leaves barely room between the cliffs for the river and the railroad.

Noncoal-bearing member.—The noncoal-bearing upper member of the Price River formation in the Castlegate quadrangle is similar to the same member in the Sunnyside and Wellington quadrangles on the east. (See p. 20.) It is composed of beds of sandstone, shale, and sandy shale. The sandstone beds form cliffs and are composed largely of quartz grains. One sandstone 100 feet thick, near the middle of the member, is usually white, and the upper part is nearly pure quartz sand. The thickness of the entire member ranges from about 850 feet at the east edge of the quadrangle to a maximum of about 950 or 1,000 feet at the west edge. The differences in thickness are due in part to erosion at the top, before the Tertiary (Wasatch) beds were laid down, and in part to the westward increase in thickness of the Price River formation.

[7] Spieker, E. M., unpublished data.

TERTIARY ROCKS

WASATCH FORMATION (EOCENE)

The Wasatch rocks rest unconformably upon the eroded surface of the Price River formation. The contact is in places marked by a basal conglomerate, the pebbles of which are fragments of angular limestone. The relief of this old Mesaverde surface, which is due to erosion, is in places several hundred feet. Only the lower part of the Wasatch a few hundred feet in thickness is exposed in this quadrangle. This part is composed of buff sandstone, conglomeratic at the base, yellowish and greenish sandy shale, and some impure limestone. The limestone was noted only at Emma Park, in the northeast corner of the quadrangle, where it forms the top rim at the south edge of the park. Outside of Emma Park the Wasatch rocks cap only the highest hills along the north edge of the quadrangle.

STRUCTURE

General features.—The Book Cliffs and Wasatch Plateau coal fields, of which the Castlegate quadrangle includes a very small part, consist, respectively, of simple northward and westward dipping monoclines on the northern and western flanks of the San Rafael Swell. The Book Cliffs extend in broad curves in a general easterly direction parallel to the strike of the rocks, and the east face of the Wasatch Plateau trends in a northerly direction also parallel to the strike of the rocks. Thus the strike of the rocks in these two great coal fields is in general nearly at right angles, except where they join in Gordon Creek and Pleasant Valley. Here the strike must swing from an easterly direction to a northerly direction, and the resistant sandstones of the Mesaverde group and the Wasatch formation have accommodated the strains and stresses resulting from this abrupt change in strike by faults or displacements instead of by folds or warps. Faults are common in parts of the Wasatch Plateau coal field and some of them have vertical displacements of 3,000 feet.[8]

East of Price River the coal-bearing rocks of this quadrangle strike east and dip 4°–5° N. West of Price River there is a local anticlinal nose with an accompanying synclinal reentrant, and west of this small flexure the strike swings to the northwest. In the vicinity of Castlegate the rocks dip about 6° N., but elsewhere they dip north and northeast from 4° to 5°. The subsurface structural features of the Castlegate "A" coal bed, as interpreted from surface rocks, are shown on plate 22, by structure contours. The Castlegate "A" coal bed is about 500 feet below the Lower Sunnyside bed, on which structure contours are drawn on the map of Sunnyside and

[8] Spieker, E. M., unpublished data.

Wellington quadrangles, which adjoin the Castlegate quadrangle on the east. The datum of each set of contours is sea level, but the Castlegate "A" set is about 500 feet lower than the Lower Sunnyside set. Each contour represents a line connecting all points of equal altitude above sea level on the base of the Castlegate "A" coal bed. The contour interval, or vertical distance between adjacent contours, is 100 feet. Near the outcrop of the coal beds the structure contours may be drawn with certainty, but owing to the uncertain thickness of the subsurface rocks, the possible discordance in dip between the Price River and the Wasatch formation, and the unknown amount of erosion at the top of the Price River it is impossible to interpret with certainty the structure of the coal under thick cover.

The structure contours and the surface contours are referred to the same datum (sea level), and therefore the depth of the coal at any point may be calculated by subtracting the altitude of the structure contour from the altitude of the surface contour where the two intersect, or by interpolation between the contours. Thus Castlegate "A" coal on the divide at the head of Sowbelly Gulch, in the southeast corner of the NW. ¼ sec. 32, T. 12 S., R. 8 E., is estimated to lie at a depth of 2,250 feet. The structure-contour altitude is interpolated as 6,250 feet, and the surface altitude is 8,500 feet; the difference is 2,250 feet. By similar calculation and interpolation the depth of the Castlegate "A" coal may be obtained at other points, and the depth to the other coals at any point may be calculated by adding or subtracting the distance below or above the Castlegate "A" at which the coal lies. These distances are shown on Plate 5.

Faults.—The coal-bearing rocks in the Castlegate quadrangle are affected by faults at only a few places. The faults are of small vertical displacement and small horizontal offset. From location 386, in the SW. ¼ sec. 13, T. 13 S., R. 8 E., a fault which trends N. 70° E. was traced to a point slightly beyond location 394, in the same section. At location 386 the vertical displacement is 10 feet, with the downthrow on the north, and at location 394 the vertical displacement is 25 feet, with a similar downthrow. As will be seen by reference to Plate 22, this break in the rocks is the result of a local flexure. At location 395, in the NW. ¼ sec. 20, T. 13 S., R. 9 E., is a two-pronged fault. The south prong trends N. 80° W. and the north prong N. 60° W. from a common point not far southeast of location 395. The block between the prongs has dropped relatively to the rocks on each side of it. The lowest coal in the Spring Canyon coal group has been displaced 8 feet along the south prong and 11 feet along the north prong, and the Castlegate "A" coal bed has been displaced 7 feet along the south prong and 14 feet along the north prong. At location 408, in sec. 12, T. 13 S., R. 8 E., in Spring Can-

yon, is a dip fault trending northeast. The vertical displacement is 13 feet, and the south side has dropped relatively to the north side. This fault could be traced only a short distance and is too small to interfere greatly with mining operations. About 100 feet north of location 639, in sec. 12, T. 13 S., R. 8 E., is a quartz-bearing vein from 2 to 4 feet wide trending N. 70° W. This vein or joint plane is filled with large secondary quartz crystals, but where it was observed there appears to be no displacement of the rocks.

COAL

GENERAL FEATURES

The coal of economic importance in the Castlegate quadrangle crops out within a stratigraphic distance of about 700 feet, in which the workable beds exposed at any one place range from a maximum of twelve to a minimum of six. The coal is bituminous in rank and is extensively mined at several places in Spring Canyon and Price River Canyon and at Kenilworth, east of Price River. In the early history of mining at Castlegate the coal was coked in beehive ovens, but it was found later that the coal at Sunnyside was better suited for coking, and the ovens at Castlegate were abandoned. The beds generally are lenticular, but some of them are persistent and have been traced with certainty for considerable distances. The Castlegate "A" coal bed has been traced across the quadrangle, and although it is lenticular and thin in places it is estimated to be the most valuable coal bed in the quadrangle. The Kenilworth coal bed, perhaps the next in value, crops out about 175 feet above the Castlegate "A" bed. It has been traced with certainty as far west as Hardscrabble Canyon by means of the massive cliff-forming sandstone on which it rests. The next most valuable coal deposits belong to the Spring Canyon coal group, which in places is composed of three beds. The lowest bed of this group occurs about 175 feet below the Castlegate "A" bed and generally rests on a massive cliff-forming sandstone, by means of which the coal outcrop has been traced in this quadrangle. It is of economic value west of Price River only, being absent or below workable thickness east of the river. The coal beds here, though generally lenticular and of uncertain thickness, are not seriously "split" by bone and shale partings but over relatively small areas are confined to one bench.

The coal beds that could be definitely traced for a greater or less distance in this quadrangle, named in the order of position from the top downward, are the Kenilworth coal (Castlegate "D"), Castlegate coal group (Royal Blue and Castlegate "A"), and Spring Canyon coal group.

Altitude of the bottom of coal beds at some localities where sections were measured in the Castlegate quadrangle, Utah

Spring Canyon coal group [Altitude is that of lowest coal bed unless otherwise noted. For locality numbers see pl. 22]	Feet
380	8297
381	8192
382	8065
383	7848
384	7863
385	7943
386	7888
387	7740
388	7946
389	7893
390 (middle bed)	7713
391	7845
392 (middle bed)	7650
393 (top bed)	7738
394	7735
396	7524
398	7248
399	7429
400	7509
401	7520
402 (middle bed)	7606
403 (middle bed)	7583
404 (top bed)	7758
405 (top bed)	7678
406	7571
407	7496
408	7512
409 (top bed)	7460
410	7456
411	7414
412	7397
413 (top bed)	7424
414 (middle bed)	7443
415 (middle bed)	7377
416 (top bed)	7343
417	7394
418 (middle bed)	7266
419 (middle bed)	7243
420 (top bed)	7335
421 (top bed)	7305
422	7241
423 (middle bed)	7183
424 (middle bed)	7175
425 (top bed)	7165

Spring Canyon coal group—Continued	Feet
426	7107
427	7047
428 (middle bed)	7052
429 (middle bed)	7065
430	7094
431	7150
433	7035
434	7052
435	6986
436	6988
437	6915
445	6874
446	6985
447	7011
448	7008
450	7039
453	6972
451	6990
452	6956
454	7066
455 (middle bed)	7080
456	7089
457	7036
458 (middle bed)	7057
459	7034
460 (middle bed)	7077
461 (middle bed)	7059
462	6943
463	7032
467	6891
468	6962
469	6918
470 (middle bed)	6755
471	6726
472	6689
473 (middle bed)	6724
474	6637
475 (middle bed)	6718
476	6727
478	6578
479 (top bed)	6484
480	6576
481	6332
482 (top bed)	6400
483 (middle bed)	6247
485 (middle bed)	6238
487 (middle bed)	6400
488	6412

Castlegate "A" coal bed	Feet
489	8288
490	8250
491	8028
492	8035
493	8025
494	8029
495	7870
496	7828
497	7805
498	7762
499	7724
500	7650
501	7681
502	7615
503	7607
504	7757
505	7629
506	7628
507	7610
508	7573
509	7540
510	7545
511	7463
512	7457
513	7429
514	7394
515	7376
516	7383
517	7386
518	7393
519	7250
520	7276
521	7245
522	7160
523	7242
524	7100
527	7130
528	6923
531	7046
532	7148
533	7168
534	7217
535	7257
536	7255
537	7295
538	7162
539	6945

Castlegate "A" coal bed—Continued	Feet
540	6954
541	6783
542	6844
544	6895
545	6875
552	6193
553	6226
554	6304
555	6328
556	6407
557	6414
558	6554
559	6655
560	6775
561	6788
562	6745
563	6823
564	6872
565	6927
566	6924
567	6856
568	6875
570	7120
571	7094
573	7148
574	7241
575	7307
576	7456
577	7331
578	7347
579	7469
580	7221
582	7128
583	7321
584	7181
585	7140
587	7143
588	7170
589	7101
590	7228
591	7276
592	7280
593	7426
594	7538
595	7419
596	7553
597	7110
598	7186
599	7350
Royal Blue coal bed	
600	6927
601	6634
602	6248
603	6394
605	6775
606	6873
607	7188
608	7305
609	7280
610	7412
611	7425
612	7225
613	7215
Kenilworth coal bed	
614	6845
615	6325
616	6560
617	7197
618	7488
619	7492
620	7460
Kenilworth coal bed—Contd.	
	Feet
621	7345
622	7335
623	7182
624	7725
625	7207
626	7350
Coal beds for which no definite correlations can be made	
628	8220
629	8335
630	8055
631	8235
633	7970
634	7855
636	7950
637	7740
638	8060
639	7808
640	7445
641	7455
642	7246
643	7263
644	6935
645	7075
646	6770
647	6905
648	6405
651	6805
652	7275
653	7705
654	7315
655	7270
656	7340
657	7610

The Kenilworth, Castlegate "A," and Spring Canyon coal beds rest each on a massive cliff-forming sandstone. These sandstones were used as key rocks and were the main basis for the field mapping. In some places the coal rests directly on the sandstone, and in others it is separated from the sandstone by a few inches or a few feet of shale. The Royal Blue coal at Kenilworth, where it is best developed, is directly overlain by a massive sandstone, which in places contains horsebacks at the base that cut out a part of the coal bed. East of Price River no prominent key rocks are associated with the coals above the Kenilworth bed, and west of Price River the same condition prevails as to coal beds above the Castlegate "A" bed.

The coal has been so extensively burned at the surface that exposures showing the full thickness of the beds are rare. Because of this con-

dition it is difficult to give a proper interpretation of the character and thickness of the coal under cover. Many exposures show the bands of ash left from the burning of the coal, but these are of little value in mapping because of the slumping and caving of the rocks as the coal burns out.

STRATIGRAPHY OF THE COAL BEDS AND ASSOCIATED ROCKS

Graphic sections of the rocks.—A number of stratigraphic sections showing the general character of the coal-bearing rocks and the thickness and relative position of the coal beds were measured and are shown in Plate 5. Sections believed to represent the same bed are connected by broken lines. In plotting these sections the datum used was the top of the Aberdeen sandstone, on which the Castlegate "A" coal rests. (See pl. 16, *C*.) Each important coal-forming period was preceded by the deposition of great quantities of sand and the resulting sandstones differ in thickness from place to place. The coal beds and the associated rocks are lenticular, and it is impossible to make definite correlations for coals that are not associated with key sandstones.

The numbers on the left side of the sections in Plate 5 and in the detailed coal-section township plates correspond with the numbers used to designate the location of these sections on Plate 22. In order to avoid duplication of reference numbers in this bulletin the numbers for the Castlegate quadrangle begin with 380, the next consecutive number following the last number used on the Sunnyside quadrangle, and continue consecutively to 657.

The vertical section (pl. 4) gives a general graphic picture of the stratigraphy and the history of deposition of the coal-bearing rocks in the Castlegate quadrangle and farther east. The prominent features there shown are the sandstone tongues, which unite farther west and form the thick, massive sandstones that underlie and separate the chief coal groups; the thick sandstone beds which precede in time each of the chief coal groups; the eastern limit of the Spring Canyon and the Castlegate coal groups, which indicates the extent in that direction of the coal-forming swamp; the lenticular character of the coal and sandstone beds above the Castlegate "A," Kenilworth, and Lower Sunnyside coal beds; and the prominent sandstone beds in the upper part of the coal-bearing member, which thin and become more or less broken toward the west.

Spring Canyon coal group.—The Spring Canyon is the lowest coal group exposed in the Castlegate quadrangle. It contains a maximum of five and a minimum of two workable coal beds in an interval of 100 to 125 feet between two massive beds of sandstone. The lower sandstone, the Spring Canyon tongue, is about 200 feet thick, and the

upper one, the Aberdeen member, is about 100 feet thick. The interval between these two sandstones diminishes and the coal beds become fewer toward the east, and not far east of Price River the sandstones merge and "pinch out" the coal group. The lowest coal of this group generally rests on the Spring Canyon tongue of the Star Point sandstone, but in places is separated from it by a few feet of shale. The coal in this bed ranges in thickness from 8 inches at location 388, in sec. 24, T. 13 S., R. 8 E., to 7 feet 4 inches at location 439, in sec. 9, T. 13 S., R. 9 E. At most places where the coal is exposed between location 380, in sec. 23, T. 13 S., R. 8 E., and location 488, in sec. 6, T. 13 S., R. 10 E., it exceeds 1 foot 2 inches in thickness. It is thickest in Spring and Hardscrabble Canyons between location 401, in sec. 11, T. 13 S., R. 8 E., and location 474, in sec. 10, T. 13 S., R. 9 E., where it ranges from 1 foot 6 inches to 7 feet 4 inches and averages about 4 feet.

The highest coal in the Spring Canyon group could not be traced with certainty for long distances, but it is believed to be persistent and of workable thickness between location 380, in sec. 23, T. 13 S., R. 8 E., and location 425, in sec. 7, T. 13 S., R. 9 E. It ranges in thickness from 1 foot 1 inch to 6 feet 9 inches and averages about 4 feet 9 inches. The easternmost exposure on the outcrop that can be called definitely the highest bed of this coal group was found at location 425, where a part of the bed has been burned; the remainder is 3 feet 4 inches thick. It is believed, however, that this bed is of workable thickness for a considerable distance farther east.

Three workable coal beds crop out between the lowest and highest beds of the Spring Canyon group between locations 380 and 425, and the average aggregate thickness of all beds in this interval that exceed 1 foot 2 inches in thickness is about 7 feet 6 inches. No more definite correlation of these beds, however, can be made than is shown by the difference in interval between them and the lowest or highest coal bed. East of location 425 the middle part of the Spring Canyon coal group is generally exposed in two beds, but in places only one bed crops out, and the aggregate thickness of the coal ranges from 1 foot 7 inches to 7 feet 3 inches and averages about 4 feet 2 inches.

In plate 4 the eastern limit of the Spring Canyon coal group and the reasons for this limit are apparent. The swamp in which the vegetation that formed the Spring Canyon coals accumulated extended from somewhere west of the Castlegate quadrangle eastward to and beyond Price River. Exposures in the vicinity of Price River indicate that the coal swamp was cut off from the open sea on the east by sand bars. In this locality there appears to have been continuous sand deposition from the end of Mancos time to the change that produced the extensive swamp in which the Castlegate "A" coal bed was formed. The sandstone now present east of the limit

of the Spring Canyon coal group is 425 feet thick. From the available outcrops it appears that the greatest quantity of vegetation which was converted into the Spring Canyon coals accumulated in the vicinity of upper Spring Canyon.

The Spring Canyon coals are extensively mined at Storrs, Standardville, and other places in Spring Canyon. At Storrs the mines working these coals are designated No. 1, which is on the lowest bed, and No. 2, on the middle bed. At Standardville and in Spring Canyon mine No. 3, at Storrs, the Castlegate "A" coal is being worked.

Castlegate coal group.—The Castlegate coal group in the Castlegate quadrangle includes four beds; named in order from the lowest upward they are the Castlegate "A," the Castlegate "B," the Royal Blue, and the Castlegate "C."

The Castlegate "A" bed generally rests on the Aberdeen sandstone, which ranges in thickness from 80 to 150 feet, or is separated from it by a few feet of shale. The stratigraphic distance between the top of the Spring Canyon tongue of the Star Point sandstone and the top of the Aberdeen sandstone ranges from 180 feet at location 488, in sec. 6, T. 13 S., R. 10 E., to 250 feet at location 464, in sec. 14, T. 13 S., R. 9 E., and averages about 200 feet. In places the Castlegate "A" bed is one of the thickest coals in the quadrangle, and at Kenilworth it attains a maximum thickness of 19 feet. It has been traced with the aid of the Aberdeen sandstone from the west edge of the Castlegate quadrangle eastward to Coal Creek, in the Wellington quadrangle, a distance of 18 miles by air line. At Kenilworth this bed is confined to one bench with only thin bone and shale partings, but both east and west of Kenilworth it occurs at many places in two or more benches. West of Kenilworth there is a "split" in this bed, and the upper bench, which is generally the thicker, is as much as 30 feet above the Aberdeen sandstone. The lowest bench at Castlegate, where it is lenticular and of uncertain thickness, is called the Castlegate "A" bed. Its greatest thickness is in the vicinity of Kenilworth (pl. 17, *A*) and in Spring Canyon. Between these two localities and east of Kenilworth, in the Wellington and Sunnyside quadrangles, it is in places of less than workable thickness.

The Castlegate "B" bed occurs between the Castlegate "A" and the Royal Blue beds and crops out in places between location 491, in sec. 13, T. 13 S., R. 8 E., and location 609, in sec. 17, T. 13 S., R. 10 E. It is generally exposed in two benches, ranges in thickness from 10 inches to 9 feet 7 inches, and averages about 4 feet 9 inches. The correlations suggested in Plate 5 for this bed are doubtful, and the exposures are so widely scattered that it is impossible to determine definitely the character, thickness, and continuity of this coal under cover. The No. 2 bed in the mine of the Cameron Coal Co., in sec. 35, T. 12 S., R. 9 E., which is there more than 9 feet thick, is

believed to be the equivalent of the Castlegate "B." East of Castlegate the Utah Fuel Co., in its No. 2 mine, and the Panther Coal Co., at Panther, are mining this coal where it is of good thickness, but it contains many thin bone and shale partings.

The Royal Blue coal is the highest bed of the Castlegate coal group at Kenilworth, but it is extensively mined, and it ranges from 2 to 8 feet in thickness. It is there separated from the Kenilworth bed by a massive sandstone 70 feet thick. The sandstone rests directly on the Royal Blue coal and contains many horsebacks, which cut out a part of the coal. In Plate 5 a broken line connecting adjacent sections indicates a possible correlation of the Royal Blue bed as far west as location 496, in sec. 19, T. 13 S., R. 9 E. In most places, west and south of Colgate, however, this coal at the outcrop is only a few inches thick and is of small economic value. The Royal Blue bed was traced definitely and is known to be of workable thickness between location 608, in sec. 17, and location 613, in sec. 11, both in T. 13 S., R. 10 E.

West of Kenilworth a coal occurs above the Royal Blue and below the Kenilworth which in the Castlegate mines is called the Castlegate "C." This coal generally occurs in one bench, but in places there are three benches. It crops out in several places between location 634, in sec. 19, T. 13 S., R. 9 E., and location 607, in sec. 8, T. 13 S., R. 10 E. The aggregate thickness of all benches ranges from 1 foot 3 inches to 6 feet 10 inches and averages about 4 feet.

The conditions that limited the eastern extent of the Castlegate "A" coal are clearly shown in Plate 4 and are similar to the conditions that limited the eastern extent of the Spring Canyon coal group. In the vicinity of Soldier Creek, in the Wellington quadrangle, the swamp in which the Castlegate coal group formed was cut off from the open sea by sand bars, and the protection thus afforded enabled the vegetation which later formed the present coal beds to accumulate. In the vicinity of Soldier Creek there appears to have been continuous sand deposition for a long period, which resulted in a sandstone that is now 400 feet thick. A considerable portion of this sand, near the middle of the bed, was laid down during the same time that the vegetation was accumulating to form the Castlegate coal group.

Kenilworth coal bed.—The Kenilworth coal bed generally rests on a sandstone that ranges in thickness in this quadrangle from 10 to 110 feet. This sandstone has its maximum thickness at the east edge of the quadrangle and gradually thins toward the west. It is not traceable on the outcrop west and south of Hardscrabble Canyon, but a close study of the sections in Plate 5 suggests the correlation for this sandstone as far west as location 633, in sec. 19, T. 13 S., R. 9 E. This sandstone, together with the overlying coal, appears to be pres-

ent in a diamond-drill core taken at location 530, in sec. 9, T. 13 S., R. 9 E., a record of which was obtained through the courtesy of the Spring Canyon Coal Co. The distance between the top of this sandstone and the top of the Aberdeen sandstone ranges from 145 feet at location 620, in sec. 15, T. 13 S., R. 10 E., to 200 feet at location 530, in sec. 9, T. 13 S., R. 9 E., and averages about 170 feet.

The Kenilworth coal bed is one of the most persistent and widespread coals in the Castlegate, Wellington, and Sunnyside quadrangles. Its outcrop has been traced, with the aid of the underlying sandstone, from a point near the south side of the Sunnyside quadrangle northwestward to Hardscrabble Canyon, a distance of 33 miles by air line. From a careful study of the sections shown in Plate 5, this bed appears to be present and of workable thickness as far west as location 630, in sec. 18, T. 13 S., R. 9 E., so that it possibly extends for a distance of 38 miles on the outcrop in an air line.

The Kenilworth coal has been burned at the surface over a considerable part of its outcrop, and therefore the true thickness of this bed is difficult to estimate from the few exposures. The thicknesses measured on the outcrop range from 1 foot 4 inches at the west edge of the area to 18 feet 9 inches at Kenilworth and average about 6 feet 8 inches. The thickest portion of this coal bed is in the vicinity of Kenilworth and east of Castlegate, where the coal is extensively mined. The correlations of sections on this bed indicated in Plate 5 are definite as far west as location 614, in sec. 3, T. 13 S., R. 9 E., but west of this place the correlations suggested are based on the character and thickness of the associated rocks as shown in Plate 5. In the mines at Castlegate the Kenilworth coal is called the Castlegate "D" bed.

Coal beds above the Kenilworth bed.—In the upper part of the coal-bearing member of the Blackhawk formation, within a stratigraphic distance of 325 feet above the Kenilworth coal, many thin coal beds occur for which no definite correlation between adjacent exposures can be made. In this interval a minimum of two and a maximum of five workable beds are known, which range in thickness from 1 foot 2 inches to 4 feet 6 inches. The highest of these coals is the Lower Sunnyside, which was traced continuously across the Sunnyside and Wellington quadrangles and into the east edge of the Castlegate quadrangle, where, at location 657, in sec. 13, T. 13 S., R. 10 E., it is 4 feet 6 inches thick. The Lower Sunnyside could not be traced within the Castlegate quadrangle because the coal is extensively burned at the outcrop and because the underlying massive sandstone thins westward and ceases to be a traceable unit. The aggregate thickness of the group of thin coal beds referred to above ranges from 3 feet 7 inches to 11 feet 3 inches and averages about 5

feet 10 inches. These thicknesses, however, are general, because they are based on sections measured at points considerable distances apart. The diamond-drill record made at location 530, in sec. 9, T. 13 S., R. 9 E., may be taken as a fair index of the number and thickness of the coal beds in the interval penetrated by the drill. As is shown in Plate 5, this record includes many thin beds of coal, three of which are each 1 foot 6 inches thick.

Further details of each coal bed are given below together with graphic sections of coal beds which are exposed in each township.

DESCRIPTION OF COAL BY TOWNSHIPS

GENERAL FEATURES

Coal beds in this quadrangle are lenticular and irregular in thickness, and therefore can be described best by separating the quadrangle into relatively small geographic units. The legal subdivision, the township, is taken as the unit for grouping the coal sections on the plates and for the detailed description of the coal beds that follows. The townships are taken up in geographic order, beginning at the west edge of the quadrangle. These sections are numbered from west to east on the outcrop, beginning with the Spring Canyon coal group. (See pl. 22.) The numbers on the Spring Canyon group run from 380 to 488. The numbers on the Castlegate coal group, the next one above the Spring Canyon group, run from 489 to 599. Numbers from 600 to 657 are used to designate exposures on the Royal Blue and Kenilworth beds and several other beds that can not be definitely correlated.

T. 12 S., R. 8 E.

General features.—The portion of T. 12 S., R. 8 E., that lies within the Castlegate quadrangle includes parts of secs. 25, 26, and 35 and all of sec. 36 and is situated in the extreme northwest corner of the quadrangle. The southeast corner of sec. 36 lies 1 mile north of the nearest coal outcrop, but there is every reason to believe that several of the coal beds exposed in Spring Canyon and elsewhere in this quadrangle are present under cover in T. 12 S., R. 8 E. It is difficult to determine what coals may underlie this township or to estimate their thickness. It is believed that the Spring Canyon group, the Castlegate group, and the Kenilworth coal bed, together with the thin coal beds above the Kenilworth, are present in this township and should equal the average thickness of these beds in near-by territory.

Tonnage estimate.—It is estimated that the equivalent of four groups of coal beds, each having an average thickness between 3 and 15 feet, are present in the southeast corner of T. 12 S., R. 8 E. The aggregate thickness of all beds in this portion of the township is

estimated to be at least 25 feet, which would give a potential tonnage of about 61,000,000 short tons of coal. This tonnage includes estimates for the Spring Canyon group, the thin coal beds above the Kenilworth, the Castlegate group, and the Kenilworth bed, named in the order of their estimated tonnage yield. The details of the tonnage estimate by beds is given in the table on page 161.

Accessibility.—The coal in that part of T. 12 S., R. 8 E., which lies within the Castlegate quadrangle is economically inaccessible at the present time, because it can be reached only by shafts or by drift mining from the outcrop in Spring Canyon, and because vast beds of thick coal in near-by areas are more accessible. The most efficient method of mining is by drifts from the outcrop. A main entry from 2 to 2½ miles long would be required to reach the coal in this township. This main entry could be driven on a low grade, as the rocks strike northwest. A railroad could easily be extended from Standardville up Spring Canyon to the point where the coal passes below drainage level.

T. 13 S., R. 8 E.

General features.—The greatest number of coal beds found anywhere in this quadrangle are exposed in the part of T. 13 S., R. 8 E., which is included in the quadrangle. Twelve beds which exceed 1 foot 2 inches in thickness are exposed, but only the Spring Canyon coal group and the Castlegate "A" coal bed could be definitely mapped, although tentative correlations are suggested in Plates 5 and 18 for the Kenilworth coal bed and several other beds.

Many sections showing the relative positions and thicknesses of the coal beds and the character and thickness of the associated rocks were measured in this quadrangle and are included in Plate 5.

Several coal sections which were measured in this township are shown graphically in the text under the descriptions of the several beds instead of in Plate 18.

The coal here is generally well exposed where it has not been burned at the outcrop and 62 sections that exceeded 1 foot 2 inches in thickness were measured in this township, 57 of which are shown in Plates 5 and 18.

Spring Canyon coal group.—The Spring Canyon is the most valuable coal group in T. 13 S., R. 8 E. At location 409, in sec. 12, there is 15 feet 4 inches of coal in six beds, each exceeding 1 foot 2 inches in thickness. These beds may be separated into three divisions, the lower generally containing two beds, the middle two or three beds, and the upper containing one bed.

The Spring Canyon coal group here, as elsewhere in this quadrangle, was mapped with the aid of the underlying sandstone (the

Spring Canyon tongue of the Star Point sandstone). The lowest coal bed is generally separated from the sandstone in this township by a few feet of shale. The sections in Plate 18 are plotted with this sandstone as a datum, and the correlation of the several beds and benches of the coal group is based on their distances above this sandstone, on field observations, and on the character of the interbedded rocks. The beds of this group are here lenticular and irregular in thickness, and it is difficult to map and correlate them with certainty. The lowest and highest beds are the most easily mapped, and the correlations suggested for them are fairly certain. The sections in Plate 18 suggest that the interval between the two beds of the middle division thins toward the north and east and that these two beds nearly merge to form one bed in two benches at location 414, in sec. 12.

The lowest bed of the Spring Canyon group is erratic and lenticular. At location 380–x (pl. 18) the coal is only 13 inches thick; it increases to 1 foot 9 inches in thickness at location 381 and to 2 feet 11 inches at location 384, in sec. 13. At location 386, also in sec. 13, the coal is 3 feet 7 inches thick, but it decreases to only 8 inches thick at location 388, in sec. 24. From location 389, where this bed is 3 feet 3 inches thick, it is of workable thickness where exposed throughout the remainder of the township and attains a maximum of 6 feet 11 inches at location 403–x in sec. 11. In secs. 13 and 14 the upper bench of the lowest bed appears to be of no economic value, as there are only two exposures, at locations 384 and 386, where the coal in this bench is 1 foot 2 inches or more in thickness. The upper bench of the lowest bed is 1 foot 9 inches thick at location 406, in sec. 11, and gradually increases in thickness toward the east, attaining a maximum of 4 feet 2 inches at location 411a, near the center of sec. 12. The two benches of the lowest bed of this group are so near together at most places that they may be mined from the same haulage ways and entries.

The highest bed of the Spring Canyon group is more uniform in thickness than any other bed of this group in the township. At location 380b, in sec. 23, it is not workable, being only 13 inches thick, but it appears to increase rapidly in thickness toward the north and east, and at location 382, near the center of sec. 14, it is 4 feet 7 inches thick, and at location 387, near the south line of sec. 13, 6 feet 9 inches. Elsewhere in this township where this bed is exposed it ranges in thickness from 3 feet 7 inches at location 420, in sec. 12, to 5 feet 4 inches at location 404, in sec. 11.

The Spring Canyon group in this township is not so extensively burned at the surface as the higher coals, and therefore exposures of it are more plentiful. At several places, however, a portion of the

coal was burned, and the true thickness of the beds could not be determined. These partly burned outcrops occur at locations 383 and 385, in sec. 13, 390, in sec. 24, and 408–b, in sec. 12. The aggregate thickness of the Spring Canyon group, in beds exceeding 1 foot 2 inches in thickness at places where all the coal appears to be exposed, ranges from 6 feet at location 380, in sec. 23, to 19 feet 4 inches at location 403, in sec. 11, and averages about 14 feet 6 inches. The coal at location 391, in sec. 24, is completely burned at the surface.

Castlegate coal group.—The Castlegate coal group in T. 13 S., R. 8 E., as here described, includes a maximum of four beds that exceed 1 foot 2 inches in thickness at location 518, in sec. 12. These beds are distributed through a vertical distance of 100 feet above the Aberdeen sandstone, which lies at the base of the lowest coal bed. The beds in this group include the Castlegate "A," Castlegate "B," Royal Blue, and Castlegate "C." These beds are here lenticular and irregular in thickness, and the correlations suggested in Plate 5 and in the text are only tentative, except that of the Castlegate "A" bed, which is fairly certain because of the sandstone underlying the bed.

The Castlegate "A" bed is only 12 inches thick in two benches at location 489 and 4 inches thick in two benches at location 491, both in sec. 14, and only 8 inches at locations 492–x and 493–x, in sec. 13. It increases in thickness toward the north and east from these locations, however, being 2 feet 4 inches thick at location 490, in sec. 14, and 2 feet 2 inches thick in two benches at location 495–y, in sec. 13. At location 501, in the northeast corner of sec. 13, this bed is composed of four benches, which aggregate 3 feet 10 inches in thickness, and at location 504, in sec. 11, there are two benches, aggregating 3 feet 1 inch. At location 505, in sec. 11, the lower bench of this bed is absent and the upper bench is only 11 inches thick, and at location 506, in sec. 12, the lower bench is 5 inches thick and the upper bench 2 feet 3 inches. East and north of location 506 the top bench appears to be thin or absent. The next exposure is at location 512, in sec. 12, where two benches together have a thickness of 4 feet 5 inches, but this is not the total original thickness of the coal, because a part of it has been burned. The Castlegate "A" bed between locations 507 and 512, both in sec. 12, ranges from 1 foot 10 inches to 2 feet 6 inches in thickness. From location 513 to location 518 the coal on the outcrop is confined to one bench, which attains a maximum thickness of 10 feet at location 518, near the east line of sec. 12. The Castlegate "A" bed has been burned at the surface at several places on Burnt Tree Fork of Spring Canyon.

The following exposures show only part of the thickness of the Castlegate "A" coal:

Sections of Castlegate "A" coal in T. 13 S., R. 8 E.

Location 511, sec. 12

	Ft.	in.
Shale, burned.		
Coal	2	1
Shale		3
Sandstone (Aberdeen)	10	

Location 515, sec. 1

	Ft.	in.
Shale, burned.		
Shale and ash		6
Coal, altered	2	6
Base not exposed.		

Location 517, sec. 12

	Ft.	in.
Sandstone (top not exposed).		
Coal	2	8
Ash and shale		1
Sandstone (Aberdeen)	35	

It appears from the sections in Plates 5 and 18 that the Castlegate "B" bed may be represented in this township, but the suggested correlation is conjectural, because the outcrop of the bed can not be traced. The bed here is composed of two benches, the upper one ranging from 30 feet above the Aberdeen sandstone at location 491, in sec. 13, to 55 feet at location 642, in sec. 6, T. 13 S., R. 9 E. The Castlegate "B" bed crops out as two benches at locations 491, 492, 493, and 495, in sec. 13, where the aggregate thickness ranges from 4 feet 8 inches at location 492 to 8 feet 11 inches at location 495 and averages about 6 feet 9 inches. At location 501–a in sec. 13, the thickness of the two benches is 3 feet 5 inches and at location 504–a, in sec. 11, the lower bench only is exposed and is 12 inches thick. No exposures were found on this bed between locations 504–a and 516–a, in sec. 1, but at the latter location one bed 2 feet 2 inches thick crops out, which appears to represent the total coal at this horizon.

No exposures were found in T. 13 S., R. 8 E., at the horizon of the Royal Blue bed.

The Castlegate "C" bed, which occurs between the Royal Blue bed and the Kenilworth (Castlegate "D") bed, may be represented in this township by sections at location 635, in sec. 13, and locations 640 and 641, in sec. 1. At locations 635 and 637 there are two benches, aggregating 6 feet 10 inches in thickness; at location 640 three benches, aggregating 4 feet 6 inches; and at location 641 two benches, aggregating 4 feet 6 inches. These exposures suggest a lens of workable coal of considerable size in secs. 1, 12, and 13. This bed, however, in secs. 23 and 24 and the S. ½ sec. 14 appears to be of little value, because at location 396–c, in sec. 20, T. 13 S., R. 9 E., only 8 inches of coal is exposed.

Kenilworth coal bed.—The Kenilworth bed may contain workable coal under cover in much of T. 13 S., R. 8 E., but it crops out at only a few places. At location 628, in sec. 13, two benches, one 6 inches and the other 1 foot 5 inches thick, crop out, and these coals may be the equivalent of a part of the Kenilworth bed. At locations 639 and 639–x, in sec. 12, there is an aggregate thickness of 2 feet 9 inches

of coal in two benches, which is tentatively correlated as the equivalent of the Kenilworth bed. From exposures in this township and adjacent territory on the east it is believed that considerable coal of workable thickness is present under cover at the horizon of the Kenilworth bed.

Summary of coal beds.—Several coal beds of economic value are exposed in T. 13 S., R. 8 E. Two groups, the Spring Canyon and the Castlegate, have been mapped with considerable certainty. Each of these groups is underlain by a massive bed of sandstone, which facilitates the mapping and correlation of the lowest bed in each group. Other beds in these groups and the Kenilworth bed have been tentatively correlated as shown in Plate 5. The Spring Canyon is the more valuable of the two groups.

Tonnage estimate.—A large tonnage of good coal is estimated to be present under cover in the part of T. 13 S., R. 8 E., within the Castlegate quadrangle. Four groups of beds, the Spring Canyon, Castlegate, Kenilworth, and beds above the Kenilworth (not named nor correlated), are estimated to contain an aggregate of 137,000,000 short tons of coal. The table on page 161 gives the details of the tonnage estimate of coal groups and beds in the township.

Accessibility.—The coal under cover in T. 13 S., R. 8 E., can be most easily mined in Spring Canyon. The Spring Canyon branch of the Denver & Rio Grande Western Railroad, already in operation, could be extended up the canyon without excessive grades to the point where the coal passes below drainage level. From openings on the outcrops in Spring Canyon main entries and haulage ways could be made in a northwest-southeast direction, parallel with the strike of the rocks. From these entries raises and slopes could be driven to reach all the coal under cover in this township. The coal on the south side of Spring Canyon appears to be more extensively burned at the surface than that on the north side, and therefore entries on the south side might have to be driven farther to reach marketable coal. Furthermore, the coal is probably thicker in that part of the township lying north of Spring Canyon than it is in the territory south of the canyon.

T. 12 S., R. 9 E.

General features.—The southern part of T. 12 S., R. 9 E., comprising the south tier of forties of secs. 25 to 30 and all of secs. 31 to 36, lies within this quadrangle. Some of the coal beds above the Aberdeen sandstone crop out in Price River Canyon north of Castlegate, in secs. 35 and 36, but elsewhere the coal is under cover.

At Cameron, in sec. 35, two coal beds are mined through slopes. No. 1 is believed to be the equivalent of the Castlegate "C" bed, and No. 2, the lower one mined, is believed to be the equivalent of the

Castlegate "B" bed. According to mine officials of the Cameron Coal Co., a drill core shows 5 feet of coal at 19 feet below the No. 2 bed, which is believed to be the equivalent of the Castlegate "A" bed. These correlations are suggested on the basis of the distance between the beds and the computed altitude of the top of the Aberdeen sandstone under cover at Cameron. This altitude was computed by extending the rate of dip or pitch of this sandstone as known on the outcrop from three directions to the mine at Cameron. These computations give an average of about 6,010 feet above sea level for the Aberdeen sandstone at the Cameron mine. The altitude of the Aberdeen sandstone at Cameron, computed from data obtained from the company's engineer, is 5,990 feet. The difference between these computed altitudes may be due in part to differences in the sea-level datum used and in part to a change in the rate of pitch of the sandstone between Cameron and the nearest point on the outcrop.

The rocks above the Aberdeen sandstone crop out in the southeast corner of the township, but few exposures of coal were found. Because most of the coal in this township is under cover and because the coal has been burned where it otherwise would crop out, its character and thickness under cover must be interpreted largely by what is known of the coal in adjacent territory on the south.

Four coal groups—the Spring Canyon, Castlegate, Kenilworth, and the coals above the Kenilworth—each consisting of one or more beds and here named in their relative order of value and tonnage yield, are believed to be present under cover in T. 12 S., R. 9 E.

Spring Canyon coal group.—The Spring Canyon coal group must be interpreted wholly from exposures on the outcrop south of this township from a few hundred feet to 2½ miles distant. This coal group in T. 13 S., Rs. 8 and 9 E., increases continuously in thickness toward the west and north, and near the west edge of the quadrangle attains a thickness of nearly 20 feet. From a careful study of all exposures it is estimated that the Spring Canyon coal group will average about 11 feet in thickness in T. 12 S., R. 9 E.

Castlegate coal group.—The rocks associated with the Castlegate group crop out in Price River Canyon, in secs. 35 and 36, but the coal beds are extensively burned, and few exposures remain. The character and thickness of the coal here must be interpreted from what is shown by the outcrop on the east and south, and from the few sections which were measured in near-by mines.

The Castlegate group in the Castlegate quadrangle has two localities of maximum thickness. In one, at Kenilworth, the group is confined to a single bed, which has a maximum thickness of 18 feet, and in the other, in Spring Canyon, the Castlegate "A," in one bed, attains a maximum thickness of 17 feet. From these two localities the group as a whole appears to thin toward the west, north, and east,

and the individual beds also vary throughout small areas. The irregular thickness of the coals on the outcrops is likely to be characteristic of them throughout T. 12 S., R. 9 E., and it is impossible to estimate with certainty the thickness of this coal group under cover several miles from an outcrop. At Cameron, according to correlations already suggested, the Castlegate group attains a total thickness of 20 feet 5 inches in three beds as follows: Cameron No. 1 (Castlegate "C" bed) 6 feet 9 inches, Cameron No. 2 (Castlegate "B" bed) 9 feet 8 inches, and a 5-foot coal bed (Castlegate "A" bed) reported to lie 19 feet below the Cameron No. 2. (See pl. 20 for sections of Castlegate "A" coal in this township.) These measurements indicate another area, in the vicinity of Cameron, of thick coal in the Castlegate group, but the beds of this group are known to be lenticular and irregular in thickness where mined in the Castlegate mines. It is estimated that the Castlegate group, not including the Royal Blue bed, averages about 9 feet in thickness throughout that part of the township included in the Castlegate quadrangle.

Royal Blue bed.—The Royal Blue bed occurs between beds identified as the Castlegate "B" and "C." It is of small economic value here, as is indicated by the two exposures in this township, together with those in adjoining townships on the south and east. At location 602, in sec. 36, there are two benches whose combined thickness is 3 feet 9 inches, but at location 553–c, in sec. 36, there is only 12 inches of coal. From the available information it is estimated that the Royal Blue bed may contain an average of 1 foot 8 inches of coal and may cover an area of about 2 square miles in the southeast corner of the township.

Kenilworth coal bed.—The Kenilworth coal is not exposed in T. 12 S., R. 9 E., but evidence of burning at many places in Price River Canyon and near by suggests that considerable coal may be present under cover in this bed. The estimate of the coal under cover is based on its known thickness at the outcrop on the south and east and on information obtained in the mines at Castlegate, where this bed is called the Castlegate "D" bed. Its average thickness in this township is estimated at about 3 feet 6 inches.

Coal beds above the Kenilworth bed.—Several beds that could not be correlated with any of the known coals crop out above the Kenilworth bed in places in T. 12 S., R. 9 E. The exposures are widely scattered, and it is impossible to determine definitely the continuity and thickness of the beds under cover in any given area. It has been roughly estimated that these beds may aggregate 4 feet in thickness.

Tonnage estimate.—T. 12 S., R. 9 E., is so near the outcrop of several thick and extensive coal beds and groups of beds that there is abundant reason to believe that these beds or their equivalents will

be found of good quality and thickness in this township. On the basis of the known thickness and character of the coal in near-by territory it is estimated that at least 196,000,000 short tons of coal, in beds more than 1 foot 2 inches thick, is present under cover in the part of T. 12 S., R. 9 E., within the Castlegate quadrangle. The tonnage includes estimates for the Spring Canyon group, the Castlegate group (not including the Royal Blue bed), the Kenilworth bed, a series of beds above the Kenilworth, and the Royal Blue bed, named in the order of their estimated yield. The details of the tonnage estimate by beds are given in the table on page 161.

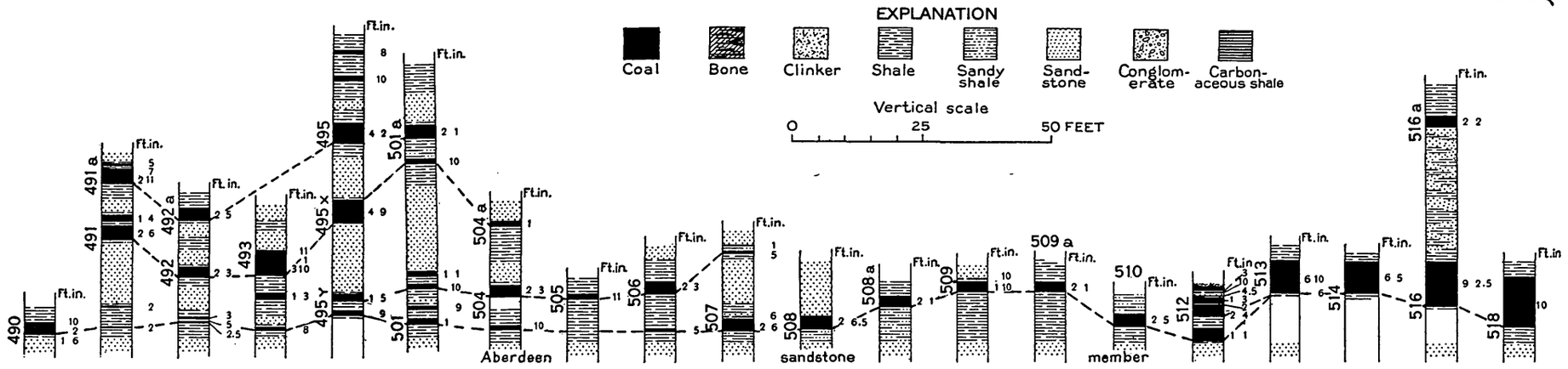
Accessibility.—The coal under cover in the east half of T. 12 S., R. 9 E., in the Castlegate quadrangle, can be made accessible from the present mining works by extending main entries parallel with the strike of the rocks and by driving raises and slopes from these entries. The coal in the west half of this township is relatively inaccessible at the present time, because it must be mined by shafts or by drift mines having main entries from 2 to 3 miles long and because there are great quantities of coal nearer the outcrop that can be mined at much less expense. Drift mining from the outcrop in Spring Canyon is the most economical method of mining the coal in the west half of this township, as the main entries may be driven on coal beds with low grades in favor of loads. In shaft mining the coal must be lifted 1,000 to 1,500 feet and after reaching the surface must be transported by tram probably for several miles to railroad connections. The Castlegate "A" bed near the head of Sowbelly Gulch, just north of the south line of the township, is about 1,000 feet below the surface, and the Spring Canyon group is from 100 to 200 feet deeper. Near the head of Robinson Gulch, close to the south boundary of the township, the coal may be reached by shafts at about 800 feet below the surface. The coal elsewhere in the west half of this township would lie at greater depths, as the surface is much higher and the coal pitches downward toward the north.

T. 13 S., R. 9 E.

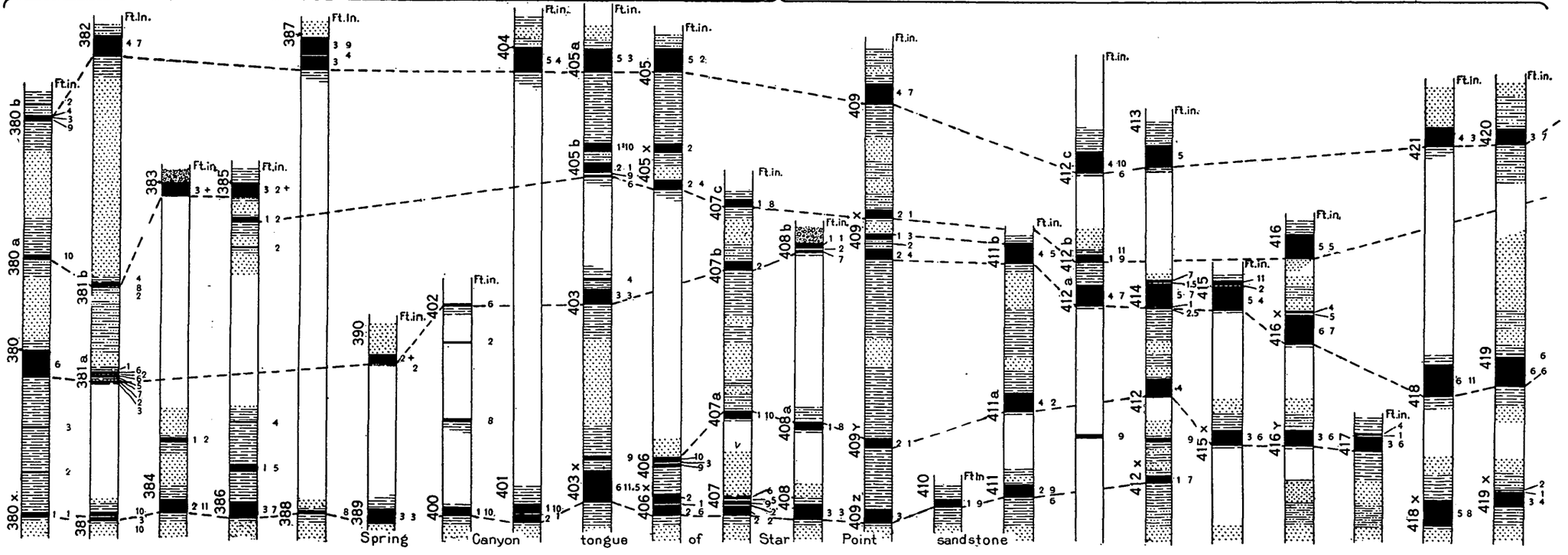
General features.—Two coal groups, the Spring Canyon and Castlegate, have been mapped with certainty throughout T. 13 S., R. 9 E., with the aid of the sandstones (Spring Canyon tongue of Star Point sandstone and Aberdeen sandstone) which underlie them. The lowest coal in each group generally rests on the top of the sandstone, but in places is separated from it by a few feet of shale.

The Kenilworth coal bed is also believed to be present in this township, and has been definitely mapped in the eastern part. Exposures believed to be the equivalent of the Kenilworth bed have been found as far west as location 630, in sec. 18, and correlations are

CASTLEGATE "A" COAL BED IN T. 13 S., R. 8 E., CASTLEGATE QUADRANGLE, UTAH

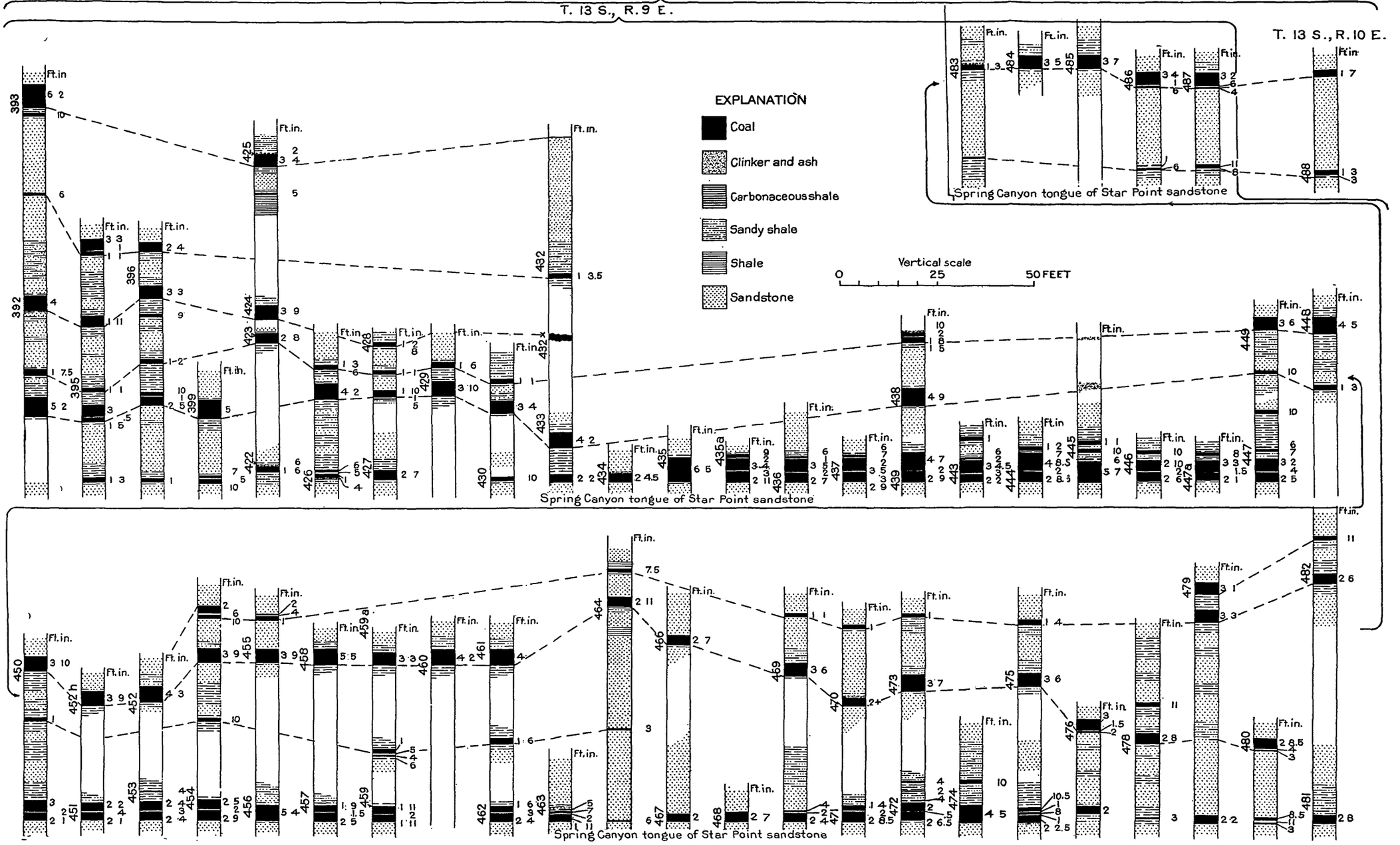


SPRING CANYON COAL GROUP IN T. 13 S., R. 8 E., CASTLEGATE QUADRANGLE, UTAH



SECTIONS OF CASTLEGATE "A" COAL BED AND SPRING CANYON COAL GROUP IN T. 13 S., R. 8 E.

SPRING CANYON COAL GROUP, CASTLEGATE QUADRANGLE, UTAH



SECTIONS OF SPRING CANYON COAL GROUP IN T. 13 S., RS. 9 AND 10 E.

suggested in Plate 5 which are based on the general character and thickness of the interbedded rocks.

Several exposures were found which indicate that in places five beds of coal of workable thickness may be found in the rocks above the Kenilworth coal. These beds, however, were not mapped, and it is impossible to make definite correlations with them or to determine their thickness and continuity under cover, because their exposures are too widely scattered and no traceable key rocks are associated with the beds.

The Spring Canyon coal group here consists of a lower bed, an upper bed, and a middle subgroup, in places containing four beds that exceed 1 foot 2 inches in thickness. Most of the sections of this group are shown in Plates 5 and 19 and the remainder are given in the text.

The Castlegate coal group comprises four groups of coal beds. The lowest one, the equivalent of the Castlegate "A" bed, rests on the Aberdeen sandstone and in places embraces two beds. The next higher, the Castlegate "B" bed, consists of two beds where a complete exposure of the rocks occurs. The next higher coal, the Royal Blue, consists of one bed and in places two benches. The topmost coal of this group, the Castlegate "C," consists of one bed and in places three benches. Most of the sections measured are shown in Plates 5 and 20 and the remainder are given in the text. The Castlegate "A" bed is the best coal of the Castlegate group, and at location 521, in sec. 7, attains a maximum thickness of 17 feet in two benches, separated by 10 inches of shale.

Coal beds exposed in T. 13 S., R. 9 E., and location numbers of the sections on each bed

Coal beds above the Kenilworth bed	629, 630 to 632, 636, 638, 639, 630–e, f, g, and h, 644, 647, and 649.
Kenilworth bed (Castlegate "D")	630–x, 633, 639–x, 530–d, and 614–a.
Castlegate coal group:	
Castlegate "C" bed	496–c, 634, 530–c, 614, 601–a, 615, 553–d.
Royal Blue bed	496–b, 498–a, 503–b, 642–a, 530–b, 643, 600, 601, 648–a, 553–c.
Castlegate "B"	496–a, 498, 503–a, 642, 530–a, 643–x, 648, 552–a, 553–a and b.
Castlegate "A"	496 to 500, 502, 503, 519 to 549, 553, 554, 557, and 558.
Spring Canyon coal group	392 to 399, and 422 to 487.

The sections in Plates 5, 19, and 20 are arranged, in so far as it is practicable, from left to right in the same order as the exposures

occur on the outcrop from west to east, as shown by location numbers in Plate 22. Representative sections of the coal-bearing rocks exposed in the Castlegate quadrangle are shown in Plate 5. Most of the sections measured on the Spring Canyon coal group are shown in Plate 19, most of those measured on the Castlegate "A" bed are shown in Plate 20, and the remainder are given in the text.

Spring Canyon coal group.—Coal sections were measured at 74 locations on the outcrop of the Spring Canyon coal group in T. 13 S., R. 9 E. In the western part of the township the Spring Canyon group is composed of three subdivisions. The lower one contains one bed, the middle one contains four beds at location 396, in sec. 20, and the upper one contains one bed. The total coal in all beds exposed in this group ranges in thickness from 17 feet at the west edge of the township to 3 feet at the east edge. This decrease in thickness is due to a decrease in the number of beds as well as to a thinning of the coal in each bed.

The lowest bed generally rests on the Spring Canyon tongue of the Star Point sandstone, but in places shale separates the coal and sandstone. This bed was mapped with certainty by means of the underlying sandstone. In the 46 exposures found the thickness ranges from 3 inches to 7 feet 5 inches and averages about 3 feet 4 inches. If the nine sections less than 1 foot 2 inches in thickness are excluded, the average for those remaining is about 3 feet 10 inches. The nine exposures below workable thickness are at locations 395, 396, 430, 464, 477, 480, 483, 486, and 487. All except that at location 430 are near the face of the escarpment, and a line connecting them probably would indicate the seaward edge of the swamp in which the vegetation accumulated that formed the coal beds. In the vicinity of locations 464, in sec. 14, 477, in sec. 11, 480, in sec. 12, and 483, 486, and 487, in sec. 1, the thin coal occurs between massive beds of sandstone and on the south and east disappears so that the sandstones merge and form one continuous bed, as was observed at location 478, in sec. 11. The lowest bed of the Spring Canyon group is thickest at location 444, in sec. 9, at the mouth of the Spring Canyon Coal Co.'s mine No. 1, where it is 8 feet 7 inches thick in three benches, separated by thin shale partings. (See pl. 19.) In the sections measured between location 435, in the southwest corner of sec. 9, and location 462, in the NE. ¼ sec. 15, the coal exceeds 4 feet in thickness, but west, south, and east of this locality the coal is much thinner, except between locations 471 and 475, in sec. 10, where it ranges from 3 feet to nearly 5 feet in thickness. A sample for analysis (laboratory No. 19986) was collected at location 442, in sec. 9, where the following section was measured and sampled.

Section of lowest coal bed of Spring Canyon group in Spring Canyon Coal Co.'s mine No. 1, in sec. 9, T. 13 S., R. 9 E.

Shale.	Ft.	in.
Coal (sampled)	6	4
Bone		2
Coal (sampled)	2	2
Coal		4
Sandstone.		
Total thickness of bed	9	

The following sections were measured on the lowest bed of the Spring Canyon group, which is here not regular in thickness, even for distances of a few hundred feet.

Sections of lowest coal bed of Spring Canyon between locations 446 and 447, in sec. 16, T. 13 S., R. 9 E.

Shale, gray.	Ft.	in.
Coal		8
Shale	1	6
Coal	3	3
Shale		1½
Coal	2	1
Shale, brown.		
Sandstone (Spring Canyon tongue).		
Thickness of bed	8	7½
Thickness of coal	6	
Shale, brown.		
Coal	3	1
Shale, brown		1½
Coal	1	11
Shale, brown.		
Sandstone (Spring Canyon tongue).		
Thickness of bed	5	1½
Thickness of coal	5	

Shale, brown.	Ft.	in.
Coal		3
Shale, gray sandy	1	8
Coal	3	3
Shale, brown		2
Coal	2	
Shale, brown.		
Sandstone (Spring Canyon tongue).		
Thickness of bed	7	4
Thickness of coal	5	6

Sections of coal in prospect pits in sec. 10, T. 13 S., R. 9 E.

Location 472		
Shale, sandy.	Ft.	in.
Coal (sampled)	4	½
Sandstone (Spring Canyon tongue).		

Location 474	
Shale, sandy.	Feet
Coal (sampled)	4
Sandstone (Spring Canyon tongue).	

The coal in the lowest bed in the Spring Canyon group has been burned on the outcrop in many places between Spring Canyon and the south side of the coal-bearing escarpment. No coal crops out at locations 394, in sec. 19, 397, in sec. 21, 398, in sec. 16, and 431, in sec. 17, owing in part to the burning of the coal at the surface. The coal has been burned in part at location 422, in sec. 7, and at location 434, in sec. 16, and from the unburned part it is impossible to determine the full thickness of the bed under cover. At location 465, in sec. 14, the coal is completely burned at the surface.

The middle coal beds of the Spring Canyon coal group are well exposed throughout most of T. 13 S., R. 9 E., and are believed to be of workable thickness everywhere under cover. Of the 37 exposures of the middle beds measured, 36 are shown in Plate 19, in which broken lines indicate a tentative correlation of the several beds, based on the character and thickness of the interbedded rocks. These beds include all the coals between the lowest and the highest beds of the Spring Canyon group and embrace one to four beds, which exceed 1 foot 2 inches in thickness. The aggregate thickness of the coal in them ranges from 11 feet 8 inches at location 395, in sec. 20, to 3 feet 2 inches at location 487, in sec. 1, and averages nearly 5 feet. In secs. 19 and 20 these middle beds consist of four coals, each ranging in thickness from 6 inches to 5 feet 2 inches, and their aggregate thickness ranges from 11 feet 8 inches to 10 feet 2 inches. North and east of secs. 19 and 20 these beds consist mainly of two and in places three coals as far east as location 433, in sec. 8. Each of these beds in this extent ranges in thickness from 1 foot 1 inch to 4 feet 2 inches, and the aggregate thickness ranges from 9 feet 7 inches to 3 feet 11 inches and averages about 5 feet 7 inches. East of location 433 these middle beds consist generally of two coals, but east of location 483, in sec. 1, only one bed crops out. The aggregate thickness of all beds in this group from location 433 to location 487, in sec. 1, ranges from 8 feet to 3 feet 2 inches and averages about 4 feet. The coal in the upper bed at location 438, in sec. 9, and the coal in the lower bed at location 483, in sec. 1, has been partly burned, and the full thickness of the coal is not known here. Some coal is exposed on the middle bed at location 432–x, but the top and bottom of the bed were concealed by talus. The two beds of this subgroup at location 445, in sec. 9, have been entirely burned at the surface, and the thickness of the coal under cover is not known.

The following sections of the middle part of the Spring Canyon group are not shown in Plate 19:

Section measured 150 feet north of location 459, in sec. 15

	Ft.	In.
Sandstone.		
Coal		7
Shale, gray		1
Coal		8
Shale, brown		6
Sandstone	8	
Shale, sandy	3	6
Coal	3	5
Shale, brown.		
Total thickness of coal	4	8

Section at face of main entry in Spring Canyon Coal Co.'s mine No. 2, at location 441, in sec. 9

	Ft.	In.
Shale, sandy.		
Coal (sampled)	4	2½
Shale, sandy.		

The extent of the highest bed of the Spring Canyon coal group in T. 13 S., R. 9 E., is difficult to determine, because only two exposures were found. At location 393, in sec. 19, there is 6 feet 2 inches of coal, and at location 425, in sec. 7, there is 3 feet 4 inches, which, however, is only part of the thickness of the bed, because some of the coal has been burned.

The eastern limit of workable coal in this bed is not as definitely known as the eastern limits of the middle and lowest beds. No exposures of the highest bed have been found east of location 425, in sec. 7.

It is apparent in the field that east of sec. 8 of this township the interval between the Spring Canyon tongue of the Star Point sandstone and the Aberdeen sandstone contains other beds of sandstone and that the Aberdeen sandstone increases in thickness at the base toward the east and gradually fills the interval normally occupied by the highest coal of the Spring Canyon group. At location 449, in sec. 16, the entire interval between the coal exposed at that location and the Castlegate "A" coal bed is filled with sandstone. The highest bed of the Spring Canyon coal group is not present there and probably does not extend east of sec. 8.

Castlegate coal group.—The Castlegate coal group in T. 13 S., R. 9 E., is composed of four beds, the Castlegate "A," Castlegate "B," Royal Blue, and Castlegate "C." The only bed that can be definitely mapped and correlated is the Castlegate "A" bed, which generally rests on the Aberdeen sandstone. The coal of this bed is in general confined to one bench, but in places there are two or three benches. Of the 41 exposures measured on the Castlegate "A" bed in T. 13 S., R. 9 E., 33 are shown in Plates 5 and 20. One section of this bed at location 551–x, shown in Plate 20, was reported by the Cameron Coal Co. at its mine in sec. 35, T. 12 S., R. 9 E.

The Castlegate "A" coal ranges from 3 inches at location 499, in sec. 19, to nearly 17 feet at location 521, in sec. 7, in three benches separated by thin shale partings, and the average for the 26 exposures where the full thickness crops out, in beds exceeding 1 foot 2 inches in thickness, is about 8 feet 3 inches. At locations 497, in sec. 19, and 499, in sec. 17, there are only 4 inches and 3 inches of coal, respectively, and at 10 other locations more or less of the coal has been burned at the surface, and only part of the thickness is left. Some of these sections are shown in Plate 20, and the rest are given in the text. The bed is extensively burned at the surface in this township, and the sections given in Plates 5 and 20 and in the text are believed to be all the exposures of this bed in the township.

The following sections are not shown in Plates 5 and 20:

Sections of Castlegate "A" coal bed in T. 13 S., R. 9 E.

Location 502, sec. 18

	Ft.	in.
Sandstone	8	6
Coal	1	7
Shale, gray	3	
Sandstone (Aberdeen).		
Thickness of coal	1	7

Location 522, sec. 7

Gravel and boulders.		
Shale, sandy (burned).		
Coal	2	5
Shale, white (burned)		6
Concealed	3	
Sandstone (Aberdeen).		
Thickness of coal	2	5

Location 529, Spring Canyon Coal Co.'s mine No. 3, in sec. 9

Sandstone.		
Coal (sampled)	3	10
Bone		½
Coal (sampled)	3	10
Coal		8
Sandstone.		
Thickness of coal	8	4

Location 531, sec. 9

Concealed.		
Ash and burned shale.		
Coal, smut	1	5
Ash and clay.		
Sandstone (Aberdeen).		

Location 540, sec. 10

	Ft.	in.
Ash and clay		2
Coal (altered)	2	8
Sandstone (Aberdeen).		
Thickness of coal	2	8+

Location 532, sec. 9

Concealed.		
Ash and burned coal.		
Coal	3	2
Shale		1
Sandstone (Aberdeen).		
Thickness of coal	3	2

Location 536, sec. 15

Sandstone.		
Sandstone	2	6
Ash.		
Coal	8	5
Sand, carbonaceous.		
Sandstone (Aberdeen).		
Thickness of coal	8	5

Location 548, sec. 2

Sandstone	7	
Shale, sandy	7	
Shale, brown, carbonaceous	4	
Coal	2	5
Shale, brown		4
Coal	4	
Shale, brown.		
Thickness of coal	6	5

The above sections are of little value except to show that the coal is present here under cover and probably has a greater thickness than the measurements indicate.

The Castlegate "B" coal bed is the first workable bed above the Castlegate "A" coal, and according to the correlations suggested in Plate 5 the lower bench of the "B" bed occurs from 20 feet above the Aberdeen sandstone at location 496–a, in sec. 19, to 50 feet above at location 530–a, in sec. 9. The bed generally consists of two benches, separated by 5 to 10 feet of shale and sandstone. In places each bench is more than 1 foot 2 inches thick, and the aggregate thickness ranges from 1 foot 10 inches, at location 648, in sec. 2, to 7 feet, at location 558, in sec. 1. The thickness and continuity of this bed under cover are not known, because exposures are widely scattered, and the correlations are uncertain. The Utah Fuel Co. has done no extensive mine development on this bed in its territory

at Castlegate, west of Price River, because the coal was thought to be too thin and uncertain to mine at this time. It appears, however, to be thinner in the W. ½ sec. 1 and in secs. 2 and 11 than it is elsewhere in the township. At location 553, in sec. 1, it is of no economic value, and at location 648, in sec. 2, it is barely of workable thickness. East of Price River this bed is much thicker and so far as known reaches a maximum in the E. ½ sec. 1.

The Royal Blue coal bed of the Castlegate group, which is the middle one of three coal beds mined at Kenilworth, is one of the least valuable coals in T. 13 S., R. 9 E. The few exposures in this township indicate that the coal in most places is below workable thickness. At locations 496–b and 498–a, in sec. 19, the coal is 4 feet 5 inches and 3 feet 7 inches thick, respectively, and these measurements indicate a possible coal lens of considerable size in secs. 17, 18, and 19. At location 503–b, near the north line of sec. 18, however, the coal is only 3 inches thick. Coal of workable thickness was found at only two other places in the township—at location 643, in sec. 14, where there is 2 feet 1 inch of coal, and at location 601, in sec. 2, where there is 1 foot 5 inches. At location 553, in sec. 1, there is only 12 inches of coal. The interval between the Castlegate "B" bed and the Royal Blue bed ranges from 10 to 30 feet and is occupied by sandstone and shale.

The Castlegate "C" bed, according to the classification and correlation in the Castlegate quadrangle, is the highest bed of the Castlegate group in T. 13 S., R. 9 E. It is the next bed of workable thickness above the Royal Blue, and the interval between these two beds ranges from 10 to 50 feet and is occupied by sandstone and shale and thin beds of coal. The coal generally crops out in two benches, but in places there are three and at others only one bench. At location 496–c, in sec. 19, the equivalent of this bed crops out in three benches; the middle bench contains 8 inches of coal, and the top and bottom benches are composed of carbonaceous shale. Other exposures in the township on beds believed to be the equivalent of the Castlegate "C" bed indicate coal above workable thickness. The nine exposures measured on the outcrop of this bed are shown in Plate 5. The coal, including all benches that exceed 1 foot 2 inches in thickness, ranges from 1 foot 3 inches at location 601–a, in sec. 2, to 6 feet at location 635, near the northwest corner of sec. 18, T. 13 S., R. 9 E., and averages about 4 feet 5 inches in thickness. The correlation of this bed here is based on the character and thickness of the interbedded rocks as shown in Plate 5. The Castlegate "C" bed in the Castlegate mine No. 1 is reported to range from 3 feet 10 inches in the eastern part of the mine, in sec. 2, to 6 feet 6 inches in the northern and western parts, in sec. 3. A section was measured

and a sample was taken for analysis in this mine at location 546, in sec. 3, where the coal is 5 feet 7 inches thick. At location 551, in sec. 35, T. 12 S., R. 9 E., in the mine of the Cameron Coal Co., the Cameron bed No. 1, which is here considered to be the equivalent of the Castlegate "C" bed, was measured and a sample was taken for analysis. The coal is here 6 feet 8 inches thick.

The Castlegate "C" bed in this township probably ranks second in importance and possible tonnage yield among the coals in the Castlegate group. The Castlegate "A" bed ranks first, and the Castlegate "B" probably ranks third.

Kenilworth (Castlegate "D") coal bed.—The Kenilworth coal bed crops out at only a few places in T. 13 S., R. 9 E., and the correlation and identification of exposures in this township are based for the most part on the character and thickness of the associated rocks as shown in Plate 5. East of the township the Kenilworth coal rests on a cliff-forming sandstone, by means of which it can be definitely mapped, but this sandstone thins toward the west and could not be traced with certainty west of Hardscrabble Canyon. The diamond-drill record at location 530, in sec. 9, kindly supplied by the Spring Canyon Coal Co., shows a thin sandstone beneath what is believed to be the equivalent of the Kenilworth coal bed. At location 639, in sec. 12, T. 13 S., R. 8 E., there is a thin sandstone beneath what is believed to be the Kenilworth coal, but the sandstone can not here be traced in the field. The burning of the Kenilworth coal at the surface in this township, which appears to have been extensive, has increased the difficulty of tracing the outcrop as well as of determining the thickness of the coal under cover. At location 630–x, in sec. 18, 1 foot 4 inches of coal crops out, which is tentatively correlated with the Kenilworth bed. From this minimum the coal bed thickens to a maximum of 4 feet 6 inches at location 530, in sec. 9, and averages about 3 feet. At location 547, in sec. 3, in the Castlegate mine No. 1, a sample was collected for analysis. The coal is 5 feet thick at the point sampled but is reported to be thinner toward the east in this mine. At location 614–a, in sec. 3, the coal has been partly burned and only 2 feet 3 inches crops out.

Coal beds above the Kenilworth bed.—In places five beds that exceed 1 foot 2 inches in thickness crop out in T. 13 S., R. 9 E., above the Kenilworth bed, and their aggregate thickness ranges from 4 feet 4 inches to 6 feet 9 inches and averages about 5 feet 2 inches. This is deemed to be a moderate estimate of the amount of coal in workable beds above the Kenilworth, because the rocks in the entire interval are well exposed in very few places. The diamond-drill record at location 530, in sec. 9, is the best index and the most complete record of the amount of coal in a given interval that is available. This record, however, does not include all the coal-bearing

rocks, and there are in places two and perhaps three workable beds in rocks above those penetrated by the drill.

Summary of coal beds.—It is believed that a maximum of twelve workable coal beds are exposed in T. 13 S., R. 9 E. The relations of the coal beds to the associated rocks are shown in Plate 5, and detailed representative coal sections are arranged by beds and are shown graphically in Plates 19 and 20. The location numbers on the map (pl. 22), and the coal sections (pls. 5, 19, and 20) run in consecutive order for each group of beds from west to east on the outcrop beginning with the lowest bed.

The Spring Canyon coal group is first in order of economic importance in this township, the Castlegate "A" bed ranks second, the Kenilworth bed is perhaps third, the coals above the Kenilworth bed taken together probably rank fourth, and the Royal Blue bed appears to be the least valuable.

Tonnage estimates.—It is estimated that 331,000,000 short tons of coal is present under cover in T. 13 S., R. 9 E. About 145,000,000 tons, or 45 per cent of the total, is contained in the Spring Canyon group, and about 235,000,000 tons, or 75 per cent, in the Spring Canyon and the Castlegate coal groups combined (not including the Royal Blue bed). Several thin beds are not included, and the writer believes that this is a moderate estimate. The details of the tonnage estimate by beds are given in the table on page 161.

Accessibility.—The coal in T. 13 S., R. 9 E., is the most accessible coal in the Castlegate quadrangle. Price River and Spring Canyon have deeply trenched the coal-bearing rocks, exposing the coal beds in the walls of the canyons. All the coal in the most valuable beds may be mined without difficulty from drifts or slopes in these two canyons and from the mines already in operation. Railroad facilities for handling the coal are good. The main line of the Denver & Rio Grande Western Railroad traverses Price River canyon, and a branch of this railroad traverses Spring Canyon nearly to the west edge of the township.

T. 13 S., R. 10 E.

General features.—Three coal beds, the Castlegate "A," Royal Blue, and Kenilworth, have been definitely mapped throughout parts of T. 13 S., R. 10 E., and other less persistent beds, the Castlegate "B" and "C" beds and beds above the Kenilworth, including the Lower Sunnyside, have been measured at several locations. The three beds mapped are closely associated with cliff-forming sandstones, by which they may be readily traced. All three are thickest at Kenilworth, where they are extensively mined.

The Spring Canyon coal group, which is the principal coal group in T. 13 S., R. 9 E., is of little value here, and the workable coal in

this group is confined to secs. 6 and 7. Only two exposures were found, one on the lowest bed and one on the middle coal of the group.

The Castlegate "A" coal generally rests on the Aberdeen sandstone, which " splits " farther east and in the Wellington and Sunnyside quadrangles forms two tongues. The Castlegate "A" bed has been definitely mapped across the township.

The Royal Blue coal bed is traceable for about half the distance across the township but is less persistent and thinner than either the Castlegate "A" or the Kenilworth bed. It occurs directly beneath a thick sandstone, which here fills the interval between the Royal Blue and Kenilworth coal beds.

The Kenilworth coal is one of the most persistent beds in this region and has been traced from the south edge of the Sunnyside quadrangle to Hardscrabble Canyon, west of Price River, by means of the sandstone on which the coal generally rests. This sandstone is the basal sand of the Mesaverde group in the Sunnyside quadrangle, although in this township it is a considerable distance above the base of the Mesaverde, as shown in Plate 15.

A few exposures were found which indicate that west of Kenilworth at least five workable beds crop out above the Kenilworth bed. At the east edge of the township the Lower Sunnyside bed together with possibly four other beds are exposed. The Lower Sunnyside bed, the principal coal at Sunnyside, is about 4 feet thick at the east edge of the township, but it could not be traced westward because of extensive burning at the surface and the lack of a key rock.

Coal sections were measured at 98 locations in the township; 77 of these sections are shown in Plates 5 and 21, and the remainder appear in the text. Representative sections of the coal beds together with the character and thickness of the interbedded rocks are shown in Plate 5.

Coal beds exposed in T. 13 S., R. 10 E., and location numbers of the sections on each bed

Lower Sunnyside	657.
Beds between lower Sunnyside and Kenilworth	652, 653, 655, and 656.
Kenilworth	617 to 627.
Castlegate " C "	616, 606, and 607.
Royal Blue	608, 610 to 613.
Castlegate " B "	603, 603–a, 605, 571–a, 609, 574–a, 595–a, 598–a, 599–a.
Castlegate "A"	555, 556, 559 to 599.
Spring Canyon coal group	488, 488–a.

The sections listed above are arranged in general by beds in Plates 5 and 21 and are numbered from left to right in the same order

as that of the locations, from west to east on the outcrop. (See pl. 22.)

Spring Canyon coal group.—The Spring Canyon group contains the lowest coal exposed in T. 13 S., R. 10 E., but it crops out only at location 488, in sec. 6. The lowest bed of the group is here 1 foot 3 inches thick, and the middle bed of the group is 1 foot 7 inches thick. The highest bed of the group is not present here. Each bed at location 488 occurs between massive beds of sandstone, which merge not far to the east and pinch out the coal. These exposures are believed to lie near the edge of the area covered by the ancient swamp in which the Spring Canyon coals were formed. It is believed that the workable coal of the Spring Canyon group is confined to secs. 6 and 7 and that it is not likely to be mined while so much coal is available in thicker beds.

Castlegate "A" coal bed.—The Castlegate "A" bed is the best-exposed coal in T. 13 S., R. 10 E., but is estimated to rank second in tonnage yield. The thickest known coal in this bed in the township is at Kenilworth, where it is extensively mined.

Fifty-five sections of this bed were measured in the township; 36 of them are shown in Plate 21 and the remainder are given in the text. The coal in all sections in which a full thickness is exposed ranges from 1 foot 7 inches to 19 feet 3 inches and averages about 8 feet. The Castlegate "A" bed is thickest from location 574, in sec. 17, to location 589, in sec. 11. Here it generally crops out in one bench with minor shale and bone partings. East and west of these locations it appears to be "split," and the coal is exposed in two benches. At location 555, in sec. 6, the lower bench appears to be absent, but the upper bench is 3 feet thick in two benches and is about 20 feet above the lower bench of the Castlegate "A" bed. The westernmost coal of the lower bench in the township is at location 559, in sec. 6, where the coal is 3 feet 2 inches thick, but the upper bench here is entirely burned at the surface.

The lower bench of the Castlegate "A" bed west of location 573, in sec. 17, ranges in thickness from 1 foot 2 inches at location 571, in sec. 8, to more than 7 feet at location 567, in sec. 7. The distance between the lower and upper benches west of location 574, in sec. 17, ranges from 1 foot at location 562, in sec. 7, to 27 feet at location 570, in sec. 18. The upper bench here ranges in thickness from 1 foot 7 inches at location 556, in sec. 6, to 15 feet 3 inches at location 569, in sec. 18.

At location 590, in sec. 14, the Castlegate "A" bed again appears to "split," and the coal is exposed in two benches as far east as location 596, in sec. 14. The upper bench here is the thinner, ranging from 6 inches to 2 feet 4 inches, but west of the "split," near loca-

tion 574, in sec. 17, the upper bench is the thicker, ranging from 1 foot 7 inches to 15 feet 3 inches. From location 585, in sec. 10, to location 588, in sec. 11, the coal, which is exposed in one bench, thins rapidly from a maximum of 14 feet 8 inches to a minimum of 3 feet 2 inches in a distance of about a mile. The coal in the exposures between these locations has been partly burned at the surface, and it is impossible to tell where the decrease in thickness occurs. The lower bed east of the " split " at location 590, in sec. 14, decreases in thickness eastward, and at location 599, in sec. 13, the coal is 2 feet 4 inches thick. At locations 598–a and 599–a, in sec. 13, thin coals crop out from 20 to 25 feet above the lower bench of the Castlegate "A" and may be the equivalent of the bed at location 595–a, in sec. 14. These beds occur at about the stratigraphic position of the Castlegate " B " bed.

More exposures were measured on the Castlegate "A" bed than on any other bed in the township, although the coal is extensively burned at the surface. At many places the entire bed has been burned and the rocks have been fused, producing clinker, but at other places only a part of the coal has been burned.

The following sections together with those shown in Plates 5 and 19 give all the data that are known regarding the thickness of the Castlegate "A" coal bed in the township.

Sections measured on the Castlegate "A" coal bed in T. 13 S., R. 10 E.

Middle prospect at location 562, sec. 7

	Ft.	in.
Ash		1
Coal	5	
Brown shale	1	6
Coal	1	9
Bone		4
Sandstone (Aberdeen).		
Thickness of bed	8	8
Thickness of coal	6	9

East prospect at location 562, sec. 7

	Ft.	in.
Clinker.		
Coal	4	
Shale, brown	1	10
Coal	2	10
Sandstone (Aberdeen).		
Thickness of bed	8	8
Thickness of coal	6	10

100 feet southeast of mouth of east prospect

	Ft.	in.
Clinker.		
Coal	3	4
Shale, brown	4	2
Coal	2	9
Sandstone (Aberdeen).		
Thickness of bed	10	3
Thickness of coal	6	1

West prospect at location 562, sec. 7

	Ft.	in.
Concealed.		
Coal	4	8
Shale, brown	1	2
Coal	2	9
Sandstone (Aberdeen).		
Thickness of bed	8	7
Thickness of coal	7	5

Location 563, sec. 7

	Ft.	in.
Clinker.		
Coal		8
Brown shale	2	
Coal	1	3
Shale.		
Thickness of bed	3	11
Thickness of coal	1	11

100 feet east of location 564, sec. 7

Shale, sandy	4	
Sandstone		10
Shale, sandy	2	9
Coal	2	9
Sandstone.		
Thickness of coal	2	9

Location 575, sec. 17

Sandstone, burned.		
Ash.		
Coal	7	9
Sandstone (Aberdeen).		

Location 576, sec. 16

Sandstone, burned	10	
Shale, sandy	2	
Ash and clay		6
Coal	9	
Coal and sand		6
Sandstone (Aberdeen).		
Thickness of bed	10	
Thickness of coal	9+	

Location 577, sec. 16

Coal, top not exposed.		
Coal	12	1
Coal, not exposed.		

Location 579, sec. 16

Ash.		
Coal	6	
Shale, brown		10
Coal	4	8
Shale, brown		6
Sandstone (Aberdeen).		
Thickness of bed	12	
Thickness of coal	10	8

Location 580, sec. 9

	Ft.	in.
Burned rock.		
Coal	1	
Shale, brown		8
Coal	2	
Shale, brown.		
Sandstone (Aberdeen).		
Thickness of bed	3	8
Thickness of coal	3	

Location 581, sec. 16

Ash and clay.		
Coal	2	8
Shale, brown		8
Coal	2	8
Shale, brown.		
Thickness of bed	6	
Thickness of coal	5	4

A few hundred feet southeast of location 581

Concealed.		
Coal and ash	1	
Shale, brown		7
Shale, carbonaceous		6
Coal	3	1
Shale, brown		2
Coal	1	9
Thickness of bed	7	1
Thickness of coal	5	10

Location 582, sec. 10

Burned rock.		
Ash and clay	1	
Coal	5	6
Shale, brown.		
Thickness of bed	6	6
Thickness of coal	5	6

Location 583, sec. 15

Burned rock.		
Ash and clay.		
Coal	3	8
Shale, sandy	1	1
Sandstone	1	8
Shale, sandy		6
Coal		3
Shale, sandy		1
Coal	5	2
Shale, sandy		1
Coal	5	2
Sandstone (Aberdeen).		
Thickness of bed	12	5
Thickness of coal	9	1

Location 586, sec. 15

	Ft.	in.
Shale	2	
Ash and clay		6
Coal	2	3
Ash and clay.		
Concealed	5	
Sandstone (Aberdeen).		
Thickness of bed	2	9
Thickness of coal	2	3

Location 587, sec. 10

Sandstone	8	
Shale, burned	1	6
Ash and red clay		8
Coal	2	8
Sandstone (Aberdeen).		
Thickness of bed	3	4
Thickness of coal	2	8

100 feet northeast of location 588

	Ft.	in.
Sandstone	24	
Shale, sandy	6	
Coal, burned		6
Coal	2	8
Sandstone (Aberdeen).		
Thickness of coal	3	2

150 feet from mouth of entry at location 589

Shale, sandy		
Coal	3	7½
Sandstone.		

Several sections are shown in Plate 21 for which no location numbers are given on Plate 22. These were measured in mines or prospects where the coal was sampled for analysis, but the exact locations are not known. They are designated in Plate 21 by the laboratory numbers used by the United States Bureau of Mines. In these sections the part of the bed sampled is shown by characters in Plate 21, and the location of the mine at which the samples were collected is given in the description of coal samples on pages 87 to 93.

Castlegate "B" coal bed.—The Castlegate "B" bed, the second coal above the Aberdeen sandstone, is of economic importance only in the western part of T. 13 S., R. 10 E. From location 603, in sec. 6, to location 605, in sec. 8, five sections were measured, which range in thickness from 5 to 7 feet and average 6 feet 4 inches. Two of the sections were measured in shipping mines, where samples for analysis were collected. The section designated 19845 was measured in the Castlegate mine No. 2, at the face of the fourth right entry off No. 1 raise, and the section at location 604 (Bureau of Mines sample No. 19881), in sec. 6, was measured in the mine of the Panther Coal Co. at face of No. 2 east entry off the main slope.

Several other exposures farther south and east occur at about the same stratigraphic position as the Castlegate "B" bed, but definite correlations can not be made. The sections tentatively referred to the Castlegate "B" bed are at locations 571–a, in sec. 8, 574–a and 609, in sec. 17, 595–a, in sec. 14, and 599–a, in sec. 13. The coal in these exposures ranges in thickness from 1 foot 2 inches in two benches at location 574–a to 5 feet 10 inches in three benches at location 599–a and averages about 2 feet 8 inches. These exposures are widely scattered, and it is unlikely that this bed is continuous between

them. In the Wellington quadrangle about a mile east of location 599 coal ranging from 1 foot 8 inches to 2 feet 6 inches in thickness is exposed at the horizon of the Castlegate "B" bed. These exposures together with clinker beds between them indicate that there may be a coal lens at this horizon in secs. 12 and 13 of this township.

Royal Blue coal bed.—In this township the Royal Blue coal bed could be definitely mapped only from location 608, in sec. 17, to location 595–b, in sec. 14. Seven sections were measured on this bed, and the coal ranges in thickness from 2 feet 5 inches at location 612, in sec. 10, to 8 feet 8 inches at location 610, in sec. 16, and averages about 5 feet 4 inches. The Royal Blue bed appears to thin west of location 608, but no exposures could be found that could be identified as the Royal Blue between location 608 and location 553, in sec. 1, T. 13 S., R. 9 E., where there is only 12 inches of coal. Further evidence that the Royal Blue coal bed in the northwest corner of the township is below workable thickness is supplied by the report of mine officials of the Castlegate No. 2 mine. The mine mouth is in the Castlegate "B" bed. A rock tunnel connecting the Castlegate "B" and Castlegate "D" beds penetrates several beds of coal from 10 to 12 inches thick, one or more of which is probably the equivalent of the Royal Blue bed.

At location 613, in sec. 11, the easternmost exposure on the Royal Blue bed shows 3 feet of coal, but at location 595–b, in sec. 14, clinker and ash at this horizon indicate that considerable coal was burned. Location 595–b is probably near the eastern edge of the Royal Blue bed on the outcrop, because farther east the interval normally occupied by the coal is filled with sandstone.

Castlegate "C" coal bed.—The Castlegate "C" bed in the Castlegate mines Nos. 1 and 2 is reported to occur about 70 feet above the Castlegate "B" bed and about 20 feet below the Kenilworth (Castlegate "D") bed. This relation appears to hold true in places on the outcrop west and north of sec. 8, but at Kenilworth, in sec. 16, the interval elsewhere occupied by the Castlegate "C" bed is filled with massive sandstone.

Three exposures in this township are correlated with the Castlegate "C" bed. At location 616, in sec. 6, there is 1 foot 5 inches of coal; at location 606, in sec. 7, there is 1 foot 9 inches; and at location 608, in sec. 17, there is 5 feet 5 inches.

In sec. 6 the rock tunnel in the Castlegate No. 2 mine penetrates the Castlegate "C" bed. Here the coal is reported to be 4 to 5 feet thick, but it is said to be so erratic in thickness that extensive development at this time would involve too great a business risk. The source of the information on which this opinion is based is not known, although it is believed that the Utah Fuel Co., which operates the

mines at Castlegate, has done some core drilling in this locality. Although the Castlegate "C" bed may be lenticular and erratic in thickness the writer believes that it contains considerable coal in this township and will be mined when conditions warrant its exploitation.

Kenilworth (Castlegate "D") bed.—The Kenilworth coal bed crops out from 150 to 180 feet above the base of the Castlegate "A" bed. It is the highest coal that could be mapped with certainty in the township, because it is the highest coal associated with a key sandstone. In the Sunnyside quadrangle the coal rests on the basal sandstone of the Mesaverde group but here the underlying sandstone is a considerable distance above the base of the Mesaverde, as shown in Plate 15.

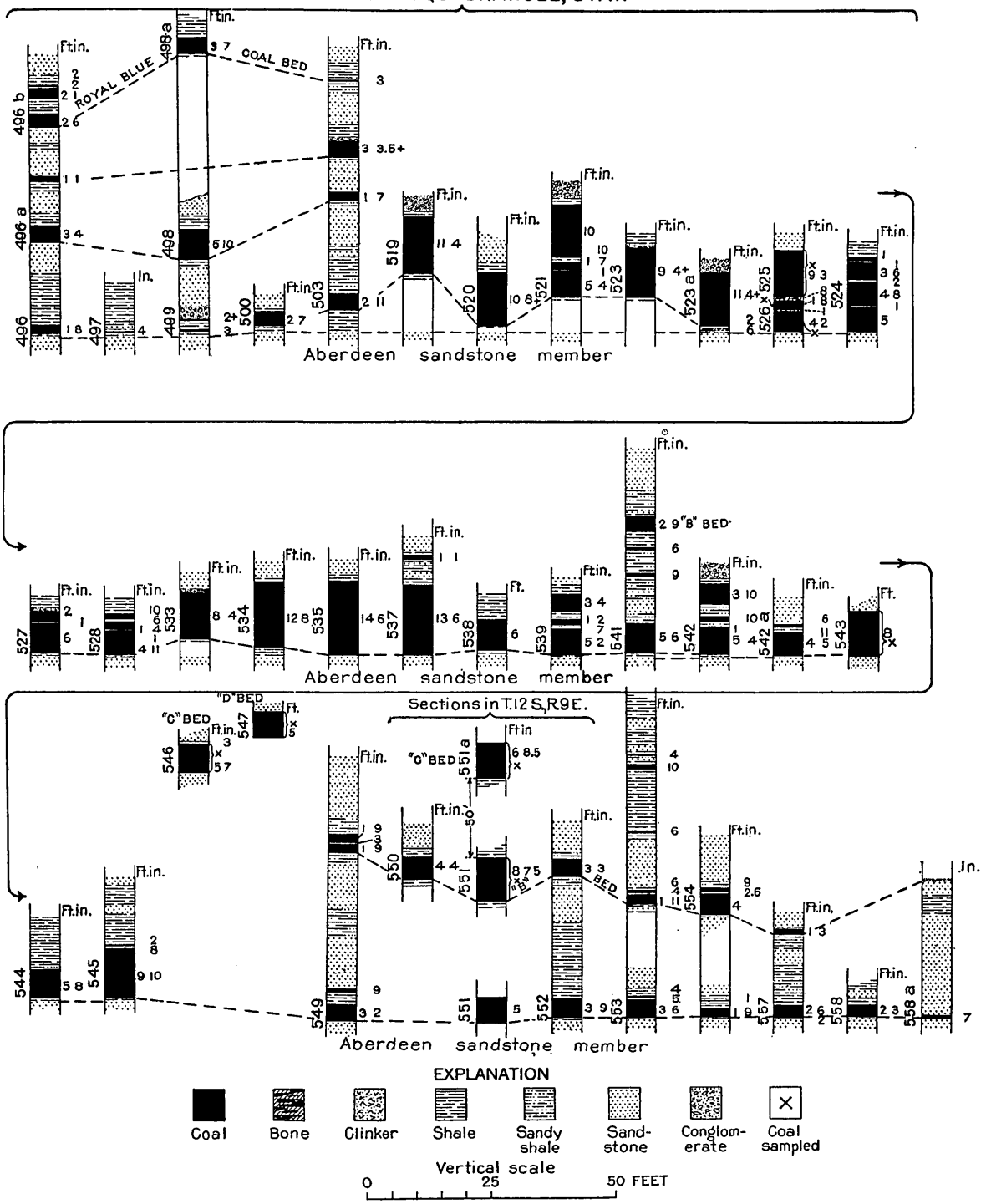
No exposures were found west and north of location 617, in sec. 8, because the coal is extensively burned at the surface. At location 616–a, in sec. 6, a little coal and ash crop out together with slag and clinker, which indicates that considerable coal was burned. In adjoining townships this coal is extensively burned on the outcrop.

The Utah Fuel Co. has made extensive openings in this bed in its No. 2 mine, in sec. 6, where the bed is thick and relatively free from partings. Here 7 feet 6 inches of coal was measured, and a sample for analysis was collected in the first left main entry off No. 1 raise. It is designated in Plate 19 by No. 19843, the Bureau of Mines laboratory number of the sample. The full thickness of coal was not being mined, but mine officials reported the coal to be 20 feet thick in places.

Fourteen sections were measured on this bed in T. 13 S., R. 10 E., which are all shown in Plate 21. In eight sections in which the full thickness is exposed the coal ranges from 1 foot 7 inches at location 627, in sec. 13, to 18 feet 8 inches at location 619, in sec. 16, and averages about 9 feet 5 inches. This computation includes the 7 feet 6 inches of coal sampled in the Castlegate mine No. 2, but does not include the 20 feet reported to be present in the mine. This bed is characterized at most places measured by shale and bone partings, which are too thin and of too small extent to give serious trouble in mining. At one place in the Kenilworth mine, in sec. 9, where sample 19681 was collected, a 3-foot shale parting occurs 2 feet from the top of the bed. The base of the coal is not exposed, and the total thickness of the bed is not known. Another sample was collected in this mine at location 19712, in sec. 8, where 7 feet is the total thickness of the coal mined.

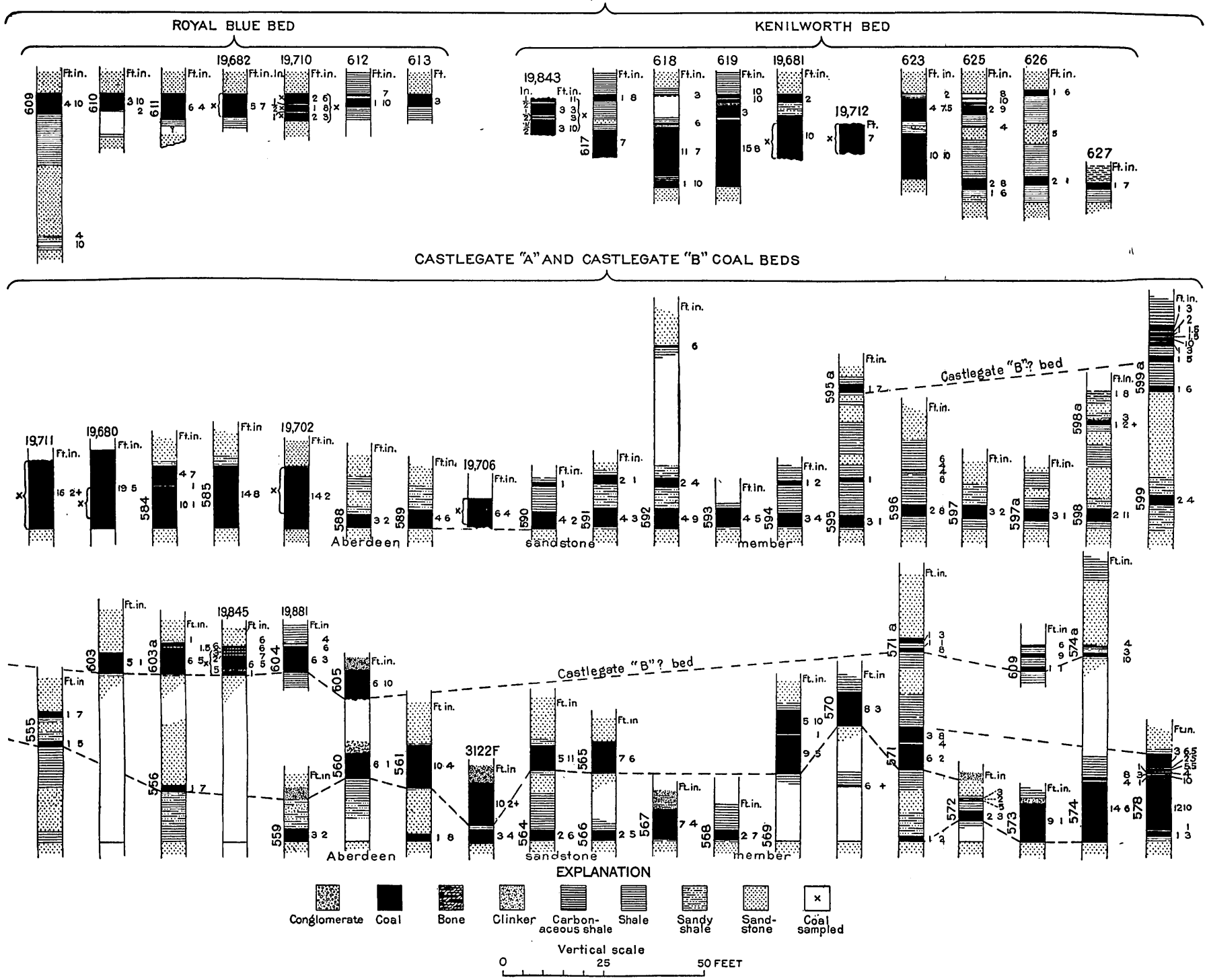
At location 623, in sec. 11, there is a 3-foot shale and sandstone parting in which the sandstone forms a wedge in the shale. This parting in the bed appears to be continuous and to increase in thickness eastward, and at location 626, in sec. 13, it is 20 feet thick. The coal above the parting appears to be the equivalent of the Gilson

CASTLEGATE COAL GROUP IN TOWNSHIPS 12 AND 13 SOUTH, RANGE 9 EAST, CASTLEGATE QUADRANGLE, UTAH



SECTIONS OF CASTLEGATE COAL GROUP IN TPS. 12 AND 13 S., R. 9 E.

COAL SECTIONS IN T. 13 S., R. 10 E., CASTLEGATE QUADRANGLE, UTAH



SECTIONS OF ROYAL BLUE, KENILWORTH, AND CASTLEGATE "A" AND "B" COAL BEDS IN T. 13 S., R. 10 E.

bed, and the Kenilworth bed in the type locality at Kenilworth appears to be the equivalent of the Kenilworth and Gilson beds as described in the chapter on the Wellington and Sunnyside quadrangles.

The Kenilworth bed has been extensively burned on the outcrop in this township, particularly east of location 619, in sec. 16. Several sections were measured in which a part of the coal has been burned and are given in Plate 5 but are not duplicated in Plate 21. At several places between location 623, in sec. 11, and location 624, in sec. 14, the coal has been entirely burned on the outcrop, and the resulting slag and clinker rest upon the underlying sandstone. (See pl. 5.)

Coal beds above the Kenilworth bed.—In T. 13 S., R. 11 E., several beds, including the Gilson, Fish Creek, Rock Canyon, and Lower Sunnyside, crop out above the Kenilworth bed. These beds may be represented in T. 13 S., R. 10 E., but no definite correlations can be made with them, because of extensive burning of the coal at the surface and the absence of key rocks.

At location 652, in sec. 8, there are two benches of coal aggregating 3 feet 6 inches in thickness, which occur at about the horizon of the Fish Creek coal or possibly the Rock Canyon coal, but this correlation is merely suggested, as there is no way to connect this exposure definitely with the known Fish Creek or Rock Canyon beds.

At locations 652–b, in sec. 8, 655, in sec. 11, and 627–a, in sec. 13, coal appears to crop out at about the same stratigraphic position and may be the equivalent of the Rock Canyon bed, exposed in the Wellington quadrangle. Such a long-range correlation is hardly warranted, as the coal bed can not be mapped between the widely separated exposures. The coal in these sections ranges from 1 foot 2 inches to 2 feet 2 inches in thickness.

At locations 652–d, in sec. 8, 656, in sec. 11, and 657, in sec. 13, the coal may be the equivalent of the lower Sunnyside bed, but this correlation is merely suggested because this bed could not be traced in the field between these locations. It is known definitely that the coal at location 657 is the equivalent of the Lower Sunnyside bed, because the sandstone that normally occurs below the coal is present and has been traced continuously from Sunnyside.

At location 652, in sec. 8, five beds that exceed 1 foot 2 inches in thickness were measured in a stratigraphic distance of 240 feet above the Kenilworth coal, and their aggregate thickness was found to be 12 feet 2 inches. At locations 627 and 657, in sec. 13, three beds exceeding 1 foot 2 inches in thickness, one bed 10 inches thick, and one clinker and ash bed occur within a stratigraphic distance of 315 feet above the Kenilworth bed. The aggregate thickness of the three

beds is 10 feet 3 inches. These scattered exposures indicate that several workable beds having a considerable acreage are present here under cover.

Summary of coal beds.—Eleven coal beds of workable thickness crop out in T. 13 S., R. 10 E. The lowest coal, the Spring Canyon group, is composed of two beds, which crop out at one place near the eastern limit of the coal group, and the tonnage yield from these beds will be small.

The next higher bed, the Castlegate "A," reaches a maximum thickness of more than 19 feet and is estimated to rank second in tonnage yield in the township.

The Castlegate "B" bed, the next higher coal, is relatively unimportant here.

The Royal Blue bed, which crops out between the Castlegate "B" and "C" beds, is of workable thickness in all exposures found.

The Castlegate "C" bed, next above the Royal Blue, is of workable thickness at several places in the western part of the township.

The Kenilworth bed, which lies from 150 to 180 feet above the Aberdeen sandstone, is the most valuable bed in the township.

The rocks for 325 feet above the Kenilworth bed contain coal beds of workable thickness, but these coals can not be mapped because there are no traceable key rocks in this interval.

Tonnage estimate.—The coal in most of the beds in T. 13 S., R. 10 E., is extensively burned at the surface and the possible exposures have been reduced, so that it is difficult to estimate the total coal tonnage under cover. Five coal beds or groups of coal beds have been used in making the tonnage estimates—the Kenilworth, the Castlegate "A," the beds above the Kenilworth, the Royal Blue, and the Spring Canyon, named in the order of their tonnage yield. It is estimated that 396,000,000 short tons of coal is present under cover in the township. The details of the tonnage estimate are given by beds in the table on page 161.

Accessibility.—The coal in T. 13 S., R. 10 E., is accessible by drifts and slopes from the outcrop in Price River Canyon and the southward-facing escarpment, but the coal in secs. 1 to 4 can be mined only by shafts. Construction of shafts and transportation of the coal to railroad connections after it is brought to the surface are both expensive. The mines already in operation at Kenilworth and Panther and the Castlegate No. 2 mine can reach most of the coal in secs. 6, 7, 8, and 9. Railroad branches may be built from Price to Cordingly and Alrad Canyons, where the coal for a short distance to the north may be reached by slope mining.

Near the center of sec. 2, in the head of Cordingly Canyon, the 6,500-foot structure contour intersects the 7,600-foot surface contour, and the distance between them, 1,100 feet, is the depth of the

Castlegate "A" bed at this place. On the high divide near the center of sec. 3 the depth to the Castlegate "A" bed is about 2,000 feet, and in Emma Park, in secs. 1 and 2, it is about 2,000 to 2,200 feet.

T. 12 S., R. 10 E.

General features.—The coal-bearing rocks above the Castlegate "A" bed crop out in sec. 31, T. 12 S., R. 10 E., but elsewhere in the township all the coal is under cover. No exposures of coal were found in the township owing to the burning of the coal at the surface and to talus and grass-covered slopes on Willow Creek. The coal that may be under cover in the township must be estimated from the character, thickness, and continuity of the coal beds on the outcrop and in mines in the adjoining townships. The estimated total thickness of all the coal in workable beds in the five townships which border or corner on T. 12 S., R. 10 E., ranges from 14 to 31 feet and averages about 24 feet. Five groups of coal beds crop out in adjoining townships, some of which have been mapped for long distances and are known to be persistent and of good thickness under large areas. On Willow Creek, in sec. 31, the Utah Fuel Co. began operations about November, 1911. The bed mined here contains many thin shale partings and many sulphur balls and lumps of resin, but the coal is bright and brittle.

Tonnage estimate.—T. 12 S., R. 10 E., is near the outcrop of several thick persistent coal beds, and there is every reason to believe that most of these beds will be found of good quality and of the same average thickness under this township that they have on the outcrop. On the basis thus indicated it is estimated that a total thickness of 24 feet of coal, in beds exceeding 1 foot 2 inches, is present and will yield 152,000,000 short tons of coal in that part of the township included in this quadrangle. The tonnage includes estimates for the Kenilworth bed, the Castlegate group (Castlegate "A," "B," and "C" beds), the beds above the Kenilworth, the Royal Blue bed, and the Spring Canyon group, named in the order of their estimated tonnage yield. The details of the tonnage estimates by beds are given in the table, page 161.

Accessibility.—The portion of this township included in the Castlegate quadrangle embraces a small part of Emma Park, which is relatively flat, but most of the area is rough, being deeply trenched by Willow Creek and Dry, Mathes, Deep, and Buck Canyons. The only feasible railroad route to reach the eastern part of the township leads from Castlegate up Willow Creek with spurs up Dry, Mathes, and Deep Canyons. The grade up Willow Creek is low, but in the canyons named the grades are steep and the canyon bottoms are narrow, conditions which would necessitate considerable cut

and fill work. As the coal can be reached in the eastern part of the township only by shafts, as the construction of a railroad to it would be difficult and expensive, and as there are known thick beds of coal near by which can be reached more easily the coal here is at the present time economically inaccessible.

The coal in the western part of the township is more accessible and may be reached by slope mines on Willow Creek. The structure of the coal is roughly shown by structure contours based on the altitude of the base of the Castlegate "A" bed. The depth to the Castlegate "A" bed in the southwest corner of sec. 29, in the bed of Willow Creek, is about 700 feet; in Dry Canyon, near the center of sec. 33, it is about 900 feet; and in Deep Canyon, west of the center of sec. 35, it is about 2,000 feet.

CHARACTER OF THE COAL

Physical properties.—The coal in this quadrangle is bituminous in rank. It is black with a brown-black powder, is massive and blocky, and seldom shows evidences of bedding. When fresh the coal has a semivitreous luster, but at weathered outcrops much of it is rusty and is covered with small crystals of alkali salts.

The coal of the Spring Canyon group is bright and jet-black, even textured, and generally free from bone and shale partings. The Castlegate "A" bed is massive, brittle, and bright but contains dull bands of coal and thin shale and bone partings and shows few or no marks of bedding. It has prominent joints and in places contains streaks of resin and sulphur balls. The Castlegate "B" bed in the vicinity of Castlegate contains thin bone and shale partings and many balls of resin and sulphur. The Royal Blue coal is hard and brittle, and at Kenilworth the basal part of the bed rings and snaps when mined. The middle part is soft and breaks into large lumps, and the upper part is soft and produces a large percentage of slack in mining. Horsebacks in the overlying sandstone in places cut out from 2 to 3 feet of the normal thickness of the coal. The Kenilworth coal is generally softer than the Castlegate "A" coal, is brittle and massive, and contains no visible bedding planes. It is characterized by bands of dull coal which contains a higher percentage of ash than the brighter coal, by thin bone and shale partings, and by streaks of resin and sulphur.

Coal from this field on exposure to the air weathers slowly and makes a good stocking fuel. It may be stored for several months, even in open bins, without perceptible deterioration.

Physical tests by the Pishel method, described on page 80, have been made of the coals from some of the beds to determine their relative coking qualities. The Upper and Lower Sunnyside beds

contain the best-known coking coal in the Book Cliffs field in Utah and are here used as a standard or type for the field. In the test of the Spring Canyon coals Nos. 1 and 2, the lowest and middle beds of the Spring Canyon group, a thick film of fine powder adhered strongly to the mortar and pestle, which indicates coking tendencies for these coals about equal to that of the Sunnyside coals. In the test of the Castlegate "A" bed in the Standard mine and Spring Canyon mine No. 3, both in Spring Canyon, only a slight film of fine powder stuck to the mortar and pestle, indicating only slight coking tendencies. No other coals in this quadrangle were tested.

Chemical composition.—The chemical composition of the coal in this quadrangle and of those in some other fields, which are likely to come into competition with the coals of Carbon County, Utah, is given in the tables of analyses on pages 83 to 86 and 94 to 97.

ORIGINAL COAL CONTENT OF THE CASTLEGATE QUADRANGLE

General features.—The coal tonnage of any field is difficult to estimate, because of the lenticular occurrence and irregular thickness of the beds, but here it is unusually difficult, because the coal is exposed on one side only of the coal under cover and because in many places the coal has been burned at the outcrop. Coal tonnage under cover is likely to be estimated differently, even by geologists and engineers using the same data. The estimate herein given is based on a detailed study of all exposures that could be found in the field and on the probable character, thickness, and continuity of the coal under cover. It is believed that at least 1,275,000,000 short tons of coal was originally present in an area not exceeding 43 square miles in the northern part of the Castlegate quadrangle. In most of the coal-bearing area five beds or groups of beds contribute to the tonnage. The acreage estimated to contain each of the coal groups ranges from 21 square miles for the Royal Blue bed to 43 square miles for the Castlegate "A" bed, and the average area for all beds is about 30 square miles. If the total estimated tonnage were comprised in one bed, evenly distributed over 30 square miles, the bed would be 37 feet thick and would contain 66,000 short tons to the acre.

Method of computation.—Several individual beds and groups of beds were studied and mapped in the field. The estimates are made for each traceable bed and group of beds, but the beds that are not traceable are lumped together, and their tonnage is estimated on their average thickness throughout a given area. All beds are more or less irregular in thickness and consist of lenses of different

sizes. The general assumption made in estimating tonnage in areas back of the outcrop is that a coal bed will extend under cover at right angles to the line of outcrop the same distance as it is known to be present on the outcrop, and that the average thickness will be approximately the same as on the outcrop unless geologic conditions known to be unfavorable to coal formation have been present.

Two principal coal groups, the Spring Canyon and Castlegate, and the Kenilworth bed were mapped in the field, and most of the exposures found were on these coals. For the purpose of estimating tonnage the irregularities in thickness of the coal in these groups and beds were taken into account by contouring thicknesses on the outcrop—that is, by drawing lines representing equal known thicknesses and projecting those lines to indicate the thickness of the coal under cover.

The Spring Canyon coal group was taken as a unit, and the aggregate thickness of all beds exposed in this group was used in drawing the lines of equal thickness. This group was not considered to be present east of sec. 31, T. 12 S., R. 10 E., and secs. 6 and 7, T. 13 S., R. 10 E.

The Castlegate group was taken as another unit, and all the beds in this group, except the Royal Blue bed, were used in drawing the lines of equal thickness. The Royal Blue bed was considered as a lens, having its maximum thickness at Kenilworth and being of workable thickness as far as Castlegate on the west and the edge of the quadrangle on the east.

The Kenilworth bed was taken as another unit in computing tonnage. For the nontraceable beds above the Kenilworth the tonnage estimate was based on the average thickness of all workable beds, but no attempt was made to draw lines of equal thickness. It is believed, however, that the estimate for these coals is moderate.

In estimating tonnage for the traceable beds and groups of beds the probable thickness of the coal was interpolated from the lines of equal thickness in each section back of the outcrop, and the tonnage shown in the following table is the sum of the tonnage computed for each section. This method, drawing and projecting lines of equal thickness and computing tonnage for small units, is believed to be more accurate than the method of averaging all exposures on the outcrop and applying these averages over a given area.

Tonnage estimates.—The following table gives the estimated tonnage by beds and townships:

Estimated coal tonnage, by beds and townships, in Castlegate quadrangle, Utah, on the basis of 1,800 tons per acre-foot

Name of bed	Calculated average thickness	Estimated area	Tonnage	
			Per square mile	Total (rounded)
	Ft. in.	*Square miles*		
T. 12 S., R. 8 E.:				
Coal beds above the Kenilworth	4 2	2.0	4,800,000	10,000,000
Kenilworth	3 4	2.0	3,840,000	8,000,000
Castlegate group	3 4	2.2	3,840,000	8,000,000
Spring Canyon group	15	2.2	17,280,000	35,000,000
				61,000,000
T. 13 S., R. 8 E.:				
Coal beds above the Kenilworth	4 2	2.0	4,800,000	10,000,000
Kenilworth	2 9	2.5	3,168,000	8,000,000
Castlegate group	4	4.25	4,608,000	20,000,000
Spring Canyon group	17 6	4.9	20,160,000	99,000,000
				137,000,000
T. 12 S., R. 9 E.:				
Coal beds above the Kenilworth	4 2	6.0	4,800,000	29,000,000
Kenilworth	3 6	7.0	4,032,000	28,000,000
Royal Blue	1 8	2.0	1,920,000	4,000,000
Castlegate group, exclusive of Royal Blue bed	5	7.5	5,760,000	43,000,000
Spring Canyon group	10 10	7.5	12,480,000	94,000,000
				198,000,000
T. 13 S., R. 9 E.:				
Coal beds above the Kenilworth	4 2	8.0	4,800,000	38,000,000
Kenilworth	3 9	9.2	4,320,000	40,000,000
Royal Blue	2 7	4.0	2,976,000	12,000,000
Castlegate group, exclusive of the Royal Blue bed	7 11	10.5	9,120,000	96,000,000
Spring Canyon group	11 8	10.7	13,440,000	145,000,000
				331,000,000
T. 13 S., R. 10 E.:				
Coal beds above the Kenilworth	5	10.0	5,760,000	58,000,000
Kenilworth	12 2	10.9	14,016,000	153,000,000
Royal Blue	3 9	11.8	4,320,000	51,000,000
Castlegate group, exclusive of Royal Blue bed	10 4	11.8	11,942,000	131,000,000
Spring Canyon group	2	1.5	2,304,000	3,000,000
				396,000,000
T. 12 S., R. 10 E.:				
Coal beds above the Kenilworth	5	6.0	5,760,000	29,000,000
Kenilworth	8 4	6.9	9,600,000	66,000,000
Royal Blue	3 3	3.5	3,744,000	13,000,000
Castlegate group, exclusive of Royal Blue bed	5 5	6.9	6,240,000	43,000,000
Spring Canyon group	2	.5	2,304,000	1,000,000
				152,000,000

	Short tons
Total original tonnage of all beds in the Castlegate quadrangle	1,275,000,000
Total coal mined, wasted in mining, or rendered useless	75,000,000
Total coal remaining	1,200,000,000
Total recoverable coal	720,000,000

Summary of tonnage estimate.—The principal part of the estimated tonnage is contained in two groups of coal beds and one single bed—the Spring Canyon group, 377,000,000 tons; the Castlegate group, exclusive of the Royal Blue bed, 341,000,000 tons; and the Kenilworth bed, 303,000,000 tons. The total for these beds is about 80 per cent of the total tonnage. The Spring Canyon group, though not present throughout the coal-bearing part of the quadrangle, contains nearly 30 per cent of the total tonnage.

The estimate of 720,000,000 tons of recoverable coal in the Castlegate quadrangle is based on a 60 per cent recovery and on the assumption that all beds exceeding 1 foot 2 inches in thickness are mined without rendering overlying beds nonrecoverable by caving. (See discussion on p. 103.)

Most of the beds above the Kenilworth are so far above it that they are not seriously affected by the mining of the Kenilworth and will therefore be available when the demand for fuel warrants their exploitation. These beds are estimated to contain 174,000,000 tons, or about 13 per cent of the total tonnage.

The coals in the Castlegate group should all be mined before a retreat or pulling of pillars is begun on any bed of the group, unless the highest bed is mined first and the lower beds are mined in turn downward. It is believed that the mining of the Castlegate group will not affect the Kenilworth bed.

The coals of the Spring Canyon group should all be mined simultaneously and could well be worked from the same main haulage ways if the several beds are connected by rock tunnels. The mining of the Spring Canyon group will probably not affect the Castlegate group.

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