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RECONNAISSANCE
OF THE
BOOK CLIFFS COAL FIELD

BETWEEN GRAND RIVER, COLORADO
AND SUNNYSIDE, UTAH

BY

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RECONNAISSANCE OF THE BOOK CLIFFS COAL FIELD, BETWEEN GRAND RIVER, COLORADO, AND SUNNY- SIDE, UTAH.

By G. B. RICHARDSON.

INTRODUCTION.^a

The Book Cliffs coal field is part of the southern rim of the Uinta Basin, which is an immense structural trough in western Colorado and eastern Utah, around whose margin the outcrop of coal-bearing rocks can be traced for more than 500 miles. (See fig. 1.) From the vicinity of Mount Hilgard, in central Utah, northward to Castlegate, the coal measures form the eastern escarpment of the Wasatch Plateau. Thence they trend southeastward to Grand River, outcropping in the Book Cliffs. Beyond Grand River they continue eastward, forming the southern face of Grand Mesa, to the vicinity of Crested Butte. From this point the coal-bearing rocks trend northward and cross Grand River again near Newcastle. North of Grand River they form the Grand Hogback, and beyond the Danforth Hills the trend is westward along the southern flank of the Uinta Mountains. This great basin of coal-bearing rocks has been but partially prospected, and mines are in operation in only a few localities, but enough of the area has been explored to prove that it is one of the most important coal reserves of the Rocky Mountain region. As a whole, this area is a distinct unit, but for convenience of study and description, it is divided into several parts. The Book Cliffs field is that portion of the southern rim of the Uinta Basin which includes the Book Cliffs and lies between Grand River, Colorado, and the Wasatch Plateau, Utah.

The geology of the Book Cliffs was first studied by A. C. Peale,^b of the Hayden Survey, who in 1876 examined the eastern part of the field. The western part was included in G. H. Eldridge's map of the Uinta Basin published in connection with his study of asphalt and bituminous rock deposits.^c Until recently these papers have

^a An abstract of this report was printed in Contributions to Economic Geology, 1906, Part II: Bull. U. S. Geol. Survey No. 316, 1907.

^b Peale, A. C., Geological report on the Grand River district: Tenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1878, pp. 170-185.

^c Eldridge, G. H., Asphalt and bituminous rock deposits of the United States: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, 1901, p. 332.

been the only available systematic geologic reports of the region. The presence of coal in the Book Cliffs has long been known. The deposits are mentioned by R. C. Hills^a in his report on the coal fields of Colorado, and by L. S. Storrs^b in his paper on the Rocky Mountain coal fields. Arthur Lakes has also referred to part of the area^c and has described the Book Cliff mine.^d But the coal field was not examined in detail until 1905, when J. A. Taff,^e of the United States Geological Survey, studied the western part of the field from the vicinity of Sunnyside to Castlegate, Utah, and its southern continuation along the escarpment of the Wasatch Plateau.

During three months of the season of 1906 the writer, assisted by W. D. Neal, L. J. Pepperberg, and C. D. Perrin, made a reconnaissance survey of the eastern part of the Book Cliffs field from Grand River westward to the termination of Taff's work. The attention of the party was devoted mainly to a study of the occurrence of the coal. The boundary between the Mancos shale and the Mesaverde formation—the most easily recognized horizon nearest the coal—was followed throughout the field, but in the time available detailed mapping of the formations could not be attempted. The location of the Dakota sandstone outcrop below the Mancos shale and the position of the base of the Eocene above the Mesaverde formation were determined only at certain localities, and the boundary between these formations, shown on Plate I by a dotted line, is only approximately located.

TOPOGRAPHY.

The Book Cliffs form the southern margin of the Book or Tavaputs Plateau, which is situated in the central part of the Colorado Plateau province, between the Rocky Mountains and the Wasatch Range. The southward-facing cliffs, which extend in a great east-west line from Grand River to Castlegate, lie north of and generally in sight of the Denver and Rio Grande Railroad and are one of the most striking topographic features along that railroad. The cliffs do not form an unbroken wall, but locally are deeply cut by small streams into a series of spurs which, although much lower than the main mass of the plateau to the north, tower above and dominate the great plain at their base. This plain is eroded in the soft shale underlying the coal-bearing rocks, and it affords a route for the railroad which closely skirts the foot of the cliffs throughout most

^a Hills, R. C., Coal fields of Colorado: Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 353.

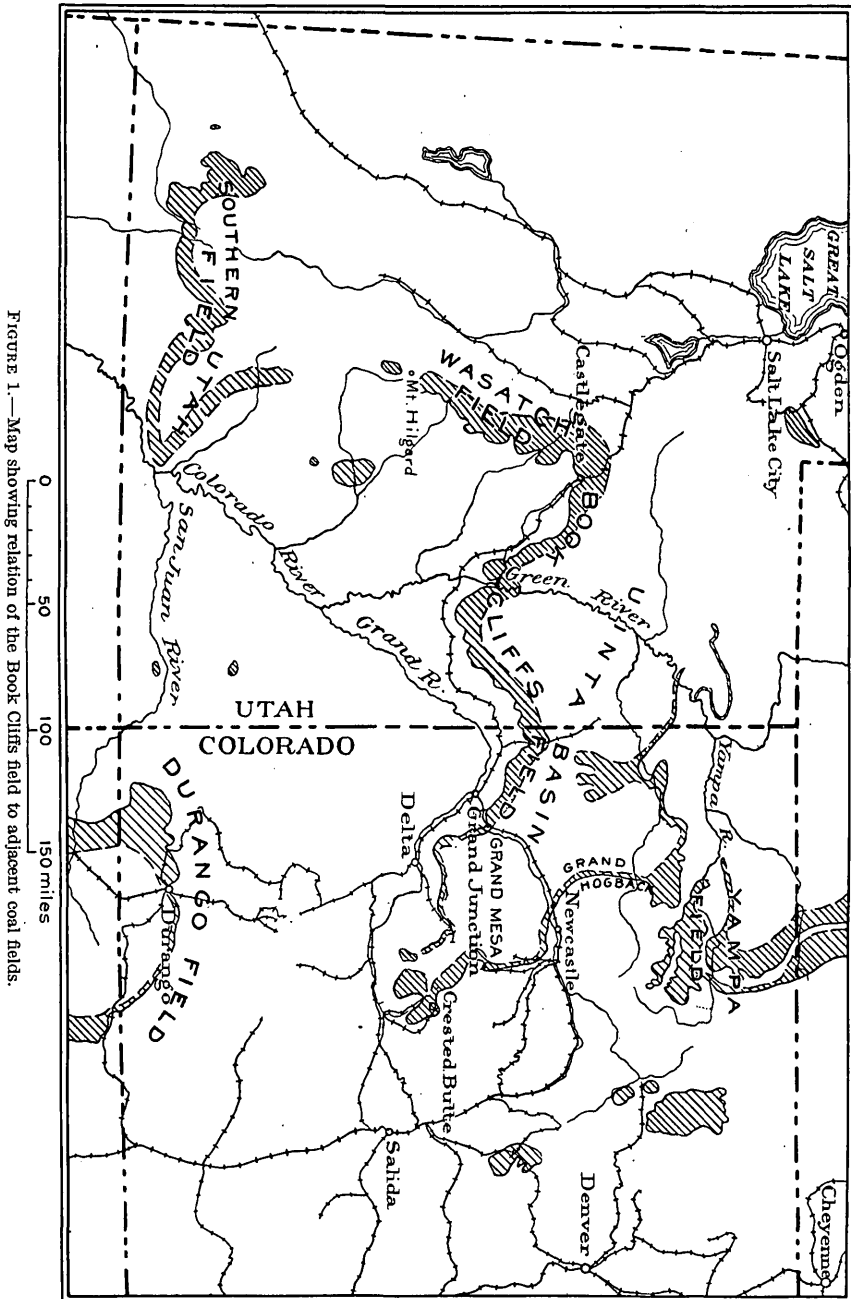
^b Storrs, L. S., The Rocky Mountain coal field: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1901, p. 436.

^c Lakes, Arthur, The Grand River coal field: Mining Reporter, vol. 51, 1905, pp. 379-381.

^d Lakes, Arthur, The Book Cliffs coal mine: Mines and Minerals, vol. 24, 1904, pp. 289-291.

^e Taff, J. A., The Book Cliffs coal field: Bull. U. S. Geol. Survey No. 285, 1906, pp. 289-302.

of their extent. South of this broad valley stratigraphically lower and harder rocks are exposed in the Uncompahgre Plateau and the



San Rafael Swell, two great anticlinal uplifts south of the Uinta Basin.

RELIEF AND DRAINAGE.

The altitude of the surface throughout the Book Cliffs field ranges from about 4,000 feet in the lowlands to 8,000 and 9,000 feet above sea level on the plateau. The area is drained by Green and Grand rivers, which unite to form the Colorado about 60 miles south of the Book Cliffs.

Green River, after leaving the Uinta Mountains, flows in a southwesterly direction across the Uinta Basin and cuts through the Tavaputs Plateau in a steep, narrow gorge known as "Desolation Canyon." At the mouth of the canyon in the Book Cliffs the stream emerges into the lowlands, where it meanders in a broad valley for 10 or 12 miles. It flows across the belt of lowland and enters another canyon on its way to its junction with the Grand. Green River receives a number of large tributaries in the Uinta Basin—Yampa and White rivers on the east and Uinta and Duchesne on the west; but in its canyon course through the Tavaputs Plateau the only important branch is Price River, and in the lowland south of the Book Cliffs there is no addition to its flow. East of Desolation Canyon the plateau drains northward by Kwiant and Yogowotsi creeks, which, rising near the rim of the Book Cliffs, enter the river a few miles below the mouth of White River.

Price River rises on the Wasatch Plateau, flows southeastward, and emerges from the canyon it has cut in the plateau at Castlegate. Thence it flows along the broad lowland valley at the base of the Book Cliffs for a distance of 25 miles. Instead of continuing in the lowland, however, it crosses the northern end of the San Rafael Swell, flows directly across the lowland valley again, cuts a deep canyon which separates Beckwith Plateau from the Tavaputs Plateau, and finally enters Green River about 6 miles above the mouth of Desolation Canyon.

Grand River, rising near the Continental Divide, on the Front Range of the Rocky Mountains, in Middle Park, Colorado, flows southwestward and enters the area under consideration at the mouth of Roan Creek in a relatively broad valley. A few miles below Roan Creek the river enters Hogback Canyon, in which it flows through the Little Book Cliffs and emerges into the lowland immediately above the town of Palisades. The river crosses the lowland, a distance of about 13 miles, to the town of Grand Junction, where it is joined by Gunnison River. The Grand then turns abruptly northwestward and follows the southern margin of the lowland for 18 miles. Below Fruita it leaves the lowland, and again flowing southwestward cuts across the northern end of the Uncompahgre Plateau, and continuing southwestward, mostly in a canyon course, finally joins the Green.

With the exception of the Gunnison, Grand River receives no large tributaries in the Book Cliffs field. The most important is Roan

Creek, which drains the area between the Little Book Cliffs and the Book Plateau northwest of De Beque. The streams which flow southward from the Book Plateau are small, and on account of the slight precipitation and limited drainage area flow intermittently throughout the year. During the dry months the discharge even within the highlands almost ceases and the stream beds across the lowlands are dry.

The relation of the through-flowing streams to the lowland indicates that their general courses were defined before the development of the present topography, for there is little adjustment between the drainage and the outcrops of the hard and soft formations. Grand River conforms only partially with the trend of the lowland; Green River maintains its way directly across the shale belt; Price River, flowing alternately over hard and soft rocks, instead of continuously in the shale lowland, is a good example of superimposed drainage.

LOWLAND AT BASE OF BOOK CLIFFS.

The lowland at the base of the Book Cliffs extends in a curved but general westerly direction from Palisades, Colo., to Helper, Utah, a distance of 190 miles. From Palisades it continues southeastward between the Uncompahgre Plateau and Grand Mesa, and from Helper the lowland extends southward between the San Rafael Swell and the Wasatch Plateau, where it is known as Castle Valley. Throughout its extent the lowland is underlain by shale and is not a stream valley in the sense of being carved and occupied by a single master stream; instead, the lowland has been eroded in soft rock by general subaerial action and forms part of several drainage basins. The lowland has been widened by the gradual recession of the Book Cliffs northward due to the weathering of the soft shale and the undermining of the overlying hard sandstone which forms the cliffs. By this process the cliffs have retreated, but they have maintained a fairly regular front.

The average width of the lowland is about 12 miles, having a maximum of 23 miles, in the vicinity of Cisco, and a minimum of 4 miles, near Woodside. The lowland is an undulating plain that rises gently toward the bordering highlands and extends between the Book Cliffs on the north and a belt of sandstone hills on the south. It practically coincides with the outcrop of the Mancos shale. The small streams that head in the Book Cliffs and cross the lowland have carved steep arroyos, which impede travel. In the vicinity of the cliffs there are outlying buttes and the shale is eroded into badlands. Adjoining the cliffs there are local fringing remnants of an old outwash gravel-covered plain into which the streams have cut their way 100 feet or more, and south of Grand River, near Palisades, a number of terraces are well developed. The largest, about 150 feet above the river, is

between a quarter and a half mile wide, and traces of several other less distinct terraces have been found above this one.

BOOK CLIFFS.

The Book Cliffs occupy a belt from 1 to 10 miles wide and rise above the adjacent lowland from 2,000 to 6,000 feet. In places the rise is abrupt in one or two sharp precipices; elsewhere it is accomplished by a series of cliffs and intervening benches. The rocks composing the escarpment are alternating beds of sandstone and shale dipping slightly northward, and the strata present the appearance of the leaves of a book lying flat, hence the name.

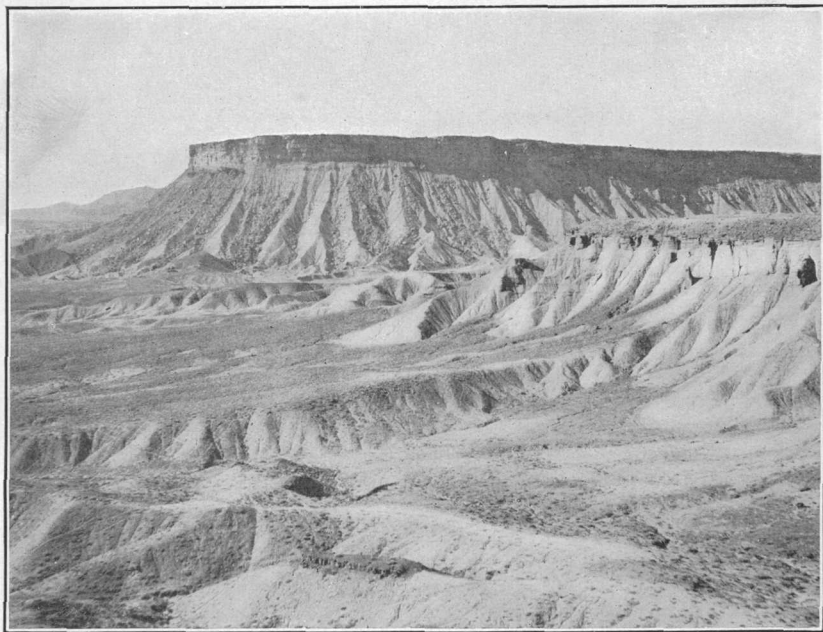
In the area here discussed the cliffs extend in an S-shaped belt from Palisades to Sunnyside. At the east they are much dissected by Roan Creek, and a subordinate escarpment known as the Little Book Cliffs extends northwestward from the mouth of Hogback Canyon. The top of the Little Book Cliffs marks the crest of a ridge whose northeastern flank constitutes a dip slope, and the area between Little Book Cliffs and Roan Creek is a gentle northeastward-sloping monocline dissected by southeastward-flowing streams.

West of the headwaters of Roan Creek the Book Cliffs proper extend to the end of the area mapped. Erosion by East and West Salt creeks has caused the rim of the plateau to recede so much that a few miles east of the Utah-Colorado boundary the distance between the lowlands and the plateau is unusually great. Between the State line and Green River the average distance is about 10 miles. Here a low bench, caused by a great lens of sandstone in the shale, forms the base of the cliffs, as shown in Plate II, A. Above this lowest bench there is a succession of dissected platforms and escarpments up to the summit of the plateau.

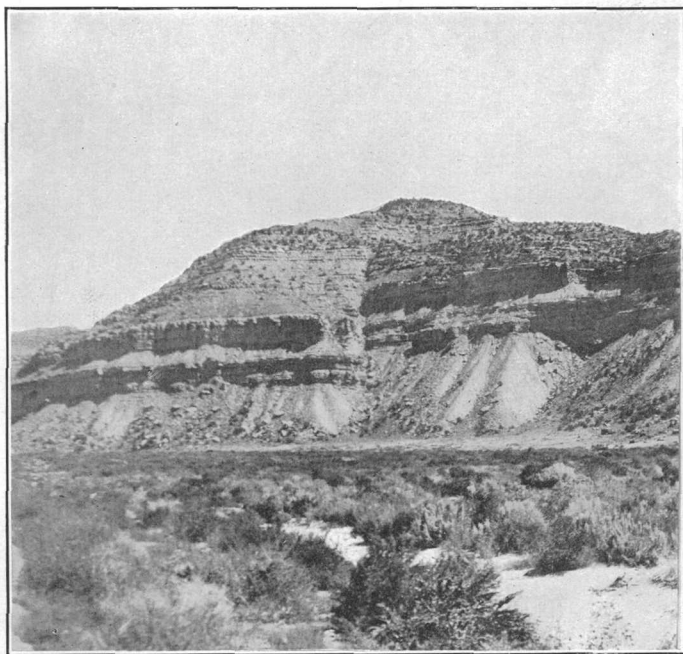
Green River has cut another embayment in the cliffs, and Price River in its canyon course separates a small area, known as the Beckwith Plateau, from the main mass of the upland. The Beckwith Plateau is considerably dissected on the north and east, but faces the lowland on the west in a practically unbroken scarp more than 1,500 feet high. Beyond Price River a similar line of cliffs extends at least as far as Sunnyside. The surface at the summit of this cliff slopes eastward and forms a platform upon which another but more dissected line of cliffs rises 1,500 feet higher.

BOOK OR TAVAPUTS PLATEAU.

The crest of the Book cliffs forms the southern rim of the Book Plateau, or, as it is known in Utah, the Tavaputs Plateau, which viewed from the south, forms an even-topped sky line. The plateau slopes gently northward toward the axis of the Uinta Basin, but is much dissected by deep canyons.



A. BENCH AT BASE OF BOOK CLIFFS, EAST OF THOMPSONS.



B. FAULT IN MESAVERDE FORMATION, 2 MILES SOUTH OF CARBONERA.

CLIMATE AND CULTURE.

The climate of the region is arid, the mean annual rainfall at Grand Junction being only 7.8 inches. The vegetation, therefore, is of the desert type, and the shale lowland in its natural state is practically bare or yields a meager growth of desert plants. The uplands receive more rain and support stunted conifers, oaks, etc. In general, timber suitable for mining purposes is scarce. In the Grand Junction region timber for this purpose is imported, but in the western part of the field it is more plentiful. In the valleys where irrigation is practiced the desert has been converted into a garden, and portions of the area rival in productiveness any part of the country. The mean annual temperature is 53°, the summers being warm and the winters usually mild. The percentage of sunshine is 75 and general climatic conditions are delightful. In the irrigated areas contiguous to Grand, Green, and Price rivers there are a number of thriving settlements where fruit growing is an important industry. Grand Junction, the most important place in the field, is a typically progressive western town. The lowland is traversed in an east-west direction by the main line of the Denver and Rio Grande Railroad.

DESCRIPTIVE GEOLOGY.**STRATIGRAPHY.**

The general sequence of formations in the coal fields of the Uinta Basin, as determined by recent work of the United States Geological Survey,^a is shown in the following table:

Geologic formations in Uinta Basin.

System.	Series.	Formation.
Tertiary.	Eocene.	Green River formation. Wasatch formation. Fort Union or older (?).
		Unconformity.
Cretaceous.	Upper Cretaceous.	Mesaverde formation. Mancos shale. Dakota sandstone.
		Unconformity.
Jurassic.		

To the subdivisions of the Cretaceous are given the names introduced by Whitman Cross for southwestern Colorado.^b This classi-

^a Taft, J. A., Pleasant Valley coal district, Utah, and Gale, Hoyt S., Coal fields of the Danforth Hills and Grand Hogback, Colorado: Bull. U. S. Geol. Survey No. 316, 1907.

^b Cross, Whitman, La Plata folio (No. 60), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

fication differs from that of Peale, of the Hayden Survey, who in his report on the Book Cliffs field^a separated the rocks here assigned to the Mesaverde formation into the "Fox Hills" and the "Laramie." It was recognized by the Hayden Survey that there is no distinct lithologic break in the Book Cliffs between the "Laramie" and the "Fox Hills," and the nomenclature employed was an attempt to conform to subdivisions used in other fields. It has been found desirable, however, to restrict the use of the name "Fox Hills" to the original area in South Dakota,^b and, as shown below, these rocks are not Laramie, but belong in the Montana group. The classification here adopted is based on the general stratigraphic and areal relations of the rocks and on fossil evidence, as explained on pages 17-19. The Uinta Basin section differs from that of southwestern Colorado and the Yampa coal field in northwestern Colorado^c by the absence of the Lewis shale and the Laramie formation between the Mesaverde and the Eocene. This hiatus in the Book Cliffs field appears to be accounted for by the unconformity at the base of the Eocene, which implies that these formations, if they were ever present in the area under discussion, were removed by erosion previous to the deposition of the overlying Tertiary rocks.

In the Book Cliffs field the general character and sequence of the rocks is shown by the section in Plate III. The strata are separable into four distinct lithologic divisions, the three Cretaceous formations named and the Eocene rocks, all easily recognizable throughout the field by their physical character and sequence.

CRETACEOUS SYSTEM.

DAKOTA SANDSTONE.

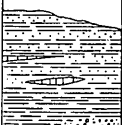

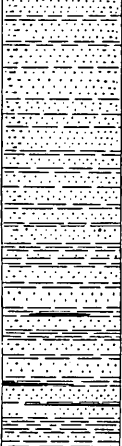
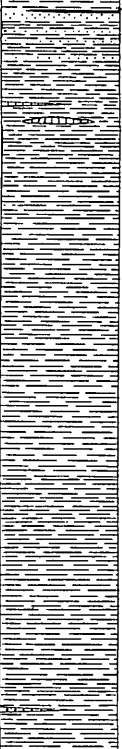


The Dakota sandstone in the area here considered possesses the characteristic features common to the formation in this general region. It is composed of buff quartzitic sandstone, generally conglomeratic, and local beds of carbonaceous shale and low-grade coal are provisionally included in the formation, although no fossils have been found in them in the Book Cliffs field. The Dakota varies in thickness from about 200 feet to less than 25 feet. The outcrop forms a narrow belt of low hills parallel to and about 12 miles south of the Book Cliffs.

The formation is extremely variable in composition and arrangement of the beds, as shown by the following sections measured in different parts of the field. At the mouth of Gunnison River, south of Grand

^a Peale, A. C., Geologic report on the Grand River district: Tenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1878.

^b Stanton, T. W., Geology and paleontology of the Judith River beds: Bull. U. S. Geol. Survey No. 257, 1905, p. 66.

^c Fenneman, N. M., and Gale, Hoyt S., The Yampa coal field: Bull. U. S. Geol. Survey No. 297, 1906.

AGE.	FORMATION.	SECTION.	THICKNESS, IN FEET.	DESCRIPTION.
Eocene.	Mostly Wasatch.		500+	Varicolored shales, buff sandstone, local basal conglomerate, and subordinate thin beds of limestone containing fresh-water shells. Different sections show diverse stratigraphy. These rocks form the highest cliffs and constitute the floor of the Uinta Basin.
Upper Cretaceous.	Unconformity			
	Mesaverde.		1,200 to 2,200	Alternating beds of buff sandstone and drab shale with workable beds of coal in the lower part of the formation. Fossils occur at several horizons, including leaves, invertebrates, and occasional bones. These are the cliff-making rocks of the Book Cliffs.
	Mancos shale.		3,000±	Fissile black to drab clay shale and local lenses of limestone. Thin beds of buff sandstone at the top mark the transition to the overlying formation. Marine shells are abundant at two general horizons in the upper and lower parts of the formation. This shale underlies the broad lowland at the base of the Book Cliffs.
	Dakota sandstone. Unconformity		25 to 200	Buff sandstone, often conglomeratic.
Jurassic.	Morrison.		300+	Red, green, and purple shales with lenses and thin beds of buff sandstone containing dinosaur bones.

GENERALIZED COLUMNAR SECTION OF THE ROCKS OF THE BOOK CLIFFS COAL FIELD.

Junction, the following measurements were made, but no Dakota fossils were found, and the limits of the formation were not determined:

Section of strata south of Grand Junction.

	Feet.
Shale, drab (Mancos).....	5
Sandstone, buff, lens (Dakota?).....	
Shale, carbonaceous, containing thin layers of coal (Dakota?).....	20
Sandstone, massive, cross-bedded, cream-colored, quartzitic, including irregular lenses of conglomerate with rounded pebbles of chert and quartzite up to 1 inch in diameter (Dakota).....	20
Shale, drab, probably below Dakota.....	1
Sandstone, greenish drab, shaly.....	2
Shale, greenish drab.....	20+
	<hr/> 68

Between Grand Junction and Fruita the outcrop of the Dakota lies immediately south of Grand River, but the formation is covered by sand and gravel at many places. In this locality the carbonaceous shale is well developed, and at several places there are coal prospects. In a creek about midway between Grand Junction and Fruita the following section is exposed:

Section of Dakota (?) coal beds in creek midway between Grand Junction and Fruita.

	Ft.	in.
Sandstone, buff.....	4	
Shale, carbonaceous.....	2	
Coal.....	1	6
Shale, carbonaceous.....	1	
Coal (varies from 2 to 3 feet).....	2	6
Shale, carbonaceous.....		6
Coal.....		8
Shale, carbonaceous.....		8
	<hr/> 12	<hr/> 10

The formation crosses the river west of Fruita and the following section was measured south of Loma:

Section of Dakota sandstone south of Loma.

	Feet.
Shale, dark with local carbonaceous layers (Colorado).	
Sandstone, buff, including thin layers of shale and lenses of conglomerate with pebbles of chert and quartzite.....	40
Shale, greenish, sandy.....	50
Sandstone, buff, and conglomerate.....	25
Sandstone, white.....	20
Shale, varicolored (Jurassic).	
	<hr/> 135

South of Thompsons, Utah, there are 100 feet of massive white and buff sandstones, cross-bedded and locally conglomeratic, lying between drab shale above and varicolored shale below. At this place the carbonaceous beds seem to be absent, and they were not found farther

west in the area examined. Near Green River the formation is variable. In places south of Elgin the sandstone thins out to a few feet and locally disappears, while nearby it thickens to 40 feet or more. Some exposures show considerable conglomerate, while others show but little conglomerate and much sandstone.

Characteristic Dakota leaves were found in the sandstone near Elgin and in the vicinity of Woodside. They were examined by F. H. Knowlton, who furnishes the following lists:

Dakota fossils from Woodside.

Laurus proteæfolia Lesq.

Laurus modesta? Lesq.

Dakota fossils from Elgin.

cf. *Pecopteris striata* Heer, from the Unter Atanekerdruk (Cenomanian) beds of Greenland.

Gleichenia sp.?

Torreya oblanceolata Lesq.

Pinus sp. (cone scales).

Liquidambar integrifolium Lesq.

Andromeda linearifolia? Lesq.

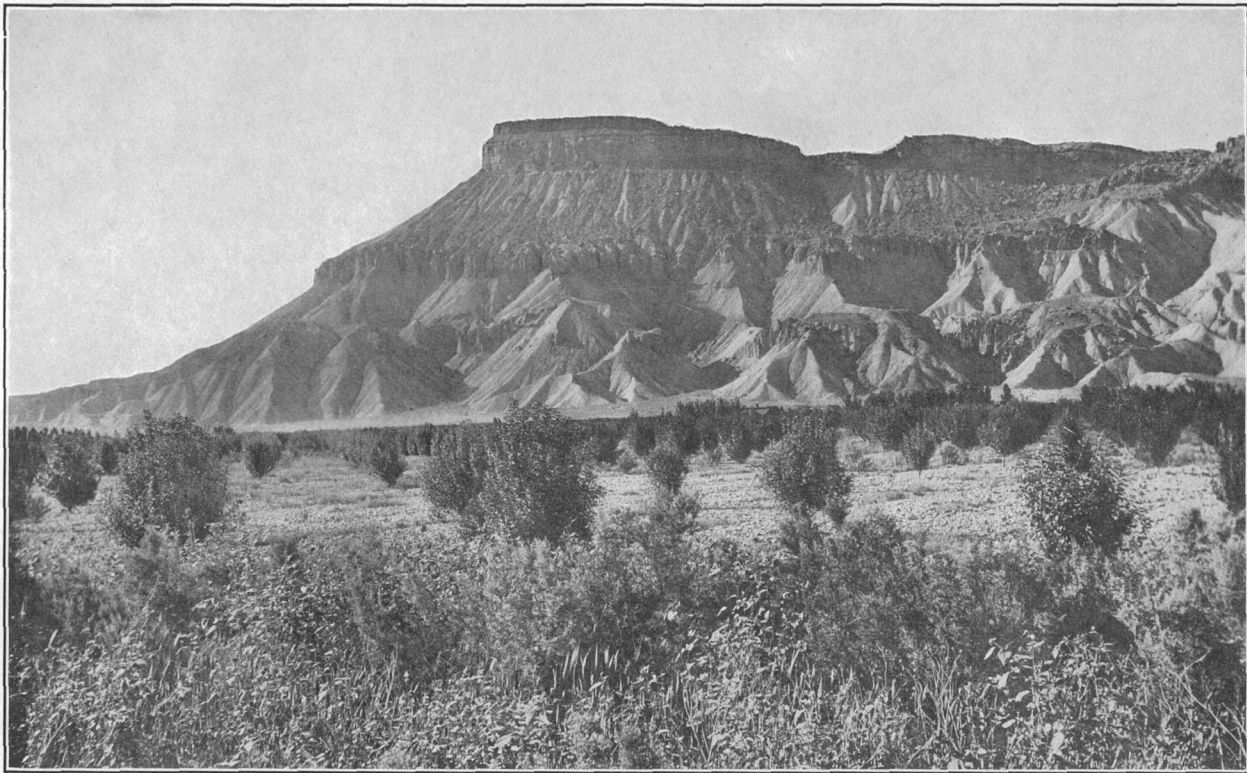
Salix proteæfolia Lesq.

The Dakota sandstone is underlain by several hundred feet of red, green, and purple shales with intercalated layers of buff sandstone and thin blue limestone. A number of dinosaur^a bones have been found in these beds, which probably represent the Morrison formation. The contact between the Cretaceous (Dakota) and Jurassic is not everywhere distinct, but in several localities the former is exposed lying unconformably on an undulating surface of varicolored Jurassic shale.

MANCOS SHALE.

The Mancos shale forms the base of the Book Cliffs (Mount Garfield, Pl. IV), where it is sculptured into badland topography, and it underlies the broad valley between the cliffs and the hills of Dakota sandstone to the south. It is a fissile black, blue-gray, and drab clay shale, which contains local lenses of limestone, and, at the top, thin beds of buff sandstone. The shale constitutes a distinct lithologic unit in which there is little variation, though the color of the lower part is generally darker than the upper. It is much broken by cracks and joints, which frequently contain thin saline films. These locally effloresce in patches of white powder, some of which were found to consist chiefly of calcium carbonate, and the unreclaimed areas of shale are characteristically coated with "alkali." Lenses of blue-gray fossiliferous limestone, from several inches to a few feet in thickness,

^a Riggs, E. S., The dinosaur beds of Grand River valley, Colorado: Field Columbian Mus. geol. series, vol. 1, 1901.



MOUNT GARFIELD, 9 MILES EAST OF GRAND JUNCTION.

Shows weathering of Mancos shale at the base of Book Cliffs. The "lower coal" occurs beneath the massive sandstone.

occur at several horizons, but chiefly in the upper few hundred feet of the formation. This part of the formation is also characterized by beds of buff sandstone, usually thin bedded, by which the Mancos shale grades into the overlying Mesaverde formation.

From the nature of the exposures the thickness of the Mancos shale is difficult to determine. The best measurement was obtained from a drill hole near the upper terminus of the Book Cliffs Railroad, about 10 miles northeast of Grand Junction. This began about 200 feet below the top of the formation, and was still in shale when drilling was stopped at a depth of 2,600 feet, showing a minimum thickness of 2,800 feet. The dip of the shale in the valley can be only roughly estimated; but assuming an average of 2° and allowing 1,200 feet for the difference in elevation between the outcrops of base and top of the shale, and a width of outcrop of 11 miles, gives a thickness of about 3,200 feet.

Marine shells have been found in the shale at two general horizons, one near the base and the other near the top. The lower collections were obtained at several localities within 200 feet of the base of the formation, and among these T. W. Stanton has identified the following forms:

Fossils from lower part of Mancos shale.

Anomia sp.	Prionocyclus macombi Meek.
Modiola sp.	Callista sp.
Ostrea lugubris Conrad.	Pyropsis? sp.
Inoceramus dimidius White.	Baculites gracilis Shumard?
Inoceramus fragilis H. and M.	Gryphæa newberryi Stanton.
Scaphites warreni M. and H.	

Most of the fossils from the upper part of the shale were found in limestone lenses about 250 feet below the lowest coal bed, but a few specimens were obtained in sandstone only 50 feet below the coal. They include the following forms, identified by T. W. Stanton:

Fossils from upper part of Mancos shale.

Lucina sp.
 Baculites compressus Say.
 Baculites ovatus Say.
 Inoceramus cripsi var. barabini Morton.

Concerning these fossils Stanton reports as follows:

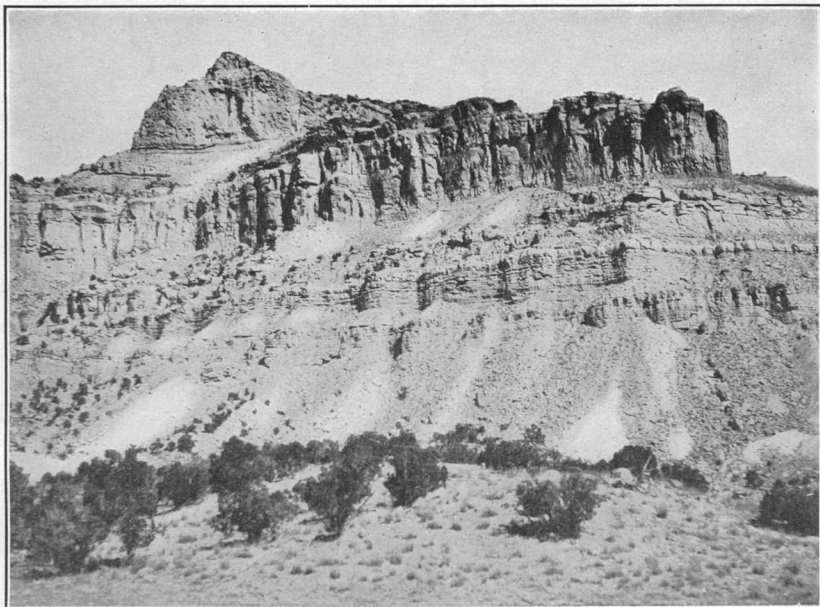
The fossils of the shale between the Dakota and the coal-bearing rocks indicate that two distinct faunas are represented, one, in the lower part, being characteristic of the Benton shale of the Colorado group, and the other, near the top, equally characteristic of the Montana group. As this agrees perfectly with the fauna of the Mancos shale in the type locality, and as there is also essential agreement in other respects, such as stratigraphic position, lithologic character, and thickness, it seems justifiable to apply the name Mancos to this shale.

MESAVERDE FORMATION.

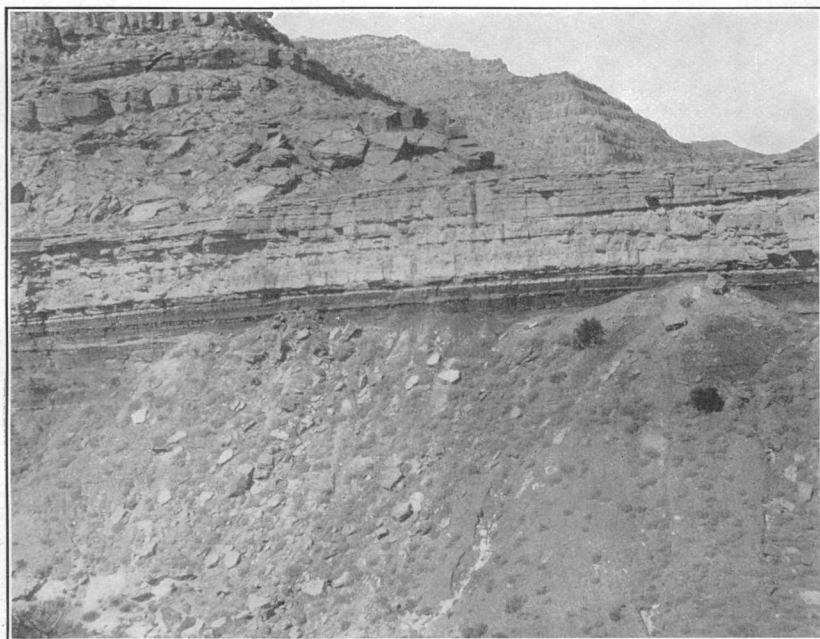
Well-exposed sections in the face of the Book Cliffs (Pls. IV and X) show that the Mancos shale grades upward into the overlying Mesaverde formation with no apparent break in sedimentation. The transition is marked by the increasing prevalence of sand in the upper part of the Mancos, and in the Book Cliffs field a sharp boundary can not be drawn between the formations. The Mesaverde consists of alternating beds of buff sandstone and drab or dark shale with workable beds of coal in the lower part (Pl. V). These are the escarpment-making rocks of the Book Cliffs, and they are well exposed throughout the area.

The sections in Plate VI show the general character of the formation. About a third of it is composed of shale, most of which occurs in the lower half, while the upper part consists principally of sandstone. The areal distribution of the different strata is varied, and no two sections are exactly alike. Some beds of sandstone, however, are persistent for several miles. Coal is practically limited to the lower 700 feet of the formation, and throughout the field one or more beds ranging from 2 to 21 feet thick have been found, as described on pages 24-41, wherever prospecting has been done. The shale of the Mesaverde formation is commonly sandy and is drab in color, but where associated with the coal it is usually carbonaceous. The sandstone is generally buff, though occasionally it is almost white, and in places red. The bedding ranges from thin to massive, some of the layers being only a few inches while others are 50 feet thick, the usual thickness being between 2 and 5 feet. The sandstone is prevaillingly fine textured and is conspicuously feldspathic, consisting in general of rounded grains of quartz with considerable feldspar and subordinate mica. Exposed surfaces are often coated with efflorescing salts, and the sandstone locally shows honeycomb weathering. The rocks of the Book Cliffs coal field are traversed by numerous joints, which are prominently developed in the sandstone. Two sets, at right angles, are commonly present.

At many places in the lower part of the formation the sandstone is distinctly red. The color is distributed in irregular patches, generally, if not always, a few feet above a coal bed, and usually at exposed jutting outcrops. There appears to be no difference in general composition between the normal buff sandstone and that colored red, and the distribution of the highly colored rocks is too irregular to be accounted for by differences in original deposition. Similar occurrences have been reported from several of the Rocky Mountain coal fields, and the color is believed to be due to the burning of coal in underlying beds, the formation of the color being analogous to that in the burning of bricks. In Horse Canyon, at the western limit of the present survey, the coal bed is about 16 feet



A. TYPICAL EXPOSURE OF MESAVERDE FORMATION, 25 MILES NORTH OF THOMPSONS.



B. OUTCROP OF COAL IN VALLEY OF SALERATUS CREEK.

thick and is normally overlain by buff sandstone. But south from the prospect near the mouth of the canyon, on the west side, the coal locally disappears and its place is occupied by a thin deposit of whitish, ashlike material about a foot thick, and the overlying thin-bedded red sandstone is crumpled and broken, as if it had fallen consequent to the burning of the coal. Bits of slaglike material, clinkers, etc., are in the vicinity.

The thickness of the coal-bearing formation is variable and decreases toward the west. Immediately east of Grand River the entire formation is exposed in steep cliffs, and a thickness of 2,200 feet was measured barometrically on the flanks of Grand Mesa. North of Thompsons, Utah, a thickness of about 1,800 feet was measured, but an allowance for dip makes this measurement less reliable. At the mouth of Horse Canyon, in the west end of the field, the formation is only about 1,200 feet thick. As stated on page 19, the erosion of the Mesaverde before the deposition of the overlying Tertiary rocks is probably the cause of the observed difference in thickness.

Fossils occur in this formation at several horizons and include invertebrates, leaves, and a few bones. Shells were found in many localities between 200 feet above the lowest coal bed and 250 feet below the overlying varicolored deposits. Among the fossil shells Stanton has identified the following species:

Fossils from Mesaverde formation.

Ostrea sp.	Corbula perundata M. and H.
Ostrea glabra M. and H.	Corbula subtrigonalis M. and H.
Anomia gryphorhynchus Meek.	Corbicula cytheriformis M. and H.
Anomia micronema Meek.	Campelema? sp.
Modiola laticostata White?	Tulotoma thompsoni White.
Modiola cf. regularis White.	Goniobasis sp.
Unio, several species.	Molluscan burrows in fossil wood.

A number of small lots of fossil leaves were collected from this formation at several localities, and at a few places fairly good collections were obtained, which were identified by F. H. Knowlton as follows:

About a quarter of a mile northwest of the present Book Cliff mine, from a sandstone 30 feet above the upper coal, the following were collected:

Fossil leaves from sandstone near the Book Cliff mine.

Sequoia Reichenbachii (Gein.) Heer.	Ficus latifolia (Lesq.) Knowlton.
Eriocaulon? porosum Lesq.	Myrica Torreyi Lesq.
Palm (new).	Magnolia sp.

Near the mine entry several specimens of *Halymenites major* Lesq. were obtained.

Three-fourths of a mile northwest of Cameo, about 100 feet above the upper coal, a narrow leaf, apparently *Salix*, *Sequoia Reichenbachii*? (Gein.) Heer, and fragments of dicotyledons were found.

Fifty feet above Ballard's coal mine north of Thompsons *Anemia elongata* (Newb.) Knowlton and *Myrica Torreyi* Lesq. were found.

About 200 feet above the coal at Carbonera fragments of dicotyledons, including *Myrica Torreyi*? Lesq., were found.

About 8 miles north of Thompsons, 250 feet below the conglomerate which is regarded as marking the base of the Eocene, the following were obtained:

Fossil leaves from a locality about 8 miles north of Thompsons.

Sequoia Reichenbachii (Gein.) Heer.

Sabalites Grayanus? Lesq.

Ficus planicostata Lesq.

Cinnamomum affine? Lesq.

Malapoenna new.

Ficus sp., very large, apparently new.

Dicotyledon, very large, with three ribs, prominent teeth, etc., probably new.

The only fossil bones from this formation were obtained east of Green River, about 500 feet above the top of the Mancos shale. They were determined by J. W. Gidley, of the United States National Museum, to be the distal ends of femurs of a dinosaur.

There has been much misapprehension concerning the age of the coal-bearing rocks of the Uinta Basin. In the Book Cliffs field, as already stated, Peale mapped the rocks here referred to the Mesaverde as two formations and correlated them respectively with the "Fox Hills" and the "Laramie." Later writers have considered the entire formation to be Laramie, because it overlies marine Cretaceous beds and in turn is overlain by Wasatch strata, and the fauna and flora were believed to belong to the Laramie.

Just what constitutes the Laramie has long been a problem with geologists, but recent studies of the Rocky Mountain coal fields by the United States Geological Survey have thrown new light on the subject. The reason for assigning the coal-bearing formation of the Book Cliffs to the Mesaverde is explained in the following extract from a letter of T. W. Stanton to the writer, reporting upon fossils collected from this field.

In northwestern Colorado, southern Wyoming, and elsewhere, many of the coal-bearing rocks previously called Laramie are really older and are overlain by marine Cretaceous formations, thus corresponding with the Mesaverde formation first described in southwestern Colorado. The Mesaverde formation has been identified in the Yampa field, where the stratigraphic evidence is satisfactory that it underlies a thick marine Cretaceous formation, correlated with the Lewis shale, which in turn is overlain by the Laramie and later formations. South of the Yampa field, in the Danforth Hills and the Grand Hogback, the Mesaverde is clearly recognizable, but here there is an erosional unconformity which cuts out the Lewis and the Laramie and brings the Mesaverde in contact with the Fort Union^a and possibly later formations.

^aGale, H. S., Coal fields of the Danforth Hills and Grand Hogback in northwestern Colorado: Bull. U. S. Geol. Survey, No. 316, 1907, pp. 264-301.

The invertebrate fauna of the Mesaverde includes two distinct elements; one consisting of marine species is found chiefly in the lower portion, sometimes in beds alternating with those containing the other, which consists of fresh-water and brackish-water forms. The marine element is a direct continuation of the upper Mancos fauna and is not safely distinguishable from it without full stratigraphic data. The non-marine fauna is closely related to that of the Laramie, with which it has some species in common, especially in the genera *Ostrea* and *Corbicula*. During the past season [1907] the fact has been established that *Tulotoma thompsoni*, hitherto regarded as a characteristic Laramie species, occurs in both the Laramie and the Mesaverde.

The invertebrate fossils that have been collected from the coal-bearing rocks of the Book Cliffs all occur in the Mesaverde of northwestern Colorado, and Doctor Knowlton finds that this is essentially true of the plants also. It is admitted that most of the fossils in question from the Book Cliffs would not seem out of place in the Laramie, yet their close agreement with those known to occur in the Mesaverde of a neighboring area, and the general stratigraphic and areal relations of the rocks in which they are found, make their reference to the Mesaverde most reasonable. The unconformable relations that doubtless exist between those rocks and the overlying Wasatch will explain the absence of the later Cretaceous rocks from the area.

In the Book Cliffs field the unconformity between the Mesaverde and the overlying Eocene is marked not only by the absence of the Lewis shale and the Laramie, but also by the westward thinning of the Mesaverde formation (p. 17), by the basal Eocene conglomerate, and by the distinct general difference in stratigraphy between the underlying buff sandstones and shales, which are brackish-water and fresh-water deposits, and the overlying variegated formation which accumulated under more diverse conditions, probably in part sub-aerial and in part lacustrine.

TERTIARY SYSTEM—EOCENE SERIES.

Strata of Eocene age cap the Book Cliffs and for several thousand square miles constitute the surface of the Uinta Basin to the north. In the east end of the basin the Hayden Survey^a mapped the Wasatch, Green River, Bridger, and Uinta formations of the Eocene, and in the west end G. H. Eldridge^b also recognized the same formations. The present reconnaissance survey was not extended north of the crest of the Book Cliffs, and the large area designated Eocene on the map is taken from the authorities above mentioned.

The lower Eocene beds in the area here considered are composed of local conglomerate, varicolored shale, buff sandstone, and subordinate thin lenses of limestone. The stratigraphy is characteristically varied and many adjacent sections are very unlike; in one place the varicolored shale predominates and in another it is inconspicuous. The conglomerate also is variable in occurrence. In some sections none was seen, while elsewhere there is considerable. One of the best exposures observed is north of Thompsons, where from 10 to 20 feet

^a Hayden's Atlas of Colorado.

^b Eldridge, G. H., Asphalt and bituminous rock deposits of the United States: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, 1901.

of gray conglomerate rests upon an undulating surface of massive buff sandstone. The conglomerate is interbedded with lenses of fine red sandstone and is composed of rounded pebbles of quartz, quartzite, and chert, colored red, pink, black, and white, in a sandy matrix. Above the conglomerate north of Thompsons there are several beds of buff sandstone and drab shale and three thin intercalated layers of conglomerate, above which there are several hundred feet of red, purple, green and drab shales, including a few thin beds of drab siliceous limestone.

The following sections indicate general conditions, their upper limits marking no particular horizons.

<i>Section of Eocene in Horse Canyon.</i>		<i>Section of Eocene 5 miles north of Turner's ranch.</i>	
	Feet.		Feet.
Shale, yellowish.....	4	Sandstone, buff and white.....	20
Limestone, fine buff to white (rich in fossils, p. 21).....	1	Shale, red.....	7
Shale, drab.....	20	Shale, purple.....	2
Sandstone, calcareous.....	1	Sandstone, buff.....	2
Shale, varicolored.....	10	Shale, purple.....	3
Sandstone, buff.....	5	Shale, drab.....	12
Shale, green, purple, red.....	15	Shale, red.....	7
Shale, drab.....	20	Shale, drab.....	37
Shale, varicolored.....	10	Sandstone, buff.....	15
Shale, drab.....	25	Concealed by talus.....	115
Sandstone, buff.....	4	Sandstone, buff.....	25
Shale, drab.....	10	Shale, drab.....	15
Shale, varicolored.....	40	Sandstone, gray.....	7
Shale, drab.....	20	Shale, purple.....	7
Shale, varicolored.....	40	Shale, drab.....	35
Shale, drab.....	20	Sandstone, buff.....	15
Sandstone, white.....	10	Shale, reddish.....	18
Shale, drab.....	10	Sandstone, buff.....	2
Sandstone, greenish.....	1	Shale, drab.....	25
Shale, olive-drab, sandy.....	45	Sandstone, buff.....	5
Shale, buff to drab, sandy.....	25	Shale, drab.....	25
Conglomerate and sandstone.....	4	Shale, purple.....	5
Sandstone, massive, buff (Mesa-verde?).	—	Sandstone, buff.....	5
	340	Shale, drab.....	20
		Shale, red and purple.....	75
		Sandstone, massive, white (Mesa-verde?).	—
			504

At least 750 feet of the variegated beds are exposed in this area, but the top of the formation was not determined. Peale^a gives the following measurements of the Eocene at White Mountain on Grand River north of De Beque: Green River, 2,282 feet; Wasatch, 1,650 feet; total Eocene, 3,932 feet.

^a Peale, A. C., Geological report on the Grand River district: Tenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1878, p. 190.

Fossils are not abundant in the lower part of the Eocene series in the area under consideration, and collections were made in only two localities, each from thin beds or lenses of limestone. The following determinations were made by W. H. Dall:

Fossils collected near divide of Hay Creek, north of Turner's ranch, about 200 feet above top of Mesaverde.

Goniobasis tenera Hall var. carteri Conrad.

Cast of Polygyra (aff. leidy Hall).

Impression of Unio sp.

Fossils from Horse Canyon, Utah, 200 and 350 feet above top of Mesaverde.

Physa, probably bridgerensis Meek.

Vivipara panguitchensis White.

Vivipara, probably wyomingensis Meek.

Goniobasis sp.

Dall reports that these are fresh-water shells which do not indicate with much precision their horizon within the Eocene, though they are probably Wasatch. Probably part of the area colored as Eocene on the map includes other Eocene formations in addition to the Wasatch, but the region has not been studied in detail and their differentiation was not attempted.

The presence or absence of the Fort Union formation, which normally occurs beneath the Wasatch, has not been determined in the Book Cliffs field. In the Grand Hogback, northwest of Newcastle; Colo., T. W. Stanton and H. S. Gale collected fossil plants which F. H. Knowlton refers to the Fort Union, but Gale did not find it practicable to map the rocks containing these fossil leaves distinct from the Wasatch. In the Book Cliffs field no Fort Union fossils have been found and the age of the thin, variable zone of conglomerate and buff sandstone at the base of the Eocene remains to be determined.

STRUCTURE.

The strata of the Book Cliffs coal field, forming as they do part of the southern margin of the Uinta synclinal basin, dip gently northward. The dip is not uniform, however, for this area, besides being included in the zone of folding of the Uinta Mountains and the Uinta Basin, is affected by the uplifts which produced the San Rafael Swell and the Uncompahgre Plateau. That part of the Book Cliffs coal field which is included in the present report is gently warped, the eastern part constituting the end of a low, northward-plunging anticline, and the western part the end of a northward-plunging syncline. Conforming with this structure, the irregular S-shaped outline of the cliffs coincides with the strike of the rocks. There are, also, local faults of small displacement.

The rocks in the foothills at the northern end of the Uncompahgre Plateau, near Grand Junction and Mack, dip northeastward at angles varying from 5° to 45° . Near the mouth of Gunnison River the Dakota sandstone dips 5° ; west of Fruita the dip is 40° N. 40° E., and east of Mack it is 30° N. 55° E. Several miles west of Mack the direction of the Dakota outcrop turns and trends southwestward and the sandstone dips northwestward at angles ranging from 2° to 15° .

Between the Uncompahgre Plateau and the San Rafael Swell the rocks are irregularly disturbed, but little is known of the structure. South of the railroad between Cisco and Thompsons the Dakota outcrop trends almost east-west and dips northward. Seven or eight miles southwest of Thompsons the trend turns abruptly southward, forming the nose of a northwestward-pitching anticline. The axis of this fold is eroded and the vari-colored shales of the Jurassic are exposed between ridges of Dakota sandstone which on the north dips 10° N. 25° E. South of the town of Green River the dip of the Dakota indicates the presence of another low northward-pitching anticline, the dips varying from 5° to 15° .

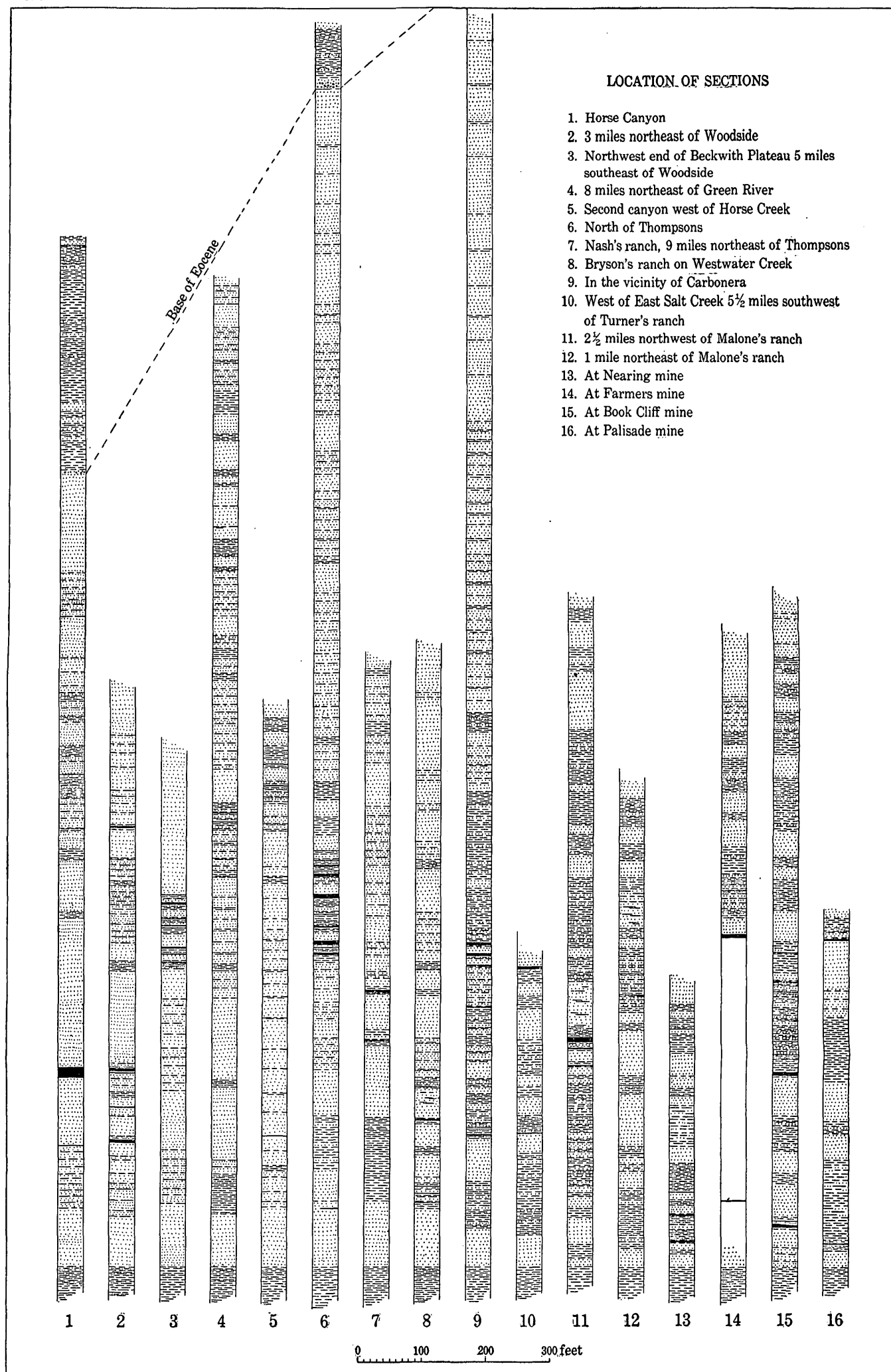
West of Green River the San Rafael uplift causes the highland to be fringed by prominent hogbacks formed by steeply dipping strata. The Dakota outcrop constitutes the outermost belt of foothills, in which the sandstone west of the town of Green River dips almost due east and in the vicinity of Price River northeast, the angles averaging about 10° .

The Mancos shale underlying the valley between the Dakota hills and the Book Cliffs doubtless conforms to the general structure of this region, but there are few opportunities for measuring the dips. Locally, however, especially where interbedded limestone and sandstone outcrop, the dip is shown to be low, and throughout the valley it probably ranges between 1° and 5° .

On the other hand, the structure of the rocks that form the cliffs is well exposed. Between Palisades and Carbonera the general dip is northeastward, the usual angle being about 4° . But in the vicinity of the Book Cliff mine, north of Grand Junction, the dip is locally steep, amounting to 25° or 30° N. 50° E. This dip continues down the northeastern side of the Little Book Cliffs, forming a dip slope; the steep inclination soon changes, however, to the prevailing low dip.

Two miles north of Carbonera a local fold is exposed which causes a southwestward dip of 15° , but the extent of this disturbance was not determined. It is south of the zone of doming found by H. S. Gale^a in the White River valley in 1907. From Carbonera to the vicinity of Thompsons the dip in the face of the cliffs is about 5° NW., but, as is general throughout the field, it becomes less toward the

^a Gale, H. S.. Coal fields of northwestern Colorado and Utah: Bull. U. S. Geol. Survey No. 341. 1909.



DETAILED COLUMNAR SECTIONS OF COAL-BEARING ROCKS IN BOOK CLIFFS FIELD.

plateau. Northwest of Thompsons, to the end of the area examined, the influence of the San Rafael Swell is felt and the dips are north-eastward from 2° to 10° .

The rocks in the Book Cliffs are conspicuously jointed, two sets at right angles being well developed, one of which usually is parallel to the face of the cliffs. The escarpment is gradually being worn back by blocks of sandstone breaking along these cracks and falling down to the base of the cliffs.

Large faults have not been observed in the Book Cliffs coal field, but several small dislocations were found in the face of the escarpment, a few of which will be mentioned. Between Sunnyside and Woodside the coal in the face of the cliffs is so distinctly offset that a fault can be seen at a distance of several miles, and there are several other faults in this vicinity. About 10 miles north of Woodside the plane of one fault strikes N. 65° W. and the displacement amounts to 120 feet. Another fault in the cliffs 3 miles northeast of Woodside strikes N. 75° W. Here the displacement is only about 20 feet, but the fault is clearly exposed, for it involves a bed of coal and the strata are bent along the plane of dislocation. There is also a small development of breccia. Another fault is clearly exposed in the canyon $2\frac{1}{2}$ miles below Carbonera. (See Pl. II, B.) There the fault strikes N. 75° E. and the throw amounts to about 50 feet.

COAL.

GENERAL STATEMENT.

Coal of commercial importance occurs in the lower part of the Mesaverde formation at various horizons from 35 to 700 feet above its base. In some localities several beds are present, while in others only one or two have been found, but no single bed has been traced continuously for more than a few miles. (See Pl. VI.) So little prospecting has been done that an unqualified statement can not be made, but so far as known one or more workable beds are present throughout the field here considered. The thickness of the coal ranges from a maximum of 21 feet down to mere films of carbonaceous matter. The beds outcrop in the face of the Book Cliffs commonly 100 feet or more above their bases, and at distances from the Denver and Rio Grande Railroad which vary from close proximity to a maximum of about 15 miles. The dip is at a low angle northward and the coal underlies an immense area north of the cliffs. The coal is of good quality and compares favorably with that from the Rocky Mountain fields. It is but little prospected, however, and there are only four small mines with railroad connections between Grand River and Sunnyside.

OCCURRENCE AND THICKNESS.

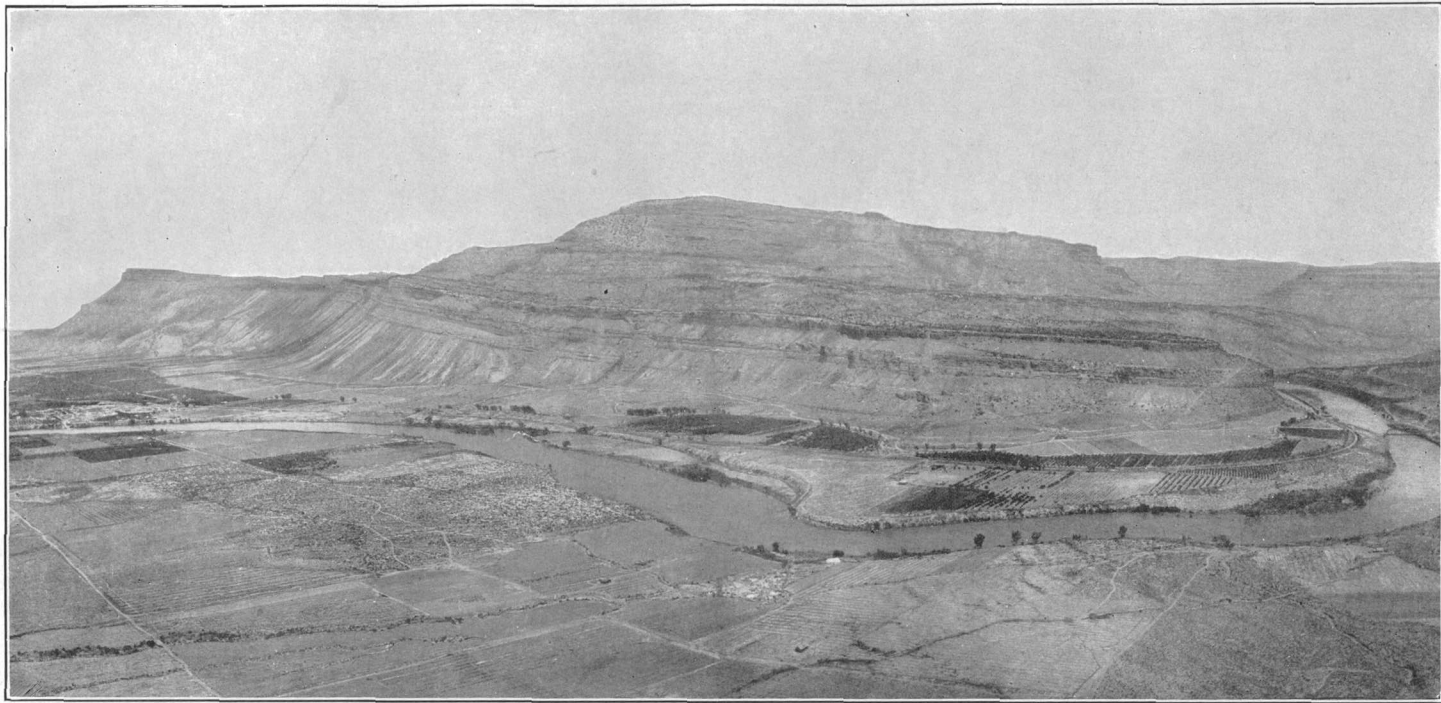
The following description begins at the east and proceeds westward. In connection with it the map (Pl. I), the stratigraphic section (Pl. III), and the detailed coal measurements shown on Plate VIII will be of service.

At the east end of the Book Cliffs two workable beds of coal are known. The lower one occurs between 35 and 60 feet above the top of the Mancos shale, and, though variable, is commonly about 4 feet thick. The upper coal is thicker, in places measuring 9 feet, and occurs from 200 to 500 feet above the lower bed. These coal beds have been prospected at several localities between the Cameo mine (No 1 on the map, Pl. I) and the Farmers mine (No. 13), and, though they have not been actually traced throughout that distance and are known to vary in thickness, the beds appear to be continuous. Besides these two main coals there are usually other thin beds, but none of commercial importance has yet been found.

The following detailed measurements made in the face of the cliffs a quarter of a mile west of the Book Cliff mine show the succession of the strata at that place and indicate the general stratigraphy of the coal measures, although no two sections are exactly alike:

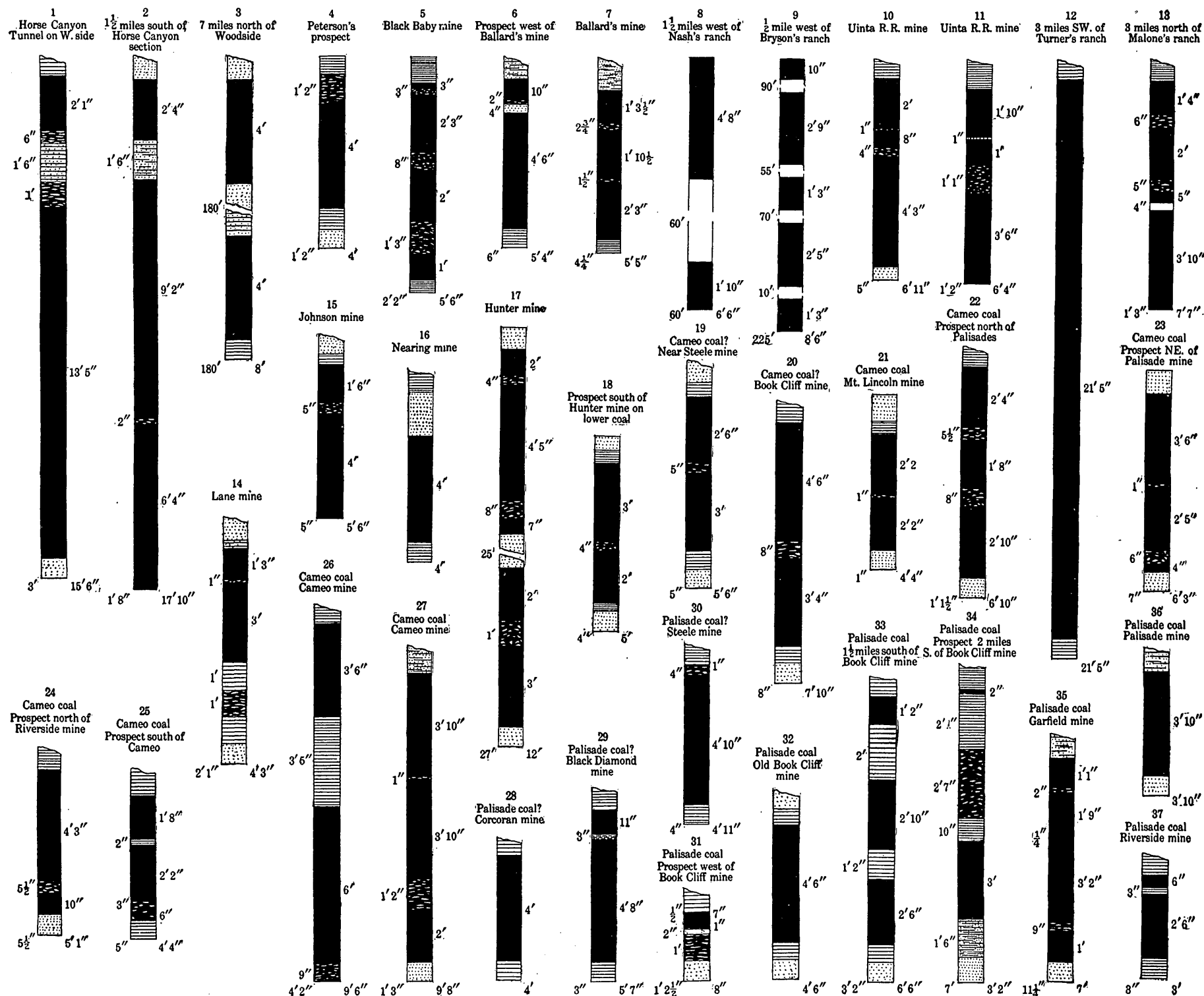
Section of coal-bearing rocks one-fourth mile west of Book Cliff mine.

	Ft.	in.
Sandstone, massive buff.....	35	
Sandstone, buff.....	15	
Shale, drab and sandy.....	15	
Coal and bone.....	1	3
Shale, drab.....	17	
Shale, carbonaceous.....	12	
Sandstone, buff.....	12	
Shale, drab.....	1	4
Bone and coal.....	1	6
Shale, drab.....	1	4
Bone and coal.....	1	9
Clay.....	2	
Bone and coal.....	1	9
Shale, drab.....	2	
Sandstone, buff.....	7	
Shale, sandy.....	1	4
Shale, carbonaceous.....	6	
Shale, drab.....	9	
Coal.....	1	6
Shale, drab.....	1	8
Sandstone, buff.....	2	
Shale, carbonaceous and bone.....	6	
Sandstone, buff.....	3	
Shale, carbonaceous.....	2	6
Sandstone, massive buff.....	6	6
Shale, carbonaceous.....	17	



LITTLE BOOK CLIFFS AND GRAND RIVER NORTHEAST OF PALISADES.

The Cameo coal outcrops on the lowest wooded bench and the Palisades coal appears 450 feet lower, immediately below the lowest heavy sandstone.



COAL SECTIONS IN BOOK CLIFFS COAL FIELD, COLORADO AND UTAH.

Section of coal-bearing rocks one-fourth mile west of Book Cliff mine—Continued.

	Ft.	in.
Sandstone, brown.....	1	4
Shale, sandy.....	1	6
Coal.....		5
Shale, drab.....	3	6
Sandstone, gray.....	3	6
Shale, carbonaceous.....	11	
Sandstone, buff.....	2	
Shale, carbonaceous.....	4	6
Sandstone, buff.....	1	
Shale, drab.....	1	
Shale, carbonaceous.....	1	4
Sandstone, drab.....	2	
Coal.....		1
Shale, drab.....	6	
Sandstone, drab.....	4	6
Shale, carbonaceous.....	4	
Coal "upper bed".....	8	5
Shale, carbonaceous.....	1	6
Shale, drab, sandy.....	14	
Coal.....	2	6
Shale, carbonaceous.....	1	5
Coal.....	1	10
Bone.....		2
Coal.....		8
Sandstone, carbonaceous.....		4
Sandstone, massive, white.....	60	
Shale, drab.....	10	
Sandstone, buff.....	3	
Shale, drab.....	26	
Sandstone, brown.....	3	
Shale, drab.....	5	
Sandstone, massive, brown.....	37	
Shale, sandy.....	16	
Sandstone, buff.....	50	
Shale, drab.....	5	
Coal.....		6
Shale, carbonaceous.....		10
Coal "lower bed".....	1	4
Shale, carbonaceous, sandy.....	1	
Sandstone, massive white.....	25	
Shale and sandstone, thin-bedded.....	30	
Shale, Mancos.....		

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The lower bed, known as the Palisades coal, outcrops at water level near the mouth of the Hogback Canyon of Grand River, about $1\frac{1}{2}$ miles above Palisades (Pl. VII). Thence the coal bed rises rapidly above the valley and can be traced westward along the base of the Book Cliffs for several miles. At the Palisade mine (No. 6) the coal is about 150 feet above the valley, at the Garfield mine (No. 7) 800 feet, and at the old Book Cliff mine (No. 9) about 1,200 feet.

Throughout this distance the coal can be easily followed. At many places it is exposed by erosion, appearing as a black streak in the cliffs, and it is usually underlain by a massive white sandstone which is conspicuous as the first heavy sandstone bed above the Mancos shale. This sandstone is not persistent, however, but locally thickens and thins and gives way to shaly beds. The Palisades coal varies in thickness from a few inches to 6 feet. At the Riverside mine (No. 4), a mile northeast of Palisades, near the mouth of the entry, the following section is exposed:

Section of coal bed at Riverside mine.

	Ft.	in.
Shale.....		
Coal.....	6	
Shale.....	3	
Coal.....	2	6
	<hr/>	
	3	3

At the face of the workings the shale parting is $1\frac{1}{2}$ inches thick and the lower bench of coal is 2 feet 10 inches thick.

At the Palisade mine (No. 6) there is from 3 feet 7 inches to 3 feet 10 inches of clean coal.

Two miles west, at the Garfield mine, the Palisades coal attains the greatest thickness yet measured. The following section is there exposed:

Section of coal bed at Garfield mine.

	Ft.	in.
Sandstone, shaly.....		
Coal.....	1	1
Bone.....		2
Coal.....	1	9
Bone.....		$\frac{1}{4}$
Coal.....	3	2
Bone.....		9
Coal.....	1	
	<hr/>	
Total coal bed.....	7	$11\frac{1}{4}$

About 2 miles south of the old Book Cliff mine (No. 9), in an abandoned prospect, the following section is exposed:

Section 2 miles south of old Book Cliff mine.

	Ft.	in.
Shale.....		
Coal.....		2
Shale, carbonaceous.....	2	1
Coal and bone.....	2	7
Shale.....		10
Coal.....	3	
Shale, sandy.....	1	6
Sandstone.....		
	<hr/>	
Total coal bed.....	5	9

In the vicinity of the old Book Cliff mine the lower coal is of variable thickness; in places it measures almost 5 feet, while near by it thins out to almost nothing, as shown by the following sections:

Section of coal bed at the old Book Cliff mine.

	Ft.	in.
Sandstone.		
Shale.....		7
Coal.....	4	6
Shale.....		8
Sandstone.		
	5	9

Section of coal bed 1 mile southeast of old Book Cliff mine.

	Ft.	in.
Shale.		
Coal.....	4	6
Shale.....		8
Coal.....	3	4
Shale.....		8
Sandstone.		
Total coal bed.....	8	6

Section of coal bed 1 mile southeast of the above section.

	Ft.	in.
Shale.		
Coal.....	1	
Shale.....		6
Coal.....	2	10
Shale.....	2	6
Coal.....	1	8
Shale.....		8
Sandstone.		
	9	2

It is reported that in working the lower coal in the old Book Cliff mine several areas were encountered in which the coal is absent. Northwest of the old mine evidences of thinning are shown by the following section:

Section of lower coal bed near Book Cliff mine.

	Ft.	in.
Shale, carbonaceous, interlaminated with thin coaly layers up to one-half inch.....	6	
Coal.....		2
Shale, carbonaceous and bony.....	4	
Bone.....		2
Coal and bone.....		9
Shale, carbonaceous.....		7
Coal.....	1	5
Shale, carbonaceous.....		7
Sandstone.		
	13	8

About a quarter of a mile west of this place the following section is exposed at the same horizon:

Section of lower coal bed near Book Cliff mine.

	Ft.	in.
Shale.....	6	
Coal.....	7	
Bone.....		$\frac{1}{2}$
Coal.....	1	
Sandstone.....	2	
Shale, carbonaceous.....	1	
Sandstone.....		
Total coal	8 $\frac{1}{2}$	

West of the Book Cliff mine less prospecting has been done than in the region to the east, but little variation in the thickness of the coal bed has been reported. At the Steele or Keystone mine (No. 11) there is 5 feet 3 inches of coal, including 4 inches of bone 1 foot from the top. The roof and floor are of shale, and the coal lies 3 feet above a bed of massive white sandstone.

At the Black Diamond mine (No. 12) the following section was measured:

Section of coal bed at Black Diamond mine.

	Ft.	in.
Shale.....		
Coal.....	10	
Clay.....	2	
Coal.....	4	8
Shale.....		
Total coal.....	5	6

Locally the coal bed is only 3 feet thick. At the Farmers mine the lower bed appears to be only 30 inches thick, but the upper coal is of greater value.

Except in two important mines, the Book Cliff (No. 10) and the Cameo (No. 1), the upper coal is not worked on a commercial scale in this locality, partly because the lower coal in general is of better quality, but chiefly because the lower coal is more accessible, occurring several hundred feet nearer the base of the cliffs.

The upper bed, known as the Cameo coal, outcrops at river level at Cameo, on the Denver and Rio Grande Railroad. To the southwest it rises, and north of Palisades is 650 feet above the valley, lying at the base of the second tier of cliffs. (See Pl. VII.) From Palisades the outcrop extends northwestward to the vicinity of the Book Cliff mine, at a distance of about a mile and a half from the crest of the lower escarpment. Thence westward the bench below the upper coal disappears and the two coal beds outcrop in the face of the cliffs, almost directly one above the other. The position of the upper coal is marked by a massive white sandstone almost immediately beneath it. This sandstone is locally 75 feet thick and can be traced for miles, but it is not constant and locally disappears.

Between the Cameo and the Bob Cat mines the thickness of the upper coal, as exposed in mines and prospects, varies from 4 feet 4 inches to 9 feet 8 inches, with one or two partings of shale or bony coal ranging from 5 inches to 3 feet 5 inches in thickness.

In the Cameo mine the roof is a good, firm, sandy shale, and the floor, where the full thickness of coal is worked, is reported to be sandstone, but usually the total thickness of the coal is not removed. The coal has the reputation of being dirty, a condition which is due to the partings it contains. The following measurements were made in the mine at the localities indicated:

Sections of coal bed in the Cameo mine.

IN THE MAIN ENTRY.

	Ft.	in.
Coal.....	3	10
Bone.....		1
Coal.....	3	10
Bone.....	1	2
Coal.....	2	
	<hr/>	
	10	11

IN ROOM 5 OFF MAIN ENTRY.

	Ft.	in.
Coal.....	2	4
Bone.....		1
Coal.....	6	2
	<hr/>	
	8	7

AT END OF MAIN ENTRY.

	Ft.	in.
Coal.....	2	2
Bone.....		1
Coal.....	6	
	<hr/>	
	8	3

AT THE NORTHWEST END OF THE WORKINGS.

	Ft.	in.
Coal.....	2	
Bone.....		1
Coal.....	5	11
	<hr/>	
	8	

At a small prospect about a mile south of Cameo, on the west side of the river, the following section was measured:

Section of coal bed 1 mile south of Cameo.

	Ft.	in.
Coal.....	1	8
Bone.....		2
Coal.....	2	2
Bone.....		3
Coal.....		6
	<hr/>	
	4	9

A stripping was made of the Cameo coal west of the Grand River bridge above Palisades which showed the following sections:

Section of Cameo coal bed west of Grand River bridge.

	Ft.	in.
Coal.....	2	4
Bone.....		5½
Coal.....	1	10
Bone.....		8
Coal.....	2	8
	7	11½

At a prospect north of Palisades the following section is exposed:

Section of coal bed at prospect north of Palisades.

	Ft.	in.
Coal.....	3	6
Bone.....		1
Coal.....	2	5
	6	

At the Book Cliff mine (No. 10) about 7 feet of coal is worked, and at the end of the main entry the following section was measured:

Section of coal bed at end of main entry in Book Cliff mine.

	Ft.	in.
Coal.....	3	
Bone.....		¼
Coal.....	4	6
	7	6¼

At the face of the northwest entry 7 feet of coal is exposed, and 14 or 15 inches of bony coal is reported above and below this. In one of the main rooms the section is as follows:

Section of coal bed in room of Book Cliff mine.

	Ft.	in.
Coal.....	7	1
Bone.....		10
Coal.....		6
	8	5

About a quarter of a mile east of the Steele mine a stripping showed the following section:

Section of coal bed one-fourth mile east of Steele mine.

	Ft.	in.
Coal.....	2	6
Bone.....		5
Coal.....	3	2
Shale.....		8
Sandstone.....		
Total coal bed.....	6	1

At the Bob Cat mine (No. 14) and in that vicinity between 44 and 55 inches of clean coal is exposed at the upper (?) coal horizon, which occurs about 400 feet above the lower bed worked at the Farmers mine. West of the Bob Cat mine the upper coal has not

been prospected and little is known of it for several miles. The coal outcrops high up in the face of the cliffs and the lower bed is more accessible.

There are two small openings on the lower coal west of the Farmers mine, which are known as the Excelsior and Corcoran mines. The Excelsior mine (No. 15) is located high up a hillside, near the head of a small gulch, where the coal is opened along the outcrop at several places. Here 4 feet 7 inches of coal is exposed at the entrance to the workings. Four feet above there is a 4-inch bed, and a foot and a half below there is 2 inches of coal, while 40 feet below the main coal there is an unprospected bed of coal and carbonaceous shale 6 feet thick. A mile west of the Excelsior mine there is a small abandoned prospect known as the Corcoran mine (No. 16). The workings have caved, but there is at least 4 feet of coal exposed near the entrance.

For 5 miles northwest of the Corcoran property little or no prospecting has been done, but at the next wide valley there are prospects on two beds of coal. An opening on the lower bed shows the following section:

Section of coal bed 5 miles northwest of Corcoran mine.

Sandstone.	Ft. in.
Shale.....	6
Coal.....	3
Bone.....	4
Coal.....	2
Shale.....	4
Sandstone.	
Total coal bed.....	5 4

Farther up the same valley an upper coal is well exposed and has been worked at the Hunter mine (No. 17), where the following section was obtained:

Section of coal beds at Hunter mine.

Sandstone.	Ft. in.
Coal.....	2
Bone.....	4
Coal.....	4 5
Bone.....	8
Coal.....	7
Sandstone.....	25
Coal.....	2
Bone.....	1
Coal.....	3
Sandstone.	
	39

The Gross or Kiel mine is situated 5 miles northwest of the Hunter property, near the mouth of Kiel Canyon. Between these mines no prospecting has been done and no information was obtained regarding the coal beds. At the Kiel mine (No. 18) from 3 feet to 3 feet 9 inches of coal is exposed at the approximate horizon of the lower bed.

The next opening is about a mile and half west of the Kiel, at the Nugent mine (No. 19). Here there are two openings on the lower (?) coal, on opposite sides of a gulch. The coal varies in thickness from 4 feet 3 inches to 4 feet 8 inches.

At the Nearing mine (No. 20), three-quarters of a mile west of the Nugent, the same bed is also worked. At the mouth of the mine the coal measures 4 feet to 4 feet 2 inches and contains a variable streak of bone up to 12 inches thick. At the end of the workings the bone disappears and the coal measures 4 feet 7 inches. The coal bed is here 45 feet above the top of the Mancos shale, and in this general vicinity the upper coal appears to be represented by only thin carbonaceous layers. Only one workable coal bed has been found in this locality. The following section was measured near this mine:

Section of coal-bearing rocks near Nearing mine.

	Ft.	in
Sandstone, buff.....	40	
Shale, drab.....	10	
Sandstone, red.....	10	
Shale, carbonaceous.....	1	6
Shale, buff.....	14	
Coal.....		8
Sandstone, buff.....	7	
Shale, buff.....	30	
Shale, carbonaceous.....	1	
Sandstone, white and buff.....	33	
Shale, carbonaceous.....		6
Sandstone, white.....	18	
Shale, carbonaceous.....	10	
Coal, bony.....		8
Sandstone, white.....	15	
Shale, sandy.....	60	
Sandstone, white.....	25	
Shale, buff.....	30	
Shale, carbonaceous.....	2	6
Shale, buff.....	10	
Coal.....		6
Sandstone, white.....	10	
Shale, buff.....	7	
Sandstone, buff.....	15	
Shale, carbonaceous.....		8
Coal.....	2	
Shale, carbonaceous.....	2	6
Shale, buff.....	10	
Sandstone, buff.....	7	
Shale, drab.....	15	
Sandstone, buff.....	1	8
Coal.....	4	
Shale, carbonaceous and drab.....	11	
Sandstone, buff.....	10	
Shale, drab.....	4	
Sandstone, buff.....	20	
Shale, Mancos,		

Openings have been made on a coal bed at the Lane and Johnson mines, on opposite sides of a creek about 2 miles northwest of the Nearing property. At this place the following measurements were made:

Section of coal bed at the Johnson mine (No. 22).

	Ft.	in.
Sandstone.		
Shale, carbonaceous.....		5
Coal.....	1	6
Bone.....		3
Coal.....	4	
Total coal bed.....	5	9

Section of coal bed at the Lane mine (No. 23).

	Ft.	in.
Sandstone.		
Shale, sandy.....		4
Coal.....	1	3
Bone.....		4
Coal.....	3	
Shale, carbonaceous.....	1	
Coal, bony.....	1	
Total coal bed.....	6	7

A mile and a half up the creek there are several coal beds which have not been prospected, but which have the following section:

Section of coal beds 1½ miles east of Lane mine.

	Ft.	in.
Shale.		
Coal.....	1	4
Bone and coal.....		8
Coal.....	1	3
Shale, carbonaceous.....	2	
Coal.....	3	10
Shale, carbonaceous.....	18	
Coal.....		8
Shale, carbonaceous.....	7	
Coal.....	4	1
Shale.		
	38	10

The following section was measured at about the same horizon north of Malone's ranch:

Section of coal beds 3 miles north of Malone's ranch.

	Ft.	in.
Shale, carbonaceous.		
Coal.....	1	4
Bone.....		6
Coal.....	2	
Bone.....		5
Coal.....		5
Bone.....		4
Coal.....	3	10
Shale, sandy.....	7	
Coal.....	3	1
	18	11

The higher coal here is in two benches, as at the Hunter mine, but it has not been prospected. Little is known of the coal between the Lane and Johnson mines and Carbonera, near the Colorado-Utah boundary. Though undeveloped, coal has been found wherever sections have been made; for instance, at the west side of the entrance to the canyon of East Salt Creek, 6 miles southwest of Turner's ranch, there are two beds of coal, one 2 feet and the other 5½ feet thick, separated by an interval of about 252 feet.

Section at entrance of East Salt Creek canyon, 6 miles southwest of Turner's ranch.

	Ft.	in.
Sandstone, red.....	20+	
Coal.....	5	6
Shale, carbonaceous.....	21	
Sandstone, white, locally red.....	20	
Shale, drab.....	19	
Sandstone, buff.....	49	
Shale, drab, and thin beds of buff sandstone.....	54	
Sandstone, buff.....	19	
Shale, drab.....	15	
Sandstone, buff and white.....	30	
Shale, carbonaceous.....	25	
Coal.....	2	
Sandstone, buff and white.....	30	
Shale, drab, and thin beds of buff sandstone.....	125	
Sandstone, buff.....	50	
Shale, Mancos.	484	6

About 3 miles southwest of Turner's ranch and half a mile up from the mouth of a small eastern tributary of East Salt Creek a waterfall exposes a bed of coal 21 feet 5 inches thick, which is the thickest bed observed in the entire area under consideration. No development and but little prospecting have been done here, and the lateral extent of this coal bed has not been determined. It appears, however, to be a lens, for in following the coal to the west along the hillside above the gulch it was found to thin out and disappear.

Considerable prospecting has been done in the valley of West Salt Creek, and at Carbonera a mine is being worked by the Uinta Railway Company. In this vicinity the local undulating structure (see p. 22) causes the coal to lie within a relatively moderate depth below the surface. The following section was measured here:

Section of coal-bearing rocks near Carbonera.

	Ft.	in.
Sandstone, fossiliferous, buff (containing <i>Unio vivipara</i> , <i>Gonio-basis</i> , and <i>Tulotoma thompsoni</i>).....	15	
Shale, drab, and thin beds of buff sandstone.....	65	
Sandstone, buff.....	4	
Shale, carbonaceous.....	3	
Sandstone, buff.....	5	

Section of coal-bearing rocks near Carbonera—Continued.

	Ft.	in.
Shale, drab.....	5	
Coal.....	3	4
Shale, carbonaceous.....	2	
Sandstone, buff.....	10	
Coal.....	3	10
Shale, carbonaceous.....	3	
Sandstone, buff.....	8	
Coal and bone.....	2	
Sandstone, thin bedded, buff, and shale.....	35	
Sandstone, buff.....	5	
Sandstone, buff, thin bedded, and shale.....	20	
Coal.....	2	
Shale, carbonaceous.....	2	
Shale, drab, sandy.....	10	
Sandstone, buff.....	5	
Shale, carbonaceous.....	15	
Sandstone, buff.....	2	
Shale, drab.....	3	
Sandstone, buff.....	7	
Shale, carbonaceous.....	18	
Sandstone, buff.....	7	
Shale, drab.....	3	
Sandstone, buff.....	10	
Shale, carbonaceous.....	2	
Sandstone, buff.....	25	
Shale, carbonaceous.....	3	
Sandstone, shaly.....	5	
Shale, carbonaceous.....	5	
Sandstone, buff.....	10	
Shale, drab.....	15	
Sandstone, shaly.....	10	
Coal.....		6
Shale, carbonaceous.....	2	
Sandstone, shaly.....	20	
Shale, carbonaceous.....	3	
Coal.....		10
Shale, carbonaceous.....	1	
Coal.....		10
Shale, carbonaceous.....	1	
Sandstone, buff, shaly.....	2	
Shale, carbonaceous.....	4	
Coal.....	2	
Shale, carbonaceous.....	5	
Sandstone, buff.....	65	
Shale, drab, including several thin beds of buff sandstone.....	70	
Sandstone, massive, buff.....	60	
Shale, Mancos.....	585	4

Within a distance of less than 500 feet above the top of the Mancos shale there are five beds of coal, each 2 feet or more thick, and several other thinner carbonaceous layers. At the Carbonera mine the coal bed measures more than 7 feet, but it is parted by two layers of bone,

which greatly decreases the value. The following sections, measured in different parts of the mine, show the general condition of the coal bed:

Sections of coal bed in Carbonera mine.

	End of back entry.	Room No. 3.	Near entrance.
	<i>Ft. in.</i>	<i>Ft. in.</i>	<i>Ft. in.</i>
Coal.....	2 1	1 10	2
Bone.....	1	1	1
Coal.....	10½	1	8
Bone.....	5	1 1	4
Coal.....	4	3 6	4 3
	7 5½	7 6	7 4

In Utah within the area covered by this report there are no shipping mines and the coal has been prospected in only a few places. The coal lands have not been surveyed by the General Land Office, and the region is even more thinly populated than Colorado; between Carbonera, Colo., and Thompsons, Utah, a distance of more than 50 miles, there are only three ranches, which are situated near the mouths of canyons at the base of the Book Cliffs, where feeble streams flow throughout the year. In Utah, as in Colorado, the Mesaverde formation constitutes the cliff-making rocks, and coal has been found at the usual horizon wherever sections have been studied. Near Bryson's ranch, on Westwater Creek, the following measurements were made:

Section of coal-bearing rocks near Bryson's ranch, on Westwater Creek.

	Ft.	in.
Sandstone, thick bedded, buff.....	65	
Shale, carbonaceous.....	1	
Coal.....		1
Shale, drab.....	2	
Sandstone, thick bedded, buff.....	5	
Shale, carbonaceous.....	3	
Sandstone, thin bedded, buff.....	40	
Shale, carbonaceous.....	3	
Sandstone, thin bedded, buff.....	10	
Coal.....		10
Shale, carbonaceous.....	5	
Sandstone, thin bedded, buff.....	5	
Shale, carbonaceous.....	1	
Coal.....	1	10
Shale, carbonaceous.....	2	
Sandstone, thick bedded, buff.....	5	
Sandstone, shaly, buff.....	35	
Sandstone, thin bedded, buff.....	4	
Sandstone, thick bedded, buff.....	4	
Shale, carbonaceous.....	3	
Coal.....	2	9
Shale, carbonaceous.....	4	
Sandstone, thin bedded, buff.....	20	

Section of coal-bearing rocks near Bryson's ranch, on Westwater Creek—Continued.

	Ft.	in.
Sandstone, thick bedded, buff.....	13	
Sandstone, thin bedded, buff.....	3	
Shale, carbonaceous.....	7	
Coal.....	1	3
Shale, carbonaceous.....	4	
Sandstone, thick bedded, buff.....	3	
Sandstone, thin bedded, buff.....	15	
Sandstone, thick bedded, buff.....	10	
Sandstone, thin bedded, buff.....	15	
Shale, carbonaceous.....	5	
Coal.....	2	10
Shale, carbonaceous.....	3	
Sandstone, thin bedded.....	4	
Coal.....	2	5
Shale, carbonaceous.....	3	
Sandstone, thin bedded, buff.....	3	
Shale, carbonaceous.....	4	
Coal.....	1	3
Shale, carbonaceous.....	5	
Sandstone, thin bedded, buff, and shale.....	90	
Shale, Mancos.....	417	3

Six beds of coal, ranging from 1 foot 3 inches to 2 feet 10 inches, were found in a zone 275 feet thick, the lowest coal occurring 95 feet above the top of the Mancos shale. From the Utah-Colorado boundary to some miles west of Thompsons a bench about 100 feet in height and half a mile to a mile in width, caused by a thick lens of sandstone in the shale, extends along the base of the cliffs, and the coal outcrop therefore lies farther back in the cliffs than usual.

Near Harms's ranch (No. 28), at the mouth of Cottonwood Canyon, there is a bed of coal 1 foot 6 inches thick. Mr. Harms reports beds varying in thickness from 2 inches to 3 feet, but says that the coal contains much bone and is of poor quality.

About a mile and a half above Nash's ranch (No. 29), in a canyon, two beds of coal were observed, separated by an interval of about 60 feet. The lower bed is 1 foot 10 inches thick and occurs 350 feet above the top of the Mancos shale; the higher bed measures 4 feet 8 inches, but little attempt has been made to develop it.

More work has been done on the coal north of Thompsons than anywhere else in Utah in the area covered by this report, although the prospecting even in this locality has not been thorough. Several beds of coal are present. The following section shows five beds more than 2½ feet thick within 125 feet of strata:

Section of coal-bearing rocks north of Thompsons.

	Ft.	in.
Sandstone, massive, buff.....	25	
Coal.....		1
Shale, carbonaceous.....	6	
Sandstone, thin bedded.....	6	

Section of coal-bearing rocks north of Thompsons—Continued.

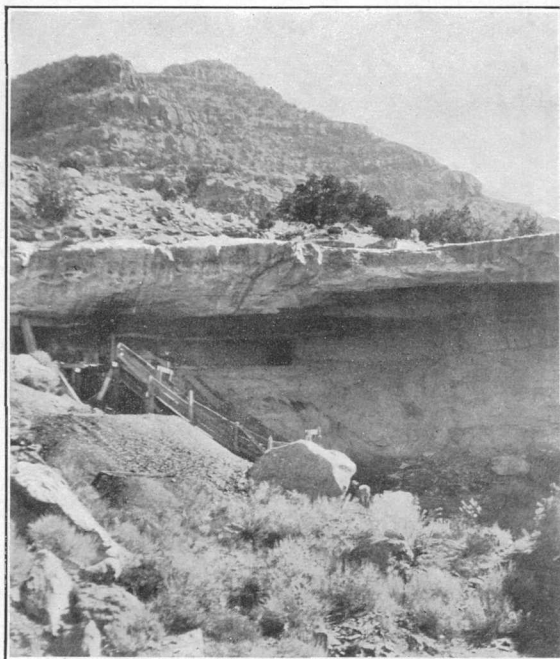
	Ft.	in.
Shale, carbonaceous.....	2	
Coal.....	1	6
Shale, carbonaceous.....	5	
Coal.....	2	6
Shale, carbonaceous.....	5	
Coal.....		5
Shale, carbonaceous.....	3	
Coal.....	4	
Shale, carbonaceous.....	2	
Sandstone, buff, shaly.....	10	
Sandstone, thick bedded, buff.....	15	
Coal.....	5	6
Shale, carbonaceous.....	15	
Sandstone, thin bedded.....	5	
Shale, carbonaceous.....	4	
Coal.....		2
Shale, carbonaceous.....	18	
Coal.....	2	6
Shale, carbonaceous.....	5	
Sandstone, thin bedded, buff.....	15	
Coal.....	6	
Shale, carbonaceous.....	3	
Coal.....	1	6
Shale, carbonaceous.....	9	
Coal.....	3	6
Shale, carbonaceous.....	10	
Sandstone, thin bedded, buff.....	40	
Sandstone, thick bedded, interbedded with shale.....	20	
Sandstone, thin bedded, buff.....	25	
Sandstone, thick bedded, buff.....	30	
Sandstone, thin bedded, buff.....	50	
Sandstone, massive, buff.....	70	
Shale, drab, interbedded with subordinate, thin, buff sandstone layers.....	95	
Sandstone, massive, fine textured, with local lenses of coal up to 1 foot 3 inches thick.....	150	
Shale, Mancos.....	670	8

The principal work here has been done at the Ballard mine (No. 29), at which the following section was measured (see Pl. IX):

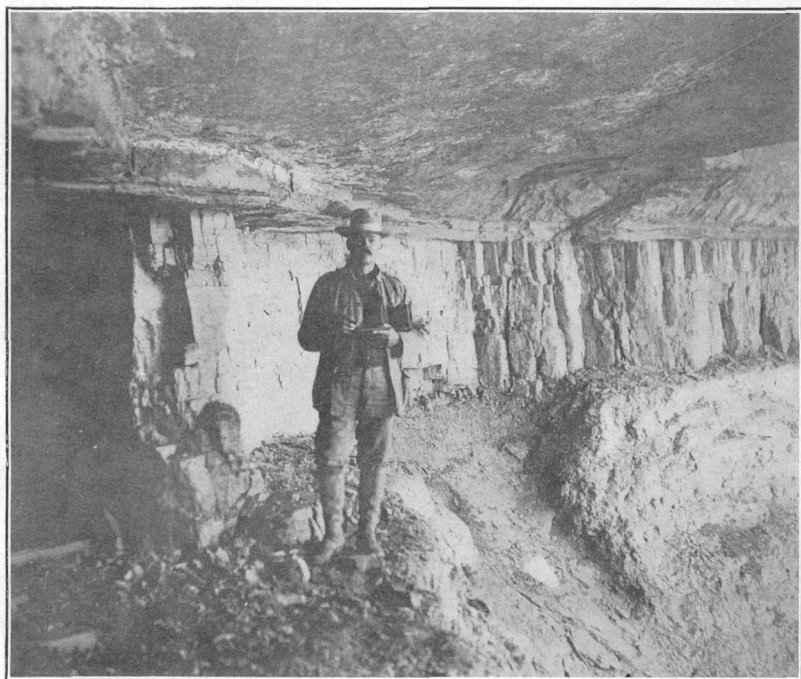
Section of coal bed at Ballard mine, near Thompsons, Utah.

	Ft.	in.
Sandstone, shaly.....		
Coal.....	1	3
Bone.....		2
Coal.....	1	10½
Bone.....		1½
Coal.....	2	3.
Shale, carbonaceous.....	5	8

At the end of the workings there is 5 feet 10½ inches of coal with no partings.



A. BALLARD'S COAL MINE, NORTH OF THOMPSONS.



B. OUTCROP OF COAL AT ENTRANCE TO BALLARD'S MINE, SHOWING JOINTING OF COAL.

At a prospect on the west side of the gulch, opposite the Ballard mine, on a coal bed below the one there worked, the following section was obtained:

Section of coal bed near Ballard mine.

Sandstone, shaly.	Ft.	in.
Coal.....	10	
Bone.....	4	
Sandstone.....	2	
Coal.....	4	6
	<hr/>	
	5	10

The thickness of the bone and shale partings is variable even in near-by sections.

A bed of coal a few inches to a foot and a half thick occurs in the first massive sandstone above the top of the Mancos shale, and shows up prominently from the valley as a black layer, but it is not thick enough to be of much importance.

Between Thompsons and Green River there is only one mine, the Black Baby, and almost no prospecting has been done. The few sections that were made did not reveal the presence of any beds more than 2 feet thick, but in the absence of prospecting little can be said of the coal in this part of the field.

At the Black Baby mine (No. 32), about 10 miles northeast of the town of Greenriver, the following section was measured:

Section of coal bed at Black Baby mine.

Shale, carbonaceous.	Ft.	in.
Coal.....	3	
Bone and shale.....	3	
Coal.....	2	3
Bone.....	8	
Coal.....	2	
Bone and shale.....	1	3
Coal.....	1	
	<hr/>	
	7	8

The lowest coal passes beneath the level of Green River about 4 miles above the mouth of Price River, but no prospects were found in that vicinity.

West of Green River and south of Price River the coal occurs in an isolated area near the summit of the Beckwith Plateau, and north of Price River coal outcrops in the face of the cliffs high above the valley.

The following section was measured half a mile below the entrance to Price River canyon, at the northwest end of Beckwith Plateau. There are four beds of coal more than 2 feet thick, and three others

more than 1 foot thick, the lowest occurring about 340 feet above the top of the Mancos shale.

Section at northwest end of Beckwith Plateau.

	Ft.	in.
Sandstone, massive, fine grained.....	240	
Coal.....	2	
Shale, carbonaceous.....	7	
Sandstone, buff.....	5	
Coal.....	4	
Shale, carbonaceous.....	6	
Sandstone, thin bedded.....	10	
Coal.....		4
Shale, carbonaceous.....	1	
Coal.....	1	6
Shale, carbonaceous.....	2	
Sandstone, carbonaceous.....	2	
Sandstone, thin bedded, buff.....	6	
Shale, buff.....		6
Coal.....	1	8
Sandstone, carbonaceous.....	1	
Coal.....	2	
Shale, carbonaceous.....	8	
Sandstone, thick bedded.....	20	
Coal.....	3	
Shale, carbonaceous, drab.....	4	
Sandstone, carbonaceous.....	3	
Shale, carbonaceous.....	1	
Coal.....	1	
Sandstone, thin bedded, and shale.....	10	
Shale, carbonaceous.....	3	
Coal.....	1	2
Shale, carbonaceous.....	1	
Shale, buff, containing fossil plants.....	2	
Sandstone, buff, containing <i>Anomia micronema</i> , <i>Modiola laticostata</i> , and <i>Corbula perundata</i>	3	
Shale, buff.....	3	
Sandstone, buff, thick bedded.....	45	
Sandstone, thin bedded, and shale.....	140	
Sandstone, thick bedded, buff.....	90	
Sandstone, thin bedded, and shale.....	80	
Sandstone, thick bedded, buff.....	65	
Sandstone, thin bedded, buff.....	30	
Shale.....		
	805	2

At Peterson's prospect (No. 33), high up on the hillside, near the entrance to Price Canyon, the following section was measured:

Section at Peterson's prospect, near Price Canyon.

	Ft.	in.
Shale, carbonaceous.....	8	
Bone.....	1	2
Coal.....	4	
Shale, carbonaceous.....	10	
Sandstone.....		
	6	8

About 225 feet above this prospect, in a location that is difficult of approach, a bed 6 feet thick has been prospected.

Along the cliffs between Price Canyon and Horse Canyon coal outcrops can be seen from the valley, but because of their situation high in the cliffs they are unprospected. Two beds of coal 4 feet thick and lying about 200 feet apart were measured about 10 miles north of Woodside.

At the western end of the area under consideration, in the vicinity of Horse Canyon, 6 miles south of Sunnyside, the coal has been considerably prospected. A large bed has been opened, and probably before long a mine will be located in Horse Canyon, although as yet there is no railroad connection and the property is 7 miles from the nearest point on the Denver and Rio Grande Railroad. The coal is between 250 and 300 feet above the top of the Mancos shale and is immediately underlain by a bed of massive white sandstone. Only one main bed of coal has been found in the vicinity of Horse Canyon, although at Sunnyside there are two beds, but neither is so thick as the one in Horse Canyon.

In the entry on the west side of Horse Canyon (No. 36) the following section was measured:

Section of coal bed in Horse Canyon.

Shale, carbonaceous.	Ft. in.
Coal.....	2 1
Bone.....	6
Sandstone and shale.....	1 6
Bone.....	1
Coal.....	13 5
Sandstone.	<hr/> 18 6

Section of coal bed at prospect No. 36.

Sandstone, thin bedded.	Ft. in.
Coal.....	2 4
Sandstone and shale.....	1 6
Coal.....	9 2
Bone.....	2
Coal.....	6 4
	<hr/> 19 6

At a prospect (No. 35) a mile east of the last, the following section was obtained:

Section of coal bed at prospect No. 35.

Sandstone.	Ft. in.
Coal.....	2 4
Sandstone and shale.....	3
Coal.....	6
Bone.....	3
Coal.....	10
Sandstone.	<hr/> 21 7

AMOUNT OF AVAILABLE COAL.

Because coal outcrops in the region of which the Book Cliffs field forms a part have been traced for several hundred miles along the southern, eastern, and northern margins of the Uinta Basin shown in figure 1, it is probable that the entire area, consisting of about 14,000 square miles, is underlain by coal. It has been estimated, however, that in the center of the basin the Eocene rocks range from 4,000 to 6,500 feet in thickness, and as the coal is overlain by this great mass of barren strata and also by 1,000 feet or more of the Mesaverde formation, the total covering of the coal in a large part of the basin is deeper than the workable limit. This, at present, under the most favorable conditions, is about 4,000 feet. The greater part, therefore, can not be considered available, and development is restricted to the vicinity of the outcrop.

A close approximation to the total amount of coal available in the Book Cliffs field can not now be made because of the present limit of knowledge. A rough estimate, however, can be arrived at by assuming that the workable limit of the field is 6 miles back from the outcrop and that the total amount of coal may be represented by a single bed 7 feet thick extending throughout the field. On this assumption, there are in the area considered in the present report 1,010 square miles of coal land, 360 of which are in Colorado and 650 in Utah. Since a cubic foot of coal of 1.3 specific gravity weighs 81.25 pounds, and a square mile of such coal 1 foot thick contains 1,132,560 short tons, on the above assumption the total amount is more than 8,000 million tons. These figures have little value beyond forcibly expressing the fact that there is here an immense coal reserve.

CHARACTER AND USE OF BOOK CLIFFS COAL.

PHYSICAL PROPERTIES.

Though differing somewhat from place to place, the coals of the Book Cliffs field possess a rather uniform appearance. They are full black, with a slightly brownish streak, and are for the most part of a dull tone which commonly is varied by the presence of narrow lustrous bands. The coal is traversed by many joints, two sets at right angles being prominently developed (Pl. IX, B). Accordingly, the coal breaks easily after it is mined, but in some of the workings the coal is dense and hard to pick. The lumps, as mined, usually range in size from 30 inches down, and there is a large amount of slack. Patches of a yellow resinous substance occur locally in the coal, and also infrequent small segregations of pyrite. A common feature is the presence in the cracks that traverse the coal of thin films of a whitish saline

substance derived from the leaching of the adjacent rocks. A test by George Steiger of some of this material from the coal in Horse Canyon, Utah, showed it to be a hydrous silicate of aluminum containing a small amount of calcium carbonate.

The moisture content of the coal is shown in the table of analyses on pages 44-46. The moisture in the "sample as received," which represents the condition of the coal in the mine, ranges from 4.71 to 18.63 per cent. By air drying in the laboratory these samples lost between 0.10 and 5.30 per cent of their moisture. On exposure to the weather the coal becomes dull and breaks up along the joints into small prisms which finally crumble to powder. The rapidity with which disintegration occurs is not well known, for little coal is allowed to remain about the mines. A considerable amount, however, was found at the prospects in Horse Canyon; although this was reported to have lain in a heap exposed to the weather for more than a year, it showed little apparent deterioration.

CHEMICAL COMPOSITION.

The following analyses show the composition of a number of samples of coal from the eastern part of the Book Cliffs field. Samples were taken from the most important mines and prospects under uniform conditions, and represent the freshest available material. The samples were collected by cutting a channel across the face of the coal from roof to floor, partings more than a quarter of an inch in thickness being rejected. The material was gathered on canvas, crushed, mixed, and quartered down to about 3 pounds, and sent to the laboratory in sealed cans. The analyses were made at the fuel-testing plant of the United States Geological Survey at St. Louis, under uniform conditions prescribed by N. W. Lord.^a

The analysis of each sample is tabulated in two forms, showing the composition of the air-dried sample and the sample as received at the laboratory. The air-dried analysis shows the percentage of the several constituents of the coal after it has been powdered and allowed to lose the moisture that evaporates on exposure to the atmosphere of the laboratory until a constant weight results, the percentage of air-drying loss being shown in the table. The analysis of the sample as received shows the percentage of the several constituents of the coal, including the total amount of water contained in the sample as received at the laboratory, and represents the condition of the coal in the mine. For general purposes the figures for the air-dried sample are best for comparison with other analyses. Proximate analyses of

^a Prof. Paper U. S. Geol. Survey No. 48, 1906, p. 174 et seq.

35 samples and ultimate analyses of 13 of the most nearly representative ones are given in the following tables:

Proximate analyses of coal samples from the Book Cliffs coal field.

[F. M. Stanton, chemist in charge.]

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Laboratory No.....	3550.	3547.	3542.	3540.	3546.	3541.	3549.	3539.	3545.
Sample as received:									
Moisture.....	8.42	8.17	7.55	4.71	7.57	7.52	8.77	9.02	13.96
Volatile matter.....	33.32	33.69	31.07	34.68	33.56	36.03	36.55	34.51	31.30
Fixed carbon.....	47.53	53.42	48.27	52.66	52.91	50.46	48.72	50.89	48.73
Ash.....	10.73	4.72	13.11	7.95	5.96	5.99	5.96	5.58	6.01
Sulphur.....	.60	.57	.57	.56	.72	.85	.83	.67	.63
Loss of moisture on air drying	4.30	2.80	2.60	.10	2.20	2.00	2.50	3.10	4.40
Air-dried sample:									
Moisture.....	4.30	5.52	5.08	4.61	5.49	5.63	6.43	6.11	10.00
Volatile matter.....	34.82	34.66	31.90	34.72	34.32	36.77	37.49	35.61	32.74
Fixed carbon.....	49.67	54.96	49.56	52.71	54.10	51.49	49.97	52.52	50.98
Ash.....	11.21	4.86	13.46	7.96	6.09	6.11	6.11	5.76	6.28
Sulphur.....	.63	.59	.59	.56	.74	.87	.85	.69	.66

	10.	11.	12.	13.	14.	15.	16.	17.	18.
Laboratory No.....	3490.	3496.	3494.	3581.	3495.	3493.	3489.	3488.	3640.
Sample as received:									
Moisture.....	11.42	10.75	10.89	11.03	9.54	15.39	6.86	6.52	5.40
Volatile matter.....	34.25	34.83	34.12	35.90	34.49	32.57	34.20	35.75	33.30
Fixed carbon.....	44.49	47.58	44.77	46.35	46.33	45.69	43.90	48.37	55.57
Ash.....	9.84	6.84	10.22	6.72	9.64	6.35	15.04	9.36	5.73
Sulphur.....	.84	.55	1.09	.68	.78	.62	.62	.67	.49
Loss of moisture on air drying	5.60	3.50	5.20	5.80	3.10	7.20	1.80	.60	.20
Air-dried sample:									
Moisture.....	6.17	7.51	6.00	5.55	6.65	8.83	5.15	5.96	5.21
Volatile matter.....	36.28	36.09	35.99	38.11	35.59	35.10	34.83	35.96	33.36
Fixed carbon.....	47.13	49.31	47.23	49.21	47.81	49.23	44.70	48.66	55.69
Ash.....	10.42	7.09	10.78	7.13	9.95	6.84	15.32	9.42	5.74
Sulphur.....	.89	.57	1.15	.72	.80	.67	.63	.67	.49

	19.	20.	21.	22.	23.	24.	25.	26.	27.
Laboratory No.....	3587.	3585.	3586.	3584.	3730.	3728.	3729.	3732.	3734.
Sample as received:									
Moisture.....	9.44	9.73	8.27	5.55	18.63	9.32	10.96	10.77	11.23
Volatile matter.....	35.51	35.27	36.90	36.01	30.61	33.64	32.19	33.68	31.51
Fixed carbon.....	49.33	49.95	48.67	52.75	46.28	49.52	42.45	48.36	45.31
Ash.....	5.72	5.05	6.16	5.69	4.48	7.52	14.40	7.19	11.95
Sulphur.....	1.02	1.30	1.26	.93	.38	.51	.48	.56	.42
Loss of moisture on air drying	5.50	5.20	3.60	1.60	9.10	3.00	4.50	3.90	4.70
Air-dried sample:									
Moisture.....	4.17	4.78	4.84	4.01	10.48	6.52	6.76	7.15	6.85
Volatile matter.....	37.58	37.20	38.28	36.60	33.68	34.68	33.71	35.05	33.07
Fixed carbon.....	52.20	52.69	50.49	53.61	50.91	51.05	44.45	50.32	47.54
Ash.....	6.05	5.33	6.39	5.78	4.93	7.75	15.08	7.48	12.54
Sulphur.....	1.08	1.37	1.31	.95	.42	.53	.50	.58	.44

Proximate analyses of coal samples from the Book Cliffs coal field—Continued.

	28.	29.	30.	31.	32.	33.	34.	35.
Laboratory No.....	3854.	3856.	3857.	3945.	3957.	4014.	4013.	4015.
Sample as received:								
Moisture.....	12.74	6.35	9.57	5.58	4.75	9.79	9.01	5.20
Volatile matter.....	33.04	31.89	32.37	32.77	33.58	33.39	31.78	36.03
Fixed carbon.....	50.06	42.74	47.09	43.61	50.24	50.44	51.03	52.69
Ash.....	4.16	19.02	10.97	18.04	11.43	6.38	8.18	6.08
Sulphur.....	.46	.58	.46	.72	1.15	.60	.46	.83
Loss of moisture on air drying.....	4.50	2.30	2.50	1.90	2.30	3.50	4.10	2.90
Air-dried sample:								
Moisture.....	8.63	4.14	7.25	3.75	2.51	6.52	5.12	2.37
Volatile matter.....	34.60	32.64	33.20	33.41	34.37	34.60	33.14	37.11
Fixed carbon.....	52.42	43.75	48.30	44.45	51.42	52.27	53.21	54.27
Ash.....	4.35	19.47	11.25	18.39	11.70	6.61	8.53	6.25
Sulphur.....	.48	.60	.47	.74	1.18	.62	.47	.86

Ultimate analyses of coal samples from the Book Cliffs coal field.

[F. M. Stanton, chemist in charge.]

	1.	5.	6.	7.	10.	18.	19.
Laboratory No.....	3550.	3546.	3541.	3545.	3490.	3640.	3587.
Sample as received:							
Ash.....	10.73	5.96	5.99	6.01	9.84	5.73	5.72
Sulphur.....	.60	.72	.85	.63	.84	.49	1.02
Hydrogen.....	5.45	5.50	5.26	5.82	5.46	5.39	5.94
Carbon.....	65.52	69.47	68.43	62.19	61.84	70.18	68.17
Nitrogen.....	1.20	1.56	1.55	1.40	1.07	1.20	1.56
Oxygen.....	16.50	16.79	17.92	23.95	20.95	17.01	17.29
Calories.....	6,466	6,913	6,838	6,034	6,166	6,894	6,811
British thermal units.....	11,639	12,443	12,308	10,861	11,099	12,409	12,260
Carbon-hydrogen ratio.....	13.00	13.20	13.59	11.66	12.77	13.07	12.85
Loss of moisture on air drying.....	4.30	2.20	2.00	4.40	5.60	.20	5.50
Air-dried sample:							
Ash.....	11.21	6.09	6.11	6.28	10.42	5.74	6.05
Sulphur.....	.63	.74	.87	.66	.89	.49	1.08
Hydrogen.....	5.19	5.38	5.14	5.58	5.13	5.38	5.64
Carbon.....	68.46	71.03	69.83	65.05	65.51	70.32	72.46
Nitrogen.....	1.26	1.60	1.58	1.47	1.13	1.20	1.65
Oxygen.....	13.25	15.16	16.47	20.96	16.92	16.87	13.12
Calories.....	6,757	7,069	6,978	6,312	6,532	6,908	7,207
British thermal units.....	12,162	12,723	12,559	11,361	11,757	12,434	12,973

Ultimate analyses of coal samples from the Book Cliffs coal field—Continued.

	20.	21.	25.	29.	34.	35.
Laboratory No.	3585.	3586.	3729.	3856.	4013.	4015.
Sample as received:						
Ash.	5.05	6.16	14.40	19.02	8.18	6.08
Sulphur.	1.30	1.26	.48	.58	.46	.83
Hydrogen.	5.81	5.54	5.63	5.01	4.97	5.26
Carbon.	68.84	67.48	58.42	59.10	62.22	71.22
Nitrogen.	1.55	1.57	1.24	1.32	1.25	1.29
Oxygen.	17.45	17.99	19.83	14.97	22.92	15.32
Calories.	6,809	6,771	5,815	5,890	6,035	7,239
British thermal units.	12,256	12,188	10,467	10,602	10,863	13,030
Carbon-hydrogen ratio.	13.16	13.13	11.39	12.45	13.77	14.41
Loss of moisture on air drying.	5.20	3.60	4.50	2.30	4.10	2.90
Air-dried sample:						
Ash.	5.33	6.39	15.08	19.47	8.53	6.25
Sulphur.	1.37	1.31	.50	.60	.47	.85
Hydrogen.	5.52	5.33	5.37	4.86	4.71	5.09
Carbon.	72.62	70.00	61.17	60.49	64.88	73.35
Nitrogen.	1.63	1.63	1.30	1.35	1.30	1.34
Oxygen.	13.53	15.34	16.58	13.23	20.11	13.12
Calories.	7,182	7,024	6,089	6,029	6,293	7,455
British thermal units.	12,928	12,643	10,960	10,852	11,327	13,419

1-3. Sec. 34, T. 10 S., R. 98 W.	21. Sec. 30, T. 8 S., R. 101 W.
4. Upper coal, sec. 3, T. 11 S., R. 98 W.	22. Sec. 18, T. 8 S., R. 101 W.
5-8. Lower coal, sec. 3, T. 11 S., R. 98 W.	23. Sec. 16, T. 7 S., R. 102 W. Weathered sample.
9. Sec. 6, T. 11 S., R. 98 W.	24. Sec. 11, T. 7 S., R. 104 W.
10-12. Upper coal, sec. 8, T. 10 S., R. 99 W.	25-27. Sec. 14, T. 7 S., R. 104 W.
13. First coal below upper coal, sec. 8, T. 10 S., R. 99 W.	28. $1\frac{1}{2}$ miles northwest of Nash's ranch, Utah.
14. Sec. 7, T. 10 S., R. 99 W.	29. 5 miles north of Thompsons, Utah.
15. Sec. 1, T. 10 S., R. 100 W. Weathered sample.	30. 5 miles north of Thompsons, Utah.
16. Sec. 36, T. 9 S., R. 100 W.	31. 6 miles northeast of Solitude, Utah.
17. Sec. 35, T. 9 S., R. 100 W. Weathered sample.	32. 4 miles east of Woodside, Utah.
18. Sec. 5, T. 9 S., R. 100 W.	33-34. 8 miles south of Sunnyside, Utah.
19. Sec. 27, T. 8 S., R. 101 W.	35. West side of Horse Canyon, 6 miles south of Sunnyside, Utah.
20. Sec. 29, T. 8 S., R. 101 W.	

Inspection of the table of proximate analyses of air-dried coals shows the following range in percentages: Moisture, from 2.37 to 10.48; volatile matter, from 31.90 to 38.28; fixed carbon, from 43.75 to 55.69; ash, from 4.86 to 19.47. The table of ultimate analyses of air-dried coals shows the following range: Hydrogen, from 4.71 to 5.64; carbon, from 60.49 to 73.35; nitrogen, from 1.13 to 1.65; oxygen, from 13.12 to 20.96; sulphur, from 0.47 to 1.37. The calorific values, determined with a Mahler bomb calorimeter, range from 10,852 to 13,419 British thermal units.

Bearing in mind that the range shown by the analyses is partly due to different stages of weathering of the samples collected, although care was taken to obtain as fresh coal as possible, the analyses indicate that the coals from the different parts of the area examined are not strikingly different. The marked variations in quality of near-by coals, not uncommon in Rocky Mountain fields, especially in Colorado, are not found in the area here considered. Igneous rocks are not known to occur in the Book Cliffs, and the coals are not locally metamorphosed. There are many minor differences, however. In the eastern part of the field, for instance, a comparison of analyses of mine samples of coal from the upper and lower beds shows that the

upper bed contains more moisture and ash and less carbon than the lower coal, and that the lower coal has a greater efficiency as expressed by the calorific values. Judged by the analyses, the sample of coal showing the best results is the one from Horse Canyon, Utah, which, with 6.25 per cent of ash, gave an efficiency of 13,419 British thermal units, while the best results obtained in the eastern end of the field were from the lower coal near the mouth of the Hogback Canyon of Grand River, which, with 6.09 per cent of ash, showed an efficiency of 12,723 British thermal units.

An important difference is in the coking quality of these coals. The coal from Sunnyside, Utah, produces a coke of good grade, whereas thus far coals from the vicinity of Grand Junction yield such a low-grade product that they are classed as noncoking. Between these extreme locations, one at the eastern end of the area examined and the other beyond the western limit, no coking tests have been made; and it remains to be determined what coals, if any, in the eastern part of the Book Cliffs field will coke.

Comparison with analyses of other coals examined at the Government fuel-testing plant shows that the coals from the eastern part of the Book Cliffs field rank favorably with the product of other fields in the Rocky Mountain region and the Mississippi Valley. The Book Cliffs coals are classed as medium-grade bituminous.

MARKET AND USE.

The part of the Book Cliffs field under consideration is situated between areas where coal of similar quality and greater thickness is already being developed. The mines in the vicinity of Newcastle, to the east, and those about Castlegate, to the west, are more favorably situated for the large markets than is the eastern part of the Book Cliffs field. However, because of the proximity of the Denver and Rio Grande Railroad, it probably will not be long before this great reserve of coal will be more actively developed. Denver and Pueblo, Salt Lake City, and the Pacific coast are likely to be the most important outside markets, and there will be a growing local demand in connection with the increase of population and the development of Colorado and Utah mines. At present the local market is the only outlet.

There are only four mines with railroad connection in the field here discussed, and practically their entire product is used by the towns of Grand Junction, Palisades, and Fruita, and by the Uintah Railway. These mines are the Cameo (No. 1), Palisade (No. 6), Book Cliff (No. 10), and Carbonera (No. 25). At Grand Junction, besides a considerable amount of coal used for domestic purposes and for the gas and electric light plants, a sugar-beet factory and a smelter use coal from the Book Cliffs field. The other mines are worked

entirely for domestic purposes and the coal is transported by wagon. In 1906 the average cost of coal at the country mines was \$1.75 a ton; at Palisades the price was quoted at \$2.25 a ton, and at Grand Junction the retail price for lump coal not delivered was \$3 a ton. Slack sold for between 50 and 75 cents a ton.

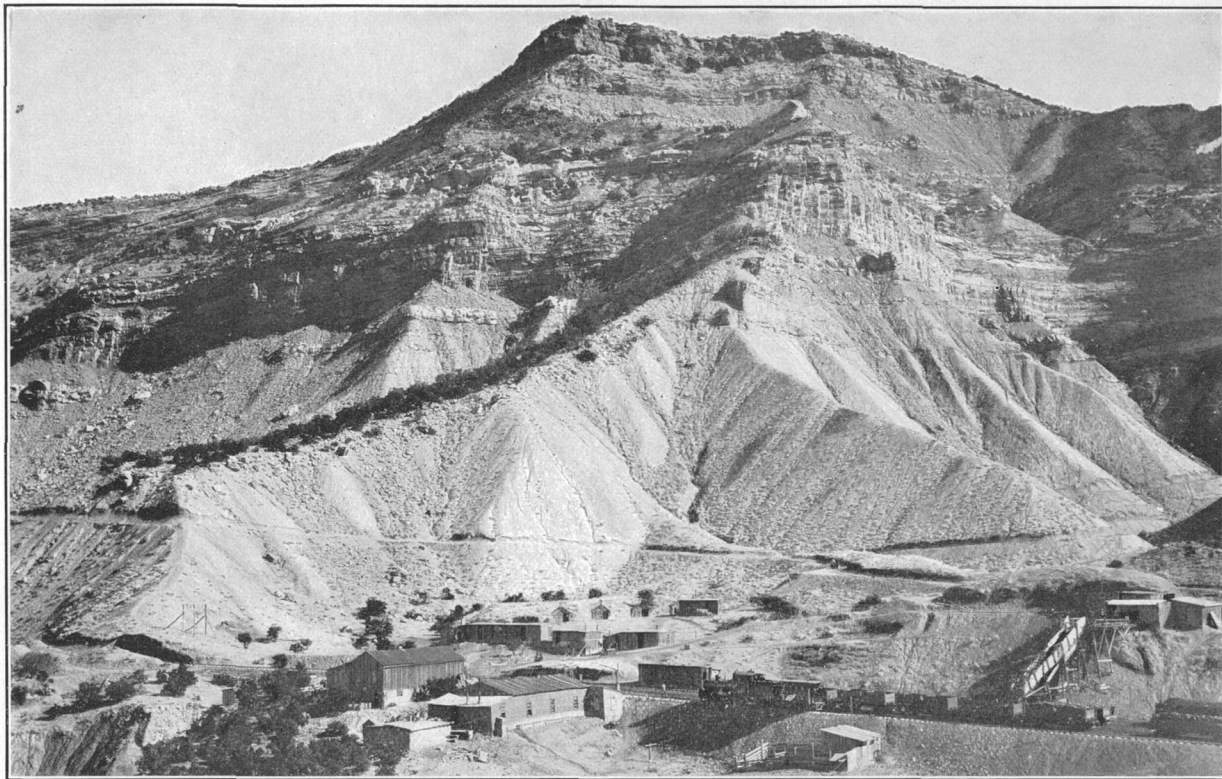
DEVELOPMENT.

Very little has been done in developing the eastern part of the Book Cliffs coal field. The four mines with railroad connections are reported to have produced in 1905 a total of only 5,300 tons, while the other mines are for the most part country banks that yield but a few hundred tons each a year.

The proximity of the field to a trunk railroad and the ease with which short branch lines can be constructed across the shale plain to the base of the cliffs render the transportation problem comparatively easy. The situation of the coal, however, several hundred feet above the base of the cliffs, except in the creek valleys, makes it difficult of access and usually necessitates the construction of a steep tramway or an aerial cable. Favorable conditions for reaching the coal by shafts are rare, except in the broader valleys, and the greater part of the coal probably will be worked from the outcrop.

An important consideration is the lack of water, which will prove a detriment to the commercial development of a large part of the field. Throughout the greater portion of the year there is either no surface water in the vicinity of the cliffs, away from Grand River, or water is present in very small quantity. Springs are scarce and the prospect of obtaining sufficient supplies of underground water is not favorable. The Cameo, Riverside, and Palisade mines, being near Grand River, do not experience this difficulty, and the Book Cliffs mine is located near one of the rare springs. Water is hauled from Atchee by the Uintah Railway for the men at the Carbonera mine. In the vicinity of several of the workings, as in Horse Creek, Utah, there is a small perennial stream, but for many miles along the cliffs there is insufficient water for mining purposes. Water from an irrigation canal is hauled by wagon to the mines north of Fruita, a distance of 8 or 10 miles.

The first development work on the coal in this area is said to have been in 1882 at the old Book Cliff mine, north of Grand Junction. The Cameo mine was opened about 1895, and the Palisade mine is reported to have been started also about that time. These are the chief mines of the area and they supply the needs of the settlements in Grand River valley. The Carbonera mine, the only other with railroad connections, was not opened until 1904, and is used entirely for the needs of the Uintah Railway, which is a short road from Mack, Colo., to the gilsonite deposits at Dragon, Utah. There are only



PROPERTY OF THE BOOK CLIFF MINE COMPANY AT THE BASE OF THE CLIFFS NORTH OF GRAND JUNCTION.

The "lower coal" occurs at the base of the lowermost massive sandstone and the "upper coal" 200 feet higher, immediately above the conspicuous bed of white sandstone. The view shows the transition from the Mancos shale to the overlying Mesaverde formation.

about thirty other small mines and prospects of any consequence within the area here reported; these are listed and their locations are shown on the map, Plate I.

The coal is opened at or near the outcrop and generally is worked by the room and pillar system. Where the dip is appreciable entries are run with the strike and the rooms are opened principally up the rise. The long-wall system is used at only one mine, the Riverside. Both roof and floor are generally a firm sandy shale. The workings usually are dry and little trouble is caused by water, but in a few instances, as at the Cameo mine, water level has been reached. Some of the workings are extremely dry and dusty and care must be taken to avoid explosion. Natural ventilation is chiefly depended on, though furnaces are used to some extent. Machines have not been introduced and in general the methods of mining are simple. The following brief descriptions will serve to indicate the present stage of development:

The Book Cliff mine, operated by the Book Cliff Coal Company, is situated in a small ravine in the Little Book Cliffs, about 12 miles north of Grand Junction. The mine is connected with the Denver and Rio Grande Railroad by a narrow-gage road, and the camp consists of a number of frame houses, a company store, workshop, etc. (See Pl. X.) Good water is supplied in moderate quantity from a near-by spring, which was an important factor in determining the location of the mine.

Considerable prospecting has been done in this vicinity. The lower bed was formerly worked; it has the advantage over the upper bed of being slightly better in quality and of outcropping about 190 feet lower down the cliffs. The old mine^a is situated in the ravine next south of the one in which the present workings are located, and was approached by a steeply inclined tramway. The coal was reached by a tunnel cut through the underlying sandstone. Development proved, however, that the lower coal bed in this vicinity varies greatly in thickness, ranging from a few inches to about 4 feet, and after a few years work on the lower bed was abandoned. A considerable quantity of coal was mined, however, the largest production of any one year being reported as 18,000 tons.

In the present mine, which was opened in 1903, the upper coal is worked. It is reached through a tunnel, the mouth of which is situated near the lower coal outcrop, about a quarter of a mile northeast of the terminus of the branch railroad and some 200 feet above it. The tunnel extends northeastward through a heavy bed of sandstone a distance of 750 feet, where the upper coal is encountered. From the end of the tunnel entries extend northwest and southeast

^a Lakes, Arthur, The Book Cliff coal mines: Mines and Minerals, vol. 24, 1904, p. 289.

about 800 feet in each direction, and several rooms have been opened up the rise. The tunnel not only avoids climbing a precipitous ledge, but has a distinct advantage over an opening on the outcrop. A gravity incline can thus be operated and the workings can be pushed along the strike and up the rise, avoiding, in the early stage of development at least, a haul up the dip, which in this mine is very steep. In the workings the coal bed dips from 25° to 30° N. 55° E., and is traversed by prominent joint planes, the most conspicuous of which strikes between N. 65° E. and N. 75° E. The bed averages about 7 feet thick, with a parting of sandstone, varying from one-fourth inch to 3 inches in thickness, about 3 feet from the top. The output of the mine for 1905 was reported as 6,000 tons.

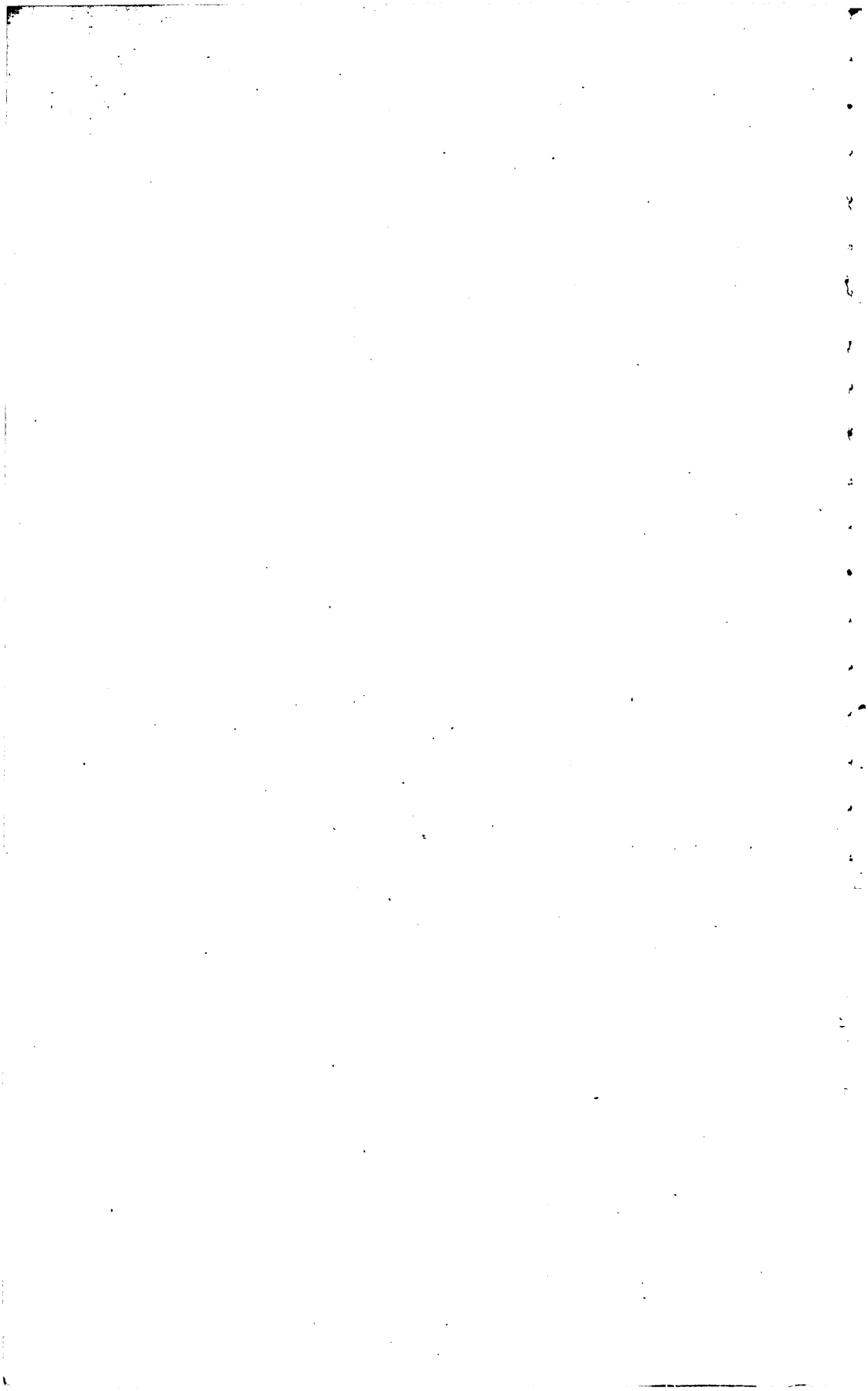
The Cameo mine, operated by the Grand Junction Mining and Fuel Company, is situated at the mouth of a small creek which enters Grand River about 4 miles above Palisades. The mine is connected with the Denver and Rio Grande Railroad by a short spur. A number of cabins, a store, a shop, etc., have been constructed and water is supplied by a steam pump from a well near the river.

The coal worked is the upper or Cameo bed. At the entrance to the mine the coal is covered by a few feet of alluvium, and the bed is reached by a slope. Nine feet or more of coal is exposed, but only 5 or 6 feet is worked. The roof is a firm sandy shale, but owing to a number of partings the coal is dirty and is reported to produce about 30 per cent of slack. The mine has been in operation eight or nine years and the workings are extensive. The entries run northwest-southeast and the rooms extend northeast and southwest, both up and down the slope. The inclination of the coal is reported to be only about 3° , so that mules can pull the cars anywhere, but the workings are at such a distance from the mouth that much time is lost in transit. Some water is encountered, but when it is reached in going down the dip the workings are abandoned. It is proposed to introduce pumps and a system of electric lighting and haulage. The annual product of the mine is reported to be 24,000 tons.

The Palisade mine is located in the face of the cliffs about 150 feet above the valley, a mile northeast of the town of Palisades. The property is controlled by the Palisade Coal and Supply Company, which began operations about 1895. A short spur connects the terminus of the gravity tramway that leads to the mine with the Denver and Rio Grande Railroad. The mine is located on the outcrop and the workings extend in about 1,600 feet. The lower coal, or Palisades bed, is worked, which averages in the mine about 3 feet 10 inches thick. No trouble is caused by water. The average output of the mine is reported to be 18,000 tons a year, about 35 per cent of which is slack.

The Carbonera mine has been in operation only two years (1906) and its output is used exclusively by the Uintah Railway Company. The mine is situated on the hillside above West Salt Creek, at the little mining settlement of Carbonera, where there are a few cabins, a shop, etc. Good mountain water is hauled from Atchee and stored in a cistern. The entrance is on the outcrop and the main entry is about 600 feet long. The roof and floor are a firm sandy shale. About 5 feet of coal is mined. Two streaks of bone, from 1 inch to 1 foot in thickness, are present, so that the coal is dirty. The daily production is reported to be about 14 tons throughout the year.

The other mines and prospects in the area under consideration are small. They are all situated on the outcrop, and the workings at the largest are only a few hundred feet in extent. They are operated only during the winter months to supply the needs of near-by settlers.



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