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GEOLOGY AND COAL RESOURCES OF CASTLE VALLEY

IN CARBON, EMERY, AND SEVIER COUNTIES, UTAH

BY

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GEOLOGY AND COAL RESOURCES OF CASTLE VALLEY IN CARBON, EMERY, AND SEVIER COUNTIES, UTAH.

By CHARLES T. LUPTON.

INTRODUCTION.

GENERAL STATEMENT.

Castle Valley includes parts of Carbon, Emery, and Sevier counties and is situated between the Wasatch Plateau and the San Rafael Swell, in the east-central part of Utah. (See Pl. XII and index map, fig. 1.) The outcrops of the coal-bearing rocks and adjacent formations of the Book Cliffs were mapped and studied by Richardson[1] from Grand River, Colo., westward and northwestward to the north end of Castle Valley. The writer traced from north to south the lowest formations studied by Richardson, beginning near Mounds (Sunnyside Junction), on the Denver & Rio Grande Railroad, and ending about 80 miles to the southwest in T. 26 S., R. 4 E., at the north end of Thousand Lake Mountain.

The rocks designated in this report the Ferron sandstone member of the Mancos shale contain the more important coal beds at the south end of Castle Valley east and south of Emery, but in the northern part of the area they contain no coal. Near Mounds these rocks consist of approximately 75 feet of soft yellowish sandstone characterized by a concretion-bearing stratum. Plate I, *A*, shows the character of the topography where these rocks crop out near Mounds. This sandstone increases in thickness toward the southwest, from about 75 feet at Mounds to about 800 feet at Last Chance Creek. (See columnar sections in Pl. IV, p. 32.) The character of the surface in this locality is shown in Plate I, *B*. In the southern part of the field 14 coal beds are exposed in these rocks. This coal has been described briefly by Taff,[2] who examined a few prospects and mines south of Emery in 1905 during his investigation of the higher (Mesaverde) coal-bearing rocks along the east scarp of the Wasatch Plateau.

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

[2] Taff, J. A., Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, p. 301, 1906.

OBJECT OF INVESTIGATION.

The primary object of this examination was to determine the quality and quantity of the coal in order that the land, part of which had been withdrawn from all forms of entry, might be classified, valued, and restored to entry. The method of determining the

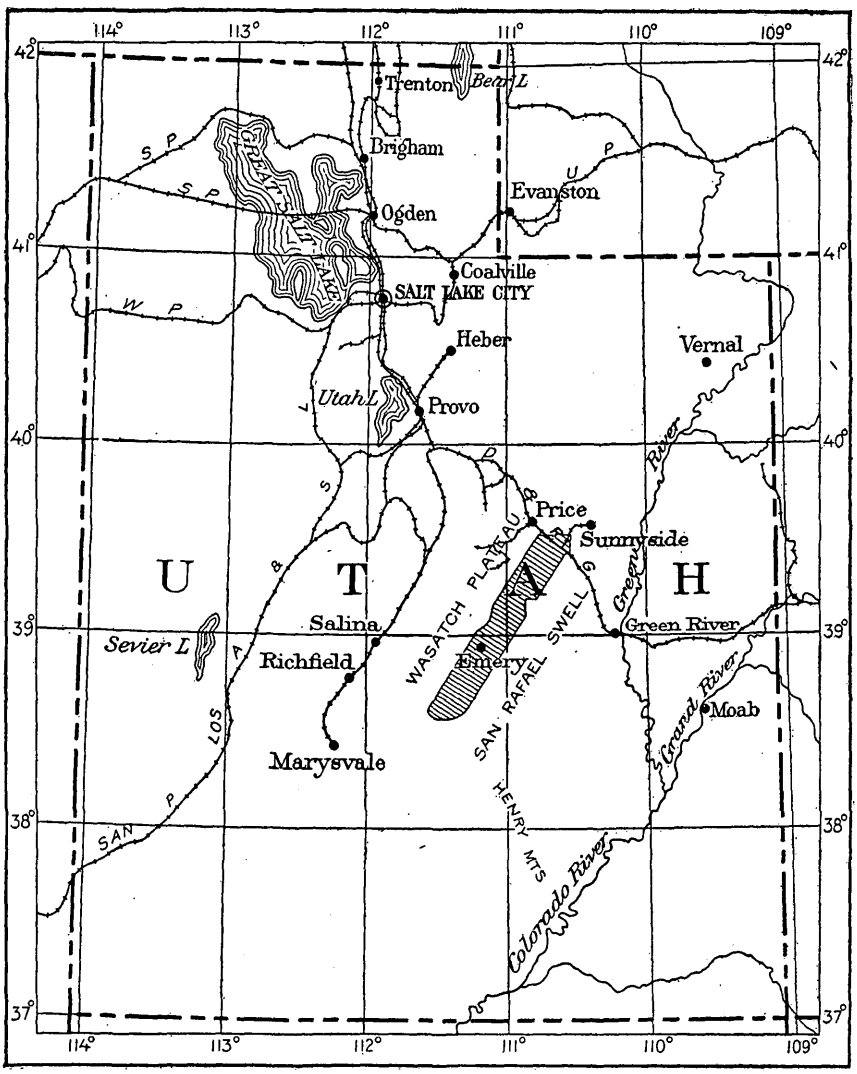
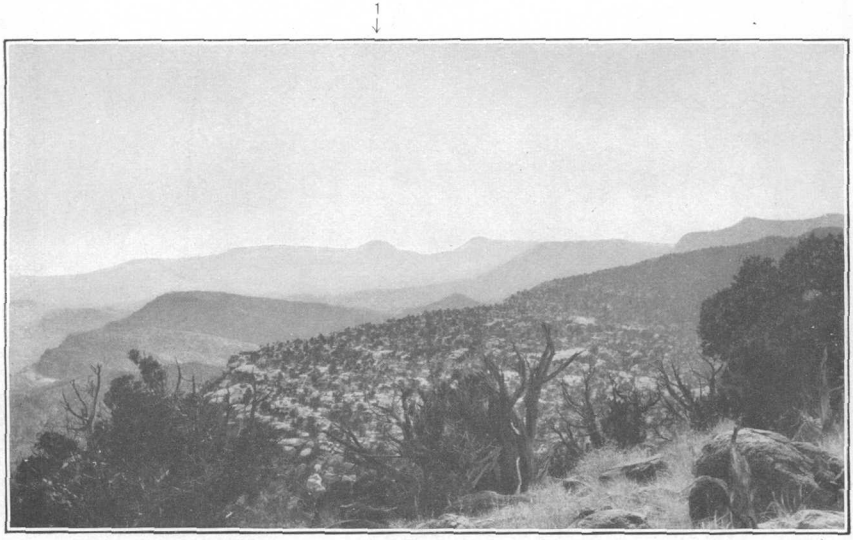


FIGURE 1.—Index map of Utah showing location of Castle Valley and the Emery coal field.

quality and quantity of the coal is discussed fully under "Method of field work" (pp. 10–11). A secondary purpose of the investigation was to collect geologic information regarding this region, of which little was definitely known. The age, character, and thickness of the coal-bearing formations, and their relations to the underlying and

A. COAL-BEARING ROCKS (FERRON SANDSTONE MEMBER OF THE MANCOS SHALE) NEAR MOUNDS, AT THE NORTHEAST END OF CASTLE VALLEY.

1, Book Cliffs, near Sunnyside.



B. COAL-BEARING ROCKS (IN FOREGROUND) NEAR LAST CHANCE CREEK, IN THE SOUTHWESTERN PART OF THE EMERY COAL FIELD.

1, *Thousand* Lake Mountain.

overlying rocks were studied. Fossils materially aid in determining geologic age, and a careful search along the outcrop was made for them. Data regarding the character and thickness of a formation are collected by carefully measuring and describing the various strata that compose it. The relations of contiguous formations are determined by an examination of the contact line separating them. The criteria that are usually relied upon as proof of a time interval between the periods of deposition of adjacent formations are (1) a discordance in the dip of the strata, (2) erosion channels, and (3) conglomerate. On the other hand, if the strata accord in dip and there are no signs of an erosional stage, fossils collected immediately above and below a contact line are often of importance in determining whether or not the beds are conformable.

HISTORY.

From 50 to 60 miles of the old Spanish Trail, which extended from Santa Fe, N. Mex., to Monterey, Cal., at the time these places were centers of Spanish civilization on this continent, lies in Castle Valley. The coal in this field may or may not have been known at the time this trail was used extensively.

Capt. J. W. Gunnison, of the Corps of Topographic Engineers,[1] traversed Castle Valley from north to south in the early part of October, 1853, on the way to Sevier Valley, where he and several of his party were killed by Indians a few days after passing through this field. Lieut. E. G. Beckwith, who wrote the report of this expedition, states, in his journal for October 11, 1853: "Specimens of coal were brought in from the hills near the camp, Capt. Gunnison and Dr. Schiel differing in opinion as to its quality." The party was camped at this date near the north end of the Emery coal field, about 3 miles east of Emery, approximately in sec. 12, T. 22 S., R. 6 E. So far as known this is the first published reference to the coal in this field.

During the summer of 1873 Lieut. R. L. Hoxie,[2] Corps of Engineers, and his party mapped the topography and geology of east-central and south-central Utah. Their route of travel led southward through Castle Valley and across this coal-bearing area. E. E. Howell,[3] who was with this party as geologist, referred to the coal in Castle Valley and along Muddy Creek. Robert Forrester[4] described briefly the coal on Quitchuppah and Ivie creeks and gave proximate analyses of both the "top vein" (bed I?) and the "bot-

[1] U. S. Pacific R. R. Expl., vol. 2, pp. 62–66, 1855.

[2] Wheeler, G. M., U. S. Geog. Surveys W. 100th Mer. Ann. Rept. for 1874, p. 5, 1874.

[3] Wheeler, G. M., U. S. Geog. Surveys W. 100th Mer. Final Rept., vol. 3, pp. 277, 279, 1875.

[4] U. S. Geol. Survey Mineral Resources, 1892, pp. 518–519, 1893.

tom vein" (bed C?). He considered these coals to be in a down-faulted portion of the Montana group, which is represented in part by the Mesaverde formation in the Wasatch Plateau, a few miles to the west. This classification has been the topic of considerable debate by those familiar with the coals of this part of Utah. J. A. Taff[1] in 1905 examined the coal-bearing rocks along the east face of the Wasatch Plateau and also noted the coal at the south end of Castle Valley described in the present report.

METHOD OF FIELD WORK.

This report is based on a detailed examination of the coal beds, of the geologic formations in which the coal occurs, and of some of the overlying and underlying formations. Field work was begun near Mounds, on the Denver & Rio Grande Railroad, July 17, 1911, and was terminated at Ivie Creek on October 7 of the same year. That part of the coal field lying south of Ivie Creek was examined from September 9 to November 3, 1912. Detailed work on the coal beds in the vicinity of and 30 miles south of Emery (see Pl. X, p. 74) was done from September 8 to October 7, 1911, and from September 9 to November 3, 1912.

A system of triangulation was developed over the area as an aid in mapping surface features other than coal, such as roads, trails, houses, streams, and rock ledges. North of Ivie Creek this primary control was established by means of a 24-inch Johnson plane table and a Gale telescopic alidade on a scale of 1 inch to 1 mile.

The outcrop of each coal bed was mapped with relation to land corners and the thickness of the coal beds was measured at as many places as seemed necessary in order to obtain accurate information regarding the variations in character and thickness. Many Government corner monuments near the coal outcrops were located, and enough others were found some distance from the coal outcrops to enable the accurate mapping of the Emery coal field. The coal beds from the vicinity of Emery at the north edge of the field southward to Willow Creek, except in a small area north of Ivie Creek and west of Quitchuppah Creek, were mapped by means of a 15-inch Bumstead plane table and a Gale alidade on a scale of 2 inches to 1 mile. (See Pl. X.) Mines, prospects, and points at which the coal beds were measured were located by stadia. The coal beds and geologic boundaries between Ivie and Quitchuppah creeks were located by triangulation at the time the primary control was obtained. That part of the coal field lying south and southwest of Willow Creek was mapped by the triangulation method on a scale of 2 inches to 1 mile. Samples of coal for analysis (see p. 80) were collected at seven places and represent the three principal coal beds

[1] Op. cit., pp. 289–302.

(A, C, and I) in the field. (See table of analysis, p. 80.) The geologic unit in which the coals occur was examined, and sections of these rocks were measured at different places. Fossils were collected wherever possible and are listed under "Geology" (pp. 19–43). Formations overlying and underlying the coal-bearing rocks were studied, and sections of them were measured in detail in order to obtain a general conception of the geologic column in this vicinity. A geologic section, from the lowest rocks observed by the writer in the interior of the San Rafael Swell, lying to the east, to the highest rocks on top of the Wasatch Plateau, a few miles to the west, is given by formations under "Stratigraphy" (pp. 19–39).

LAND SURVEY.

Castle Valley, the greater part of which has been subdivided into sections, was surveyed with relation to the Salt Lake base and meridian. Nearly all of this work was done by A. D. Ferron, after whom the town of Ferron, in Emery County, was named. The coal-bearing portion of the area included within Tps. 21, 22, 23, 24, 25, and 26 S., Rs. 4, 5, 6, and 7 E., is described in greater detail than the remainder of the field, which lies to the north and northeast of Emery. The southeastern part of T. 21 S., R. 6 E.; T. 21 S., R. 7 E., except the southeastern part; T. 22 S., R. 6 E., except about four sections in the northwestern part; and the northwestern part of T. 23 S., R. 6 E., were surveyed by Mr. Ferron in July and August, 1873. In May, 1881, T. 23 S., R. 5 E., except the northwestern part, was subdivided by the same surveyor. The eastern part of T. 22 S., R. 5 E., and the north half of T. 24 S., R. 5 E., were subdivided by Mr. Ferron in August and October, respectively, 1890. Mr. Ferron and A. Jessen subdivided the east half of T. 26 S., R. 4 E., in November, 1892, and in June, 1895, they surveyed the east-central part of T. 25 S., R. 4 E. In July, 1896, A. P. Hanson made a survey of the south-central and west-central parts of T. 25 S., R. 5 E. The survey of the northeastern part of T. 23 S., R. 6 E., was completed in November, 1909, by Mr. Ferron. All this work was done under the contract system. The two remaining tracts of the Emery coal field (see Pl. X, p. 74), the southeastern part of T. 21 S., R. 7 E., and all of T. 22 S., R. 7 E., were subdivided in May, 1910, by H. W. Miller and A. Nelson, who were in the direct employ of the General Land Office. Under the contract system the section and quarter-section corners are marked by stone monuments, a large number of which are still in place and easily read. The corners in the areas surveyed in 1910 by the General Land Office are marked by iron pipes with copper caps on which the positions of the monuments are recorded.

The recent surveys in Tps. 21 and 22 S., R. 7 E., and T. 23 S., R. 6 E., and the results of the triangulation and stadia work of the geologic party in 1911 and 1912 seem to indicate that the lines of the

older surveys are in places slightly longer than those given on the township plats.

The land net at the south end of the coal-bearing area in Tps. 24 and 25 S., Rs. 4 and 5 E., as shown on the accompanying maps (Pls. X and XII), differs from that which is given on the General Land Office plats of these townships. A sufficient number of Government corners were located by the triangulation method used by the writer to prove definitely that the line connecting the corners between T. 25 S., R. 4 E., and T. 25 S., R. 5 E., and that part of T. 25 S., R. 5 E., which was surveyed with relation to that line, are about 850 feet west of the positions indicated on the Land Office plats, thus narrowing the width of the east tier of sections of T. 25 S., R. 4 E., by that amount. In the construction of the accompanying maps (Pls. X and XII) the northeast corner of T. 25 S., R. 4 E., and the corresponding corner of T. 24 S., R. 4 E., were connected by a straight line whose bearing is greater than that (S. 4° W.) indicated on the Land Office plat of T. 24 S., R. 5 E. The change in the bearing of this line necessarily makes the east-west dimensions of the west tier of sections in T. 24 S., R. 5 E., greater than those given on the township plat. The discrepancy above described is attributed by A. D. Ferron, who ran the line between Rs. 4 and 5 E. through Tps. 24 and 25 S., to the short chaining of the fifth standard parallel south.

ACKNOWLEDGMENTS.

The field work in 1911 was done with the assistance of B. W. Clark and A. E. Fath. W. L. Mielke and Millard Massey served as camp hands and rendered efficient aid in rodding and in uncovering and measuring coal beds. In 1912 the writer was assisted in the field by R. V. A. Mills, Millard Massey, Arthur Massey, Merrill Allred, and Casper Christensen. In the office the careful work of R. V. A. Mills, Frank R. Clark, and E. R. Lloyd has made the report much more complete. The writer desires especially to acknowledge the favors granted by the officials of the Emery County recorder's office at Castledale, and also the courtesy and hospitality of the settlers throughout the field. Ira R. Browning also gave information of value.

GEOGRAPHY.

POSITION AND EXTENT.

The area mapped in Castle Valley extends S. 30° W. from Mounds and lies between meridians 110° 30′ and 111° 20′ W. and parallels 38° 35′ and 39° 30′ N. The entire field is about 80 miles long, ranges from 10 to 20 miles in width, and includes about 1,000 square miles. The index map (fig. 1) shows the relative position of this area in the State. The geology of the entire valley is represented on Plate XII.

That part of Castle Valley known as the Emery coal field is shown in detail on Plate X.

The Emery coal field is at the south end of Castle Valley, between meridians 111° 3′ and 111° 20′ W. and parallels 38° 35′ and 39° N. The greater part of this area lies along the west side of Emery County south of the middle, the remainder being included in the southeastern part of Sevier County. This coal field is about 25 miles long from north to south, and 22 miles wide from east to west, and includes about 300 square miles of land underlain by coal.

SETTLEMENTS.

The principal settlements in that part of Castle Valley described in this report are, in order from north to south, Wellington, Farnham, Mounds, Victor, Desert Lake, Cleveland, Huntington, Lawrence, Castledale, Orangeville, Clawson, Ferron, Molen, Rochester, and Emery. Wellington, on the Denver & Rio Grande Railroad, in secs. 6 and 7, T. 15 S., R. 11 E., has a population of about 375 people. Farnham is a flag station on the railroad in sec. 22, T. 15 S., R. 11 E. Mounds, in the SE. ¼ SE. ¼ sec. 5, T. 16 S., R. 12 E., is at the junction of the Sunnyside branch and the main line of the Denver & Rio Grande Railroad. It has a population of about 50 persons and consists of a few houses and a railroad station. Victor, in the S. ½ sec. 29, T. 16 S., R. 11 E., and Desert Lake, in the N. ½ sec. 11, T. 17 S., R. 10 E., are small settlements, each containing less than 100 inhabitants. Victor has a store and both have post offices. The town of Cleveland is in T. 17 S., on both sides of the line separating Rs. 9 and 10 E., in secs. 13 and 18, respectively. The 200 or more inhabitants support two or three stores and a good school. Huntington, the oldest settlement in the valley, has a population of about 800 persons, and is on Huntington Creek in T. 17 S., on both sides of the line separating Rs. 8 and 9 E., in secs. 24 and 25 and secs. 19 and 30, respectively. This town is the center of a prosperous farming community and is well supplied with schools, churches, hotels, and stores. Lawrence has about 80 inhabitants and a dozen or more houses on Huntington Creek, mainly in secs. 32 and 33, T. 17 S., R. 9 E. Castledale, the county seat of Emery County, is on Cottonwood Creek, in secs. 33 and 34, T. 18 S., R. 8 E. The 700 or more inhabitants support schools, hotels, churches, and numerous stores. The town is lighted by electricity and has the only academy in the southeastern part of Utah. Orangeville (not shown on the map), with a population of about 650, is also on Cottonwood Creek, about 3½ miles northwest of Castledale, in the southwestern part of the same township. Clawson is a small hamlet in sec. 26, T. 19 S., R. 7 E. It supports a church, school, and small store. The settlers receive their mail by means of a "star"

mail route out of Castledale. Ferron, on Ferron Creek, mainly in secs. 9 and 10, T. 20 S., R. 7 E., has a population of about 650 persons. It is similar to Castledale, Huntington, Emery, and Cleveland in the number and character of stores, hotels, schools, and churches. Molen, also on Ferron Creek, in secs. 7 and 18, T. 20 S., R. 8 E., has about a dozen houses, a church, and a school, but neither store nor post office. The settlers in this locality receive their mail at Ferron. Rochester, in the southwestern part of T. 21 S., R. 7 E., is a small settlement without a post office. Emery, a village of about 550 inhabitants, mainly in secs. 4 and 9, E. 22 S., R. 6 E., is the principal town in the coal field at the south end of Castle Valley. The people living here are for the most part farmers who cultivate the irrigated lands adjacent to the village. A few ranchers live south and southwest of Emery on Quitchuppah Creek and along Muddy Creek in sec. 36, T. 22 S., R. 6 E. Emery and the several other towns mentioned above have daily mail connections with Price, the county seat of Carbon County, on the Denver & Rio Grande Railroad, 65 miles north of Emery.

The principal occupations of the settlers of Castle Valley are farming and stock raising. Some allied industries, however, such as fruit raising and the production of honey, are given considerable attention. At Mohrland, the southern terminus of the Castle Valley Railroad, in the northern part of T. 16 S., R. 8 E., outside of the area examined in 1911, considerable coal is mined from the upper coal-bearing formation (Mesaverde), to the study of which little attention was given in this examination. Some coal is mined by the ranchers for domestic use east and south of Emery in the lower coal-bearing rocks, which are fully described in this report.

ROADS AND TRAILS.

A very good stage road extends the entire length of Castle Valley from Price through Huntington, Castledale, and Ferron to Emery. Numerous other first-class and second-class roads and trails make the greater part of the area accessible. In general, every main stream is paralleled by one or more roads leading into the canyons cut into the Wasatch Plateau to the west, where wood and coal are abundant. A good road has been constructed from Wellington, on the Denver & Rio Grande Railroad, to Huntington through Cleveland. A branch of this road connects with the Price-Emery stage road about 4 miles south of Price. A second-class road from Castledale follows closely the route of the old Spanish Trail across the north end of the San Rafael Swell to Green River, the easternmost town in Emery County, on Green River, in T. 21 S., R. 16 E. Green River Desert, which lies about 40 to 70 miles southeast of Castle Valley, is accessible by means of a poor and rarely used road from Ferron through Molen and to

the southeast. A road from Castledale through Buckhorn Flat and along Buckhorn Wash also leads through "Sinbad" to the desert. From Emery two roads to the east have been constructed. One about 20 miles in length leads through Rochester and Dry Wash to the Globe copper mine. The other extends to the southeast about 18 miles to a supposed oil field on Salt Wash, 2 miles above its junction with Muddy Creek. A wagon trail, very rarely used, connects Emery with Caineville, on Fremont River, 60 miles to the southeast. A fairly good road connects Emery with Fremont and Loa, to the south, near the head of Fremont River. Emery is also connected with Salina, west of the Wasatch Plateau, by a fair mountain road that follows the courses of Ivie, Yogo, and Salina creeks.

DRAINAGE AND WATER RESOURCES.

Castle Valley is drained entirely by Price, San Rafael, and Curtis rivers and their tributaries, each river receiving about one-third of the run-off. The following table gives the average flow, during the months when irrigation is necessary, of some of the streams in Castle Valley that have been measured by the United States Geological Survey, in 1909[1] and 1913.[2]

Partial amount of run-off across Castle Valley during May, June, July, and August, 1909 and 1913.

Stream.	May.	June.	July.	August.
1909.	*Second-feet.*[a]	*Second-feet.*	*Second-feet.*	*Second-feet.*
Price River	[b] 1,030	925	167	146
Huntington Creek	467	741	191	107
Cottonwood Creek	416	842	218	438
Ferron Creek	146	372	27.6	207
Muddy Creek	146	245	109	(?)
1913.				
Price River	480	238	193	65.0
Huntington Creek	376	218	126	70.9
Cottonwood Creek	711	401	111	50.5
Ferron Creek	257	208	75.2	27.4
Muddy Creek	169	132	80.6	51.0

[a] Second-feet is the number of cubic feet of water passing a given point in a stream channel each second
[b] Mean daily run-off.

This table indicates that the run-off is greatest in most streams during June and that in July and August they carry much smaller volumes. The irregularities in the run-off for the different streams during any month are probably due to local rainstorms. The water from the streams in Castle Valley is utilized mainly for irri-

[1] Freeman, W. B., and Bolster, R. H., Surface water supply of the United States, 1909, Part IX, Colorado River Basin: U. S. Geol. Survey Water-Supply Paper 269, pp. 77–79, 81–87, 181–183, 233, 234, 1911.

[2] Follansbee, Robert, Porter, E. A., and Gray, G. A., Surface water supply of the United States, 1913, Part IX, Colorado River basin: U. S. Geol. Survey Water-Supply Paper 359, pp. 70–76, 79–84, 175–177, 1916.

gating the adjacent valley bottoms. In the vicinity of Cleveland, however, which lies in the drainage basin of Price River, irrigation is made possible by water brought from Huntington Creek over a low divide through a canal 15 miles in length. Near Emery a similar condition exists. The water is taken from Muddy Creek near the mouth of the canyon cutting the Wasatch Plateau and is carried by a large canal through a divide by means of a tunnel to the flat country about Emery.

Practically all the water in the streams flowing east from the Wasatch Plateau across the area under consideration is now used for irrigation with the exception of that in Last Chance Creek. Part of the water from this creek is diverted from its natural course and carried by ditches to Paradise Lake, in secs. 14 and 23, T. 25 S., R. 4 E.

The irrigated area of Castle Valley may possibly be increased as much as 100 per cent by the construction of storage reservoirs to hold flood waters and the spring run-off in the deep canyons in the Wasatch Plateau.

The writer knows of few springs of any importance in Castle Valley north of Ivie Creek. One of these, on the outcrop of the Ferron sandstone member of the Mancos shale in the SW. ¼ sec. 24, T. 21 S., R. 7 E., furnishes sufficient excellent water for a few head of stock the year round. Farther north in Castle Valley there are a few small seeps of alkali water issuing from the shale above the Ferron sandstone. They are locally known as "poison springs," owing to the very alkaline character of the water. South of Ivie Creek, in the more rugged part of the valley, springs are more numerous and the character of the water is much better. Willow Spring, near the center of sec. 13, T. 24 S., R. 5 E., is the best in the southern part of the coal field. In the vicinity of Paradise Lake springs are plentiful. At the extreme southwest end of the field, in the W. ½ sec. 34, T. 25 S., R. 4 E., there is another spring of excellent water.

Paradise Lake, in the S. ½ sec. 14 and N. ½ sec. 23, T. 25 S., R. 4 E., receives part of its water from small mountain streams heading west and southwest of the lake, but, as stated above, it is partly supplied with water diverted from Last Chance Creek. The lake covers about 160 acres and has no outlet. However, should the water rise more than 32 feet from its level in October, 1912, it would flow through an old water gap into a canyon to the southeast. This lake is included within the limits of the Hogan ranch, and is used by the owners of this property to furnish water for their cattle.

In places in the area mapped (Pl. XII, p. 86) fairly good water could be obtained probably by drilling into the Dakota sandstone and also into some of the conglomeratic sandstone beds in the under-

lying McElmo formation, as has been done in the vicinity of the town of Green River, Utah.[1]

Water may be found in places in the southwestern part of the field in stream channels where depressions have been eroded into the soft massive sandstone of the Ferron member. In one locality, sec. 34, T. 24 S., R. 5 E., a pothole at least 10 feet deep and 3 or 4 feet in diameter was half full of water in October, 1912. Other natural reservoirs of the same type but of smaller dimensions exist in this general locality.

CLIMATE AND VEGETATION.

The climate of Castle Valley is semiarid, as shown by the annual rainfall,[2] which ranges from about 7½ inches at Emery to 8½ inches at Castledale. The yearly rainfall at Price is greater than either of the above measurements indicates and probably is about 11 inches. This figure was obtained by averaging the precipitation at Sunnyside, where the annual rainfall is 14.86 inches, and at Castledale. The temperature in Castle Valley ranges from 104° to −34° F. and averages about 45.7° F.

Vegetation, consisting mainly of a sparse growth of grass, a little sagebrush, greasewood, and cactus, is scanty away from stream courses where irrigation is not carried on. Piñon is common on the sandstone ridges and scarps north of Ivie Creek. South of this creek native vegetation is much more abundant. Along many of the streams willow and cottonwood trees are plentiful and other vegetation is more luxuriant than away from the streams. Irrigated lands produce grain, vegetables, alfalfa, and many kinds of fruit. In Castle Valley practically all kinds of fruits common to temperate climates with the exception of grapes are raised.

SURFACE FEATURES.

GENERAL STATEMENT.

Castle Valley is bounded on the west by the Wasatch Plateau and on the east by the San Rafael Swell. To give an adequate idea of the surface of the valley it is necessary to describe, briefly at least, the adjacent topographic features. Topographic maps of this region with a contour interval of 250 feet were made by the Powell Survey. (See San Rafael topographic map of the United States Geological Survey.)

[1] Lupton, C. T., Oil and gas near Green River, Grand County, Utah: U. S. Geol. Survey Bull. 541, pp. 117–121, 1914.

[2] Summary of the climatological data for the United States, section 10, Eastern Utah, pp. 2–4, U. S. Weather Bureau.

WASATCH PLATEAU.

The Wasatch Plateau, lying west of Castle Valley, is a southward continuation of the kinds of rocks and type of topography embodied in the Book Cliffs, which form the prominent scarp extending along the north side of the Denver & Rio Grande Railroad from Grand River, Colo., to Castle Gate, Utah. The Wasatch Plateau ranges from 2,000 to 3,000 feet in height above the floor of Castle Valley, and at many points it is impossible to scale its east face. At only a few places can it be traversed with a wagon or buggy. Deep canyons have been cut into the plateau by Huntington, Cottonwood, Ferron, Muddy, Quitchuppah, Ivie, and Last Chance creeks and some of their tributaries. Low on the east scarp of the plateau alluvium has been washed down into symmetrical fanlike forms, which in many places merge with one another, thus forming compound alluvial fans. Remnants of alluvial fans of former stages of erosion are numerous higher on the east flank of the plateau. These remnants have been rather fully dissected by minor intermittent streams.

The Book Cliffs consist of almost flat-lying beds of sandstone and shale and rise 3,000 to 4,000 feet above the adjacent country. Wherever erosion has removed the overlying sandstone the shale, being less resistant than the sandstone, has yielded readily to erosion, producing nearly sheer cliffs instead of gentle slopes.

CASTLE VALLEY.

Castle Valley is literally a monoclinal valley and owes its existence to the presence of a soft, relatively homogeneous shale which is easily eroded wherever the overlying sandstone is removed. The valley is 80 miles or more in length, and all of it is included within the area mapped except that part in Carbon County north of the Denver & Rio Grande Railroad. The topography of Castle Valley north of Ivie Creek is characterized mainly by gentle slopes, which develop into bad lands near the Wasatch Plateau and in the vicinity of stream courses. South of Ivie Creek the topography is more rugged, owing to the extensive mantle of gravel and bowlders derived from the basalt-covered area to the southwest. The gravel and bowlders have very noticeably protected the underlying shale from erosion, and the resulting topographic forms are entirely different from the forms north of Ivie Creek. Along the east side of Castle Valley parallel cliffs similar to the east face of the Wasatch Plateau above described are developed by the erosion of strata of unequal resistance. In passing from the Wasatch Plateau across Castle Valley into the San Rafael Swell one descends stratigraphically several thousand feet. A view westward from the interior of the Swell gives the impression of looking up a very gently inclined varicolored stairway, the steps of which increase in height toward the top, represented by the Wasatch Plateau.

Castle Valley ranges in altitude from 5,300 feet on Price River, at the north end of the valley, to 8,550 feet in the vicinity of the Hogan ranch, near its south end.

The boundary separating the San Rafael Swell from Castle Valley, arbitrarily adopted by the writer, roughly follows the western limit of the irregular rows of buttes, mesas, and "castles" that form the western boundary of "Sinbad." The buttes and "castles" here referred to are conspicuously shown on the United States Geological Survey's San Rafael topographic sheet.

SAN RAFAEL SWELL.

The most prominent feature of the topography of the San Rafael Swell is a series of odd-shaped sandstone forms which encircle an area in the heart of the Swell, locally known as "Sinbad," which is 40 to 50 miles long and 10 to 20 miles wide. These fantastically eroded forms are remnants of the outcrop of a massive cross-bedded gray Jurassic sandstone about 800 feet thick. It is practicable to cross the Swell at only a few places on account of the almost impassable barrier formed by this sandstone rim. Nearly vertical scarps and canyon walls 300 to 500 feet in height are common. Low hogbacks formed by resistant beds in the strata overlying this sandstone, the upper surfaces of which produce dip slopes of varying extent, depending on the inclination of the beds, encircle this belt of rugged topography. Badlands are common, especially near stream courses.

GEOLOGY.

STRATIGRAPHY.

GENERAL FEATURES.

During the investigation in Castle Valley reconnaissance excursions were made to the Wasatch Plateau and the interior of the San Rafael Swell,[1] enabling the writer to discuss in a general way the stratigraphy from the lowest rocks (Triassic and Permian) studied in the Swell to the highest (Green River?) capping the Wasatch Plateau. Throughout the greater part of Castle Valley the upper part of the McElmo formation, the Dakota sandstone, and the greater part of the Mancos shale were carefully mapped. All other formations described were examined, some in detail, as shown by the compiled stratigraphic section, and others in a general way, as indicated in the descriptions below. Numerous fossil collections were made, and the reports of the determinations of these collections are presented in the descriptions of the several formations.

[1] Lupton, C. T., Notes on the geology of the San Rafael Swell, Utah: Washington Acad. Sci. Jour., vol. 2, No. 7, pp. 185–188, 1912.

The following summarized description of the Triassic and younger strata is given in tabular form for convenient reference and direct comparison:

Rock formations outcropping across Castle Valley from the interior of San Rafael Swell to the top of Wasatch Plateau, Utah.

System and series.	Formation.	Description of strata.	Thickness.	Economic value.
Quaternary (Recent).		An extensive mantle of soil, low gravel-capped terraces, and low broad compound alluvial fans.	0–50+ feet.	
Quaternary? (Pleistocene?)		Remnants of alluvial fans high up on the east face of Wasatch Plateau and lower table-lands.	0–50 feet.	Small springs issue from these beds.
		High terrace gravel with pebbles up to 1 foot in diameter.	0–40 feet.	
		Gravel of both divisions of the Pleistocene(?) consists of yellowish-gray sandstone, gray and drab limestone, quartzitic sandstone, and black chert north of Ivie Creek and principally of dark basalt south of that creek.		
	Unconformity.			
	Green River (?) formation.	Mainly grayish-drab fine-grained calcareous sandstone and sandy shale, which weather white and outcrop in cliffs.	Not determined, probably about 800 feet.	Oil shale reported.
Tertiary (Eocene).	Wasatch formation.	Beds not well exposed but wherever observed, mainly sandstone, and sandy shale of various colors, red, yellow, and drab predominating. The outcrop of this formation forms smooth topography.	Not determined, probably about 1,000 feet.	Water bearing and is known to carry thin beds of coal near Colton and Wales, Utah.
	Unconformity,			
	Mesaverde formation.	Mainly beds of massive and medium-bedded sandstone with some sandy shale, all of a yellowish-gray color. Several coal beds are known to be present near the middle of the formation. None are known in the lower part of the formation up to a horizon 200 or 300 feet above the base. The lower part contains more shale than the upper.	About 1,200 feet, possibly more.	Commonly includes several thick beds of good bituminous coal.
Cretaceous (Upper Cretaceous).	Mancos shale.	Yellow to bluish-drab sandy shale. Upper part very sandy, containing beds and lenses of sandstone. Middle and lower parts but slightly sandy.	About 3,000 feet.	
		Ferron sandstone member. Alternating beds of sandstone and sandy shale with several coal beds present in the vicinity of Emery. At Mounds this member is represented by about 75 feet of sandy material which generally contains a concretionary zone near the middle.	Varies from 75 feet near Mounds to about 800 feet on Last Chance Creek.	Several beds of good bituminous coal at the south end of Castle Valley.
		Bluish-drab sandy shale. Sandy material most plentiful near base and top of this part of formation.	About 600 feet.	
	Dakota sandstone.	Yellowish-gray sandstone with thin beds of shale, alternating. Sandstone coarse, soft, and in places very conglomeratic. Near the north end of Castle Valley the formation is mainly conglomerate. The lower part grades into sandy shale.	60 to 100 feet and possibly more.	A little coal of no importance in Castle Valley.
	Probable unconformity.			

Rock formations outcropping across Castle Valley, etc.—Continued.

System and series.	Formation.	Description of strata.	Thickness.	Economic value.
Jurassic (?).	McElmo formation.	Variegated sandstone and sandy shale. The upper 500 feet principally gray and containing some conglomerate whose pebbles are in places 3 inches in diameter. About 800 feet above the base is a gray to white sandstone about 200 feet thick which probably corresponds to the Salt Wash sandstone member.[a] The lower 800 feet of beds are mainly red in color. About 200 feet above the base is a prominent gypsum horizon in which 40 feet of very pure gypsum is exposed. Another gypsum bed 10+ feet thick is exposed about 700 feet below the top of the formation.	About 1,850 feet.	Two or three gypsum beds of importance. Manganese southeast of Castledale.
.....				
Jurassic.	La Plata sandstone.	Highly cross-bedded coarse gray sandstone, weathering into odd-shaped buttes, mesas, and "castles." A shaly bed near the middle of the formation is present in places.	Not measured, estimated at 800 feet.	A little copper and some asphaltum-saturated sandstone; also locally water bearing.
	Probable unconformity.			
Triassic.	Vermilion Cliff sandstone.	Mainly varicolored sandstone and sandy shale. In places conglomeratic near the top. About 200 feet below the top asphaltum seeps were noted at a few places.	Full thickness not determined; about 500 feet was examined.	Asphaltum. Some thin lenses of relatively pure alum (sodium variety).
.....				
Carboniferous (Permian) and Triassic.		Gray medium-bedded sandstone exposed in the drainage basin of Mexican Spring Wash in "Sinbad."	800± feet exposed (according to Forrester's unpublished notes).	Sulphur springs and deposits on San Rafael River at east side of Swell.

[a] Lupton, C. T., Oil and gas near Green River, Grand County, Utah: U. S. Geol. Survey Bul. 541, p. 127, 1914.

CARBONIFEROUS (PERMIAN) AND TRIASSIC ROCKS.

It is believed that rocks of Permian and Triassic age older than the Vermilion Cliff sandstone are exposed on one of the southern tributaries of San Rafael River, near the west side of "Sinbad," 1 mile or more west of a prominent butte locally known as The Wickiup and about 1 mile east of Mexican Spring Wash. The sulphur deposit on San Rafael River, approximately in the north-central part of T. 21 S., R. 13 E., described by Hess[1] and visited by the writer, is situated stratigraphically a few hundred feet below the top of these rocks.

Robert Forrester in unpublished notes reports about 800 feet of Carboniferous beds exposed along San Rafael River near the Black Box, below Lockhart's cabin. These beds are lower than any examined by the writer. Fossils found by Forrester at this locality and identified by G. H. Girty are listed below.

[1] Hess, F. L., A sulphur deposit in the San Rafael Canyon, Utah: U. S. Geol. Survey Bull. 530, pp. 347–349, 1913.

The first eight in the list came from a stratum 30 feet below the one in which the remainder were found. Mr. Girty states that these fossils are characteristic of the "Bellerophon limestone" or top of the Aubrey group.

Allorisma capax.
Sedgwickia sp.
Myalina aff. M. congeneris.
Schizodus? sp.
Aviculipecten coloradoensis?
Pleurotomaria? sp.
Macrocheilina? sp.
Orthoceras? sp.
Sponge.
Lioclema? sp.
Composita mexicana?
Solenomya? sp.
Edmondia gibbosa?
Sanguinolites?? sp. a.
Sanguinolites?? sp. b.
Leda obesa.
Nucula levatiformis.
Mytilus? sp.
Pleurophorus? sp.
Astarte? sp.
Plagioglypta canna.
Dentalium mexicanum.
Euphemus subpapillosus.
Patellostium aff. P. nodicostatum.
Bellerophon sp. 1.
Bellerophon sp. 2.
Warthia? sp.
Coloceras n. sp.
Gastrioceras sp.
Ammonoid??

TRIASSIC SYSTEM.

VERMILION CLIFF SANDSTONE.

The base of the Vermilion Cliff sandstone was not determined, and the section given below represents careful estimates rather than accurate measurements of the thickness of the strata. The formation is prevailingly sandy and red. The lower part consists of thin to medium bedded sandstone and sandy shale which is yellowish gray below but changes to red in its upper part. Overlying this series is a grayish-brown coarse-grained sandstone about 90 feet thick, which in places is conglomeratic. At several localities asphaltum seeps and springs exist near the base of this bed. About 100 feet of varicolored sandy and conglomeratic material overlies this sandstone. The presence of a conglomerate near the top of this formation suggests an unconformity, but the evidence on this point is not conclusive, as no fossils were collected in the Vermilion Cliff or the overlying La Plata sandstone.

Section of part of Vermilion Cliff sandstone near west side of "Sinbad," in the San Rafael Swell.

[Thickness estimated.]

Top.	Feet.
Sandstone, red, maroon, purple, and gray, with beds of thin conglomerate and sandy shale of similar colors	100
Sandstone, grayish brown, in places conglomeratic (horizon of asphaltum seeps and springs near base of this sandstone)	90
Sandstone and sandy shale, red in upper part, yellow and gray in lower part, thin to medium bedded	300
	490

JURASSIC SYSTEM.

LA PLATA SANDSTONE.

The La Plata sandstone consists of a highly cross-bedded coarse-grained, very massive gray sandstone, but near the middle of the formation there is in places some shale, which, however, is not persistent. Careful estimates place the total thickness of this sandstone at about 800 feet along the west flank of the San Rafael Swell, where its outcrop has been eroded into prominent scarps, "castles," buttes, and mesas, from which Castle Valley probably takes its name. This sandstone is in all probability the same as the White Cliff sandstone of the eastern Uinta and southern Utah sections of Powell,[1] and corresponds to the La Plata sandstone of Cross.[2] This correlation is based solely on its stratigraphic position and physical characteristics, as no fossils were collected from it.

JURASSIC (?) SYSTEM.

McELMO FORMATION.

The McElmo formation, which is thicker in this locality than at any of the places in eastern Utah and southwestern Colorado, where it has been measured, consists of 1,800 to 1,900 feet of varicolored conglomeratic sandstone and sandy shale, with two or more gypsum beds[3] that form but a small part of the whole thickness. The lower 800 feet is composed mainly of sandstone and sandy shale, with gypsum-bearing beds about 200 feet above the base. The upper 400 feet of this part of the formation is mainly red and massive. Overlying this is a gray to white sandy series about 200 feet thick containing a thin stratum of conglomerate at the base. This portion is believed to be equivalent to the Salt Wash sandstone member[4] in the vicinity of Green River, Utah. Variegated sandstone and sandy shale, interbedded, and about 36 feet of gypsum, included in three benches, make up the overlying 350 feet of strata. The top of this 350-foot series probably coincides with the top of the Flaming Gorge formation as defined by Powell.[5] Gale,[6] however, in northwestern Colorado and northeastern Utah draws the contact between the Flaming Gorge formation and the Dakota

[1] Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto, pp. 52, 53, 152, U. S. Geol. and Geog. Survey Terr., 1876.

[2] Cross, Whitman, and Purington, C. W., U. S. Geol. Survey Geol. Atlas, Telluride folio (No. 57), p. 3, 1899.

[3] Lupton, C. T., Gypsum along the west flank of the San Rafael Swell, Utah: U. S. Geol. Survey Bull. 530, pp. 221–231, 1913.

[4] Lupton, C. T., Oil and gas near Green River, Grand County, Utah: U. S. Geol. Survey Bull. 541, pp. 124, 126, 127, 1914.

[5] Powell, J. W., op. cit., pp. 152, 157.

[6] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, p. 54, 1910.

sandstone about 500 feet stratigraphically higher, a determination that includes within the Flaming Gorge about 500 feet more of strata than Powell included in it. This 500 feet consists of sandstone, sandy shale, and conglomerate of a greenish-drab color and apparently corresponds to part of the Henrys Fork group as defined by Powell and as identified by Gilbert[1] in the Henry Mountains. In places the colors change to red, maroon, and blue. Considerable conglomerate occurs near the base. In Castle Valley the conditions apparently are similar to those described by Gale, and the positions of the geologic boundaries are similarly located. The McElmo formation as recognized in this field is believed to include not only the McElmo formation described by Cross[2] as occurring in southwestern Colorado, where it is considered the equivalent of the Morrison formation, but also a series of marine beds that probably represent a part at least of the Sundance formation. Fossils collected near the south side of sec. 10, T. 21 S., R. 9 E., on the east side of Coal Wash, about a mile slightly east of south from Dripping Spring, within 10 feet of the base of the formation were identified by T. W. Stanton as belonging to a marine Jurassic fauna. Plate II, *A*, shows the strata in which the fossils were collected and also the contact of the McElmo formation and the La Plata sandstone. The names of the species are as follows:

Ostrea strigilecula White.
Plicatula sp.
Camptonectes stygius White.
Camptonectes sp.
Modiola subimbricata Meek.
Trigonia sp.
Cyprina? sp.

As the McElmo formation in its type area is not known to include any marine strata, it is possible that the bed containing this fauna is older than the basal beds of the typical McElmo.

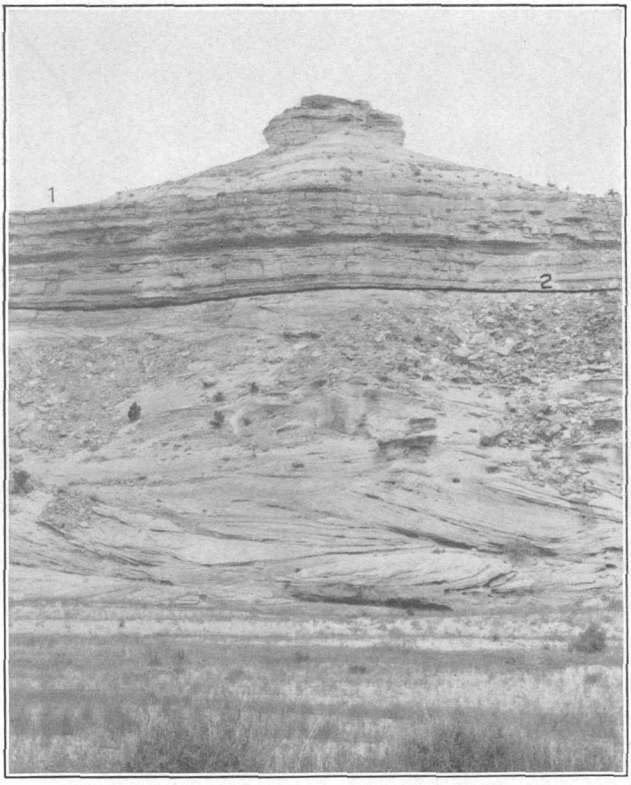
The following section was measured principally in Colt Gulch, 10 to 12 miles east of Emery, and is given in detail, except those parts near the base numbered 32 and 33:

Section of rocks of McElmo formation measured on the west flank of San Rafael Swell and the east side of Castle Valley.

	Ft.	in.
Top.		
1. Clay shale, gray to green, sandy, contains calcareous nodules; becomes more sandy and greenish near top	140	0
2. Sandstone, massive, in places conglomeratic	40±	
3. Sandstone, gray, medium bedded	11	4
4. Shale, similar to No. 6	13	2
5. Sandstone, gray; weathers brown; medium grained and medium bedded	10	0

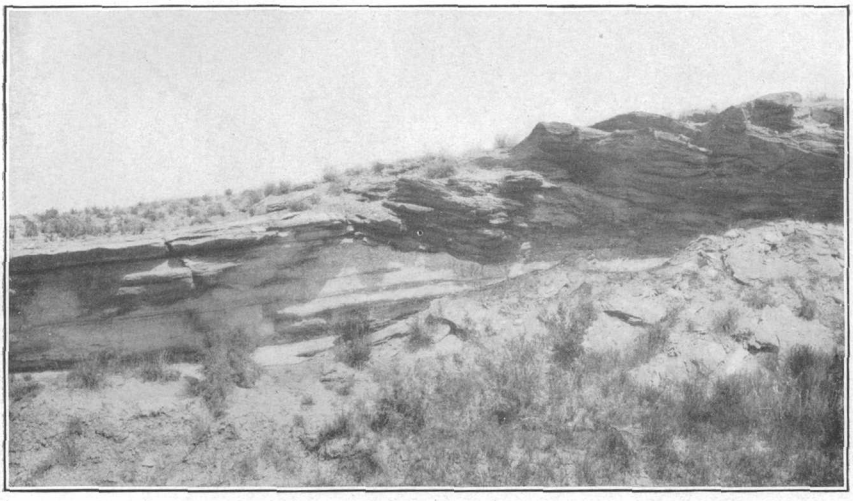
[1] Gilbert, G. K., Report on the geology of the Henry Mountains, pp. 4, 5, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1877.

[2] Cross, Whitman, and Purington, C. W., U. S. Geol. Survey Geol. Atlas, Telluride folio (No. 57), p. 3, 1899.



A. CONTACT OF McELMO FORMATION AND LA PLATA SANDSTONE ON THE WEST FLANK OF THE SAN RAFAEL SWELL.

1, McElmo formation; 2, contact between McElmo and La Plata; 3, La Plata sandstone.



B. LOCAL UNCONFORMITY IN THE DAKOTA SANDSTONE NORTHEAST OF FERRON.

Section of rocks of McElmo formation measured on the west flank of San Rafael Swell, etc.—Continued.

	Ft.	in.
6. Shale, gray, sandy	17	8
7. Sandstone, medium bedded; contains some shale; conglomeratic at top	11	6
8. Shale, sandy, variegated; contains thin beds of gray to brown sandstone; calcareous in places; general color brown	207	0
9. Conglomerate, gray; contains black chert and limestone pebbles, the largest 3 or 4 inches in diameter; contains bones, unidentified	15	6
10. Clay shale, gray, red, and white, with some sandstone and cone-in-cone concretion-like material alternating	48	0
11. Conglomerate, gray; contains black chert and limestone pebbles 3 inches or less in diameter; also some soft, friable sandstone	8±	
12. Sandstone, gray (probably top of Flaming Gorge formation as defined by Powell)	4	0
13. Gypsum, sandy, red, gray, and white	16	6
14. Gypsum, pink, impure; very shaly at base, very pure at top; contains cherty concretions	22	0
15. Shale, salmon-red and in places greenish gray	10	4
16. Gypsum, almost pure	10	0
17. Shale, red, sandy	1	3
18. Gypsum, somewhat impure	4±	
19. Clay, salmon-red, sandy	11	0
20. Sandstone, greenish gray, and red sandy shale alternating	20	8
21. Sandstone, red, argillaceous	5	0
22. Sandstone, gray, weathers brown, rather thin bedded	6	0
23. Sandstone and sandy shale, salmon-red, thin bedded; contains one or two lenses of calcareous sandstone 2 feet thick near top (within 25 feet); also a stratum of gypsum 6 to 8 inches thick near top	167	0
24. Sandstone, white, fine grained, ledge maker		5
25. Sandstone and sandy shale, chocolate-red in color; contains some thin-bedded sandstone near top; thin streaks of green sandy clay occur in this material	57	0
	857	4±
26. Shale, greenish gray, slightly pinkish at top, sandy	50±	
27. Sandstone, gray, thin bedded, shaly	45	0
28. Sandstone, massive, gray to white, friable	100±	
29. Sandstone, grayish green, shaly, thin bedded	18	0
30. Conglomerate; contains black chert and quartz pebbles up to 4 inches in diameter		5
	[1]213	5±
31. Sandstone, greenish gray to white, shaly	3	0
32. Sandstone, red, massive, thin bedded	400±	

[1] This part of the section (Nos. 26 to 30, inclusive) probably corresponds to the Salt Wash sandstone member of the Green River region. See U. S. Survey Bull. 541, p. 127, 1914.

Section of rocks of McElmo formation measured on the west flank of San Rafael Swell, etc.—Continued.

	Ft.	in.
33. Sandstone, calcareous, gray in places, slightly green, thin bedded	200±	
34. Gypsum, relatively pure	30+	
35. Sandstone, red; contains many veins of gypsum	10	0
36. Gypsum, very pure	7	0
37. Sandstone, red	5	0
38. Sandstone, greenish gray, thin bedded	60	0
39. Shale and sandstone, red, thin bedded	18	0
40. Sandstone, yellowish brown, thin bedded	15	0
41. Sandstone, yellowish brown, massive	10	0
42. Sandstone, yellowish buff and maroon, thin bedded (fossils named on p. 24 collected near base of this stratum)	15	0
	773	0
	1,843	9±

CRETACEOUS SYSTEM.

DAKOTA SANDSTONE.

The Dakota sandstone is well exposed throughout the length of Castle Valley except for about 1 mile in secs. 14, 22, 23, and 27, T. 20 S., R. 8 E., 3 to 4 miles south of Ferron Creek. It has been definitely correlated with the Dakota sandstone as mapped by Richardson[1] near Mounds, in the Book Cliffs coal field. This formation was traced continuously from Mounds to Ivie Creek, a distance of about 60 miles, but south of Ivie Creek the mapping of the Dakota is only approximate. This formation also crops out in small isolated areas near Farnham, both north and south of the Denver & Rio Grande Railroad.

The Dakota consists mostly of grayish-buff sandstone, but in places is composed of interbedded sandstone, sandy shale, and conglomerate of the same color, in varying proportions. Cross-bedding is common, suggesting that the material was deposited in shallow water where currents continuously reworked it. In many places local unconformities occur within the formation. An exposure near the center of sec. 36, T. 19 S., R. 8 E., on a small northern tributary of Ferron Creek, shows that a part of the gray massive sandstone has been replaced by dark-brown cross-bedded sandstone. The line separating the two kinds of sandstone is very distinct. This phenomenon suggests that at one time an erosion channel was cut into the gray sandstone, and that later the cut was filled by sand of a different color.

[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field, between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, pp. 12–14, pl. 3, 1909.

Plate II, *B*, is a view of this local unconformity. A thin coal bed of no economic importance is present in places near the top of the formation. A full description of this coal is given on pages 74–76. Sections of the Dakota sandstone were measured at several points along the east side of Castle Valley and are given below to show its variation in character and thickness.

Section of Dakota sandstone measured in T. 16 S., R. 11 E., 3 miles southwest of Mounds.

	Feet.
Sandstone, gray and yellow, cross-bedded, conglomeratic	7
Conglomerate; pebbles as large as 3 inches in diameter	2
Covered (probably gray argillaceous sandstone)	28
Sandstone, gray; weathers brown; massive; argillaceous in places	10
Sandstone, gray; weathers brown in places; somewhat conglomeratic; pebbles chiefly of gray clayey material	12
Covered	8
Sandstone, gray; weathers brown; massive, fine grained	8
	75

The material directly underlying the Dakota at this place consists of "lumpy" light, porous, cellular white clay. A section measured on Huntington Creek, about 25 miles southwest of this locality, shows the formation much thinner and considerably different in character:

Section of Dakota sandstone measured on Huntington Creek in sec. 4, T. 19 S., R. 9 E., about 5 miles east of Castledale.

	Ft.	in.
Sandstone, yellowish gray, somewhat friable, partly thin bedded and partly cross-bedded	22	0
Clay shale, yellowish gray	1	6
Sandstone, brownish yellow, fine grained, argillaceous	3	6
	27	0

The rocks directly underlying the Dakota sandstone at this locality consist of 300 to 500 feet of maroon to drab sandy shale, sandstone, and conglomerate. The beds of conglomerate, which occur near the base of the series, are in places calcareous and undoubtedly should be included within the McElmo formation, but their physical character in other places suggests a similarity to the Dakota.

Two or three miles southwest of the above-mentioned locality another exposure, on the south bank of Cottonwood Creek near the center of sec. 17, T. 19 S., R. 9 E., shows that the rocks have changed considerably in character and that a carbonaceous bed occurs at the top of the formation.

Section of Dakota sandstone measured on Cottonwood Creek in sec. 17, T. 19 S., R. 9 E., about 5 miles southeast of Castledale.

	Feet.
Sandstone, yellow, saccharoidal; contains small iron concretions; lower part slightly conglomeratic	11 6
Sandstone, massive, yellow and brown, conglomeratic near base	24 0
	35 6

The carbonaceous beds are not persistent and may occupy any position in the formation. In one place near this location carbonaceous material rests on the shale underlying the Dakota sandstone.

The formation is thicker toward the southwest, as shown by the following section measured near Horn Silver Gulch in sec. 9, T. 21 S., R. 8 E., about 8 miles southeast of Ferron:

Section of the Dakota sandstone measured in sec. 9, T. 21 S., R. 8 E., about 8 miles southeast of Ferron.

	Ft.	in.
Sandstone, yellow, saccharoidal; contains small iron concretions; lower part slightly conglomeratic	11	6
Sandstone, massive, yellow and brown, conglomeratic near base	24	0
	35	6

The formation at this locality contains many spherical iron concretions. The upper part of the sandstone seems to be distinct from the underlying and more massive part, which weathers into large cubic blocks. A fine-grained thin yellow "clay-ball" conglomerate separates the two parts. Directly underlying the sandstone, unconformably at this place, are beds of shale and sandstone several feet thick containing fragmentary fossil leaves that could not be identified. This section is as follows:

Section of rocks underlying the Dakota sandstone in sec. 9, T. 21 S., R. 8 E.

	Ft.	in.
Shale, bluish gray	1	3
Sandstone, brownish gray, cross-bedded, somewhat carbonaceous	2	0
Clay shale, bluish gray; contains leaves of several species (unidentified)		8
Shale, sandy, coarse grained, conglomeratic	1	0
Shale, drab		3
Clay, white, calcareous, lenticular		2
Shale, drab, with yellow iron concretions	1	0
Shale, sandy, bluish		3
Shale, sandy, drab, yellow, and gray	1	6
	8	1

It is possible that these rocks should be included in the Dakota sandstone.

About 5 miles southeast of Rochester, on the north side of Dry Wash, in the E. ½ sec. 36, T. 21 S., R. 7 E., the Dakota sandstone is much thicker and contains more conglomerate than is shown by any other section measured in this part of Castle Valley.

Section of Dakota sandstone measured in the E. ½ sec. 36, T. 21 S., R. 7 E.

	Feet.
Conglomerate, consisting mainly of quartz and black chert pebbles, 2 or 3 inches in diameter	1±
Sandstone, yellowish gray, soft, thin bedded	6
Sandstone, yellowish gray, soft, mainly thin bedded; cross-bedded in places; contains a few iron concretions stained yellow and brown	18+
Clay shale, gray, yellow, and red	3+
Sandstone, grayish yellow, indurated, massive, coarse-grained, conglomeratic in places	26
Clay shale, yellowish gray, gypsiferous	2
	56+

About 5 miles southwest of the point where this section was measured thin lenses of coal occur in the top of the Dakota sandstone. (See locations 418, 419, and 420 on Pl. XII, and p. 75.)

Another section was measured about 12 miles southeast of Emery and is given below.

Section of Dakota sandstone measured about 12 miles southeast of Emery, 3 miles south of Ivie Creek, near the west side of sec. 36, T. 23 S., R. 6 E.

	Ft.	in.
Sandstone, gray, brown wherever weathered, massive, and thin bedded; iron stained in places; contains a thin lens of shaly coal at base	36	0
Sandstone, yellowish brown; small clay balls form a thin bed of conglomerate at base	3	6
	39	6

A section of the Dakota sandstone measured near the south end of the field shows the formation to be somewhat thicker than in the vicinity of Ivie Creek, where the preceding section was measured. The character and thickness of the rocks in the Dakota sandstone at the south end of the coal field are given below.

Section of the Dakota sandstone measured in SE. ¼ sec. 25, T. 25 S., R. 4 E.

	Ft.	in.
Sandstone and bluish sandy shale alternating	30	0
Shale, brown, carbonaceous (see location 421 on p. 76)	1	0
Coal, impure		8
Shale, brown, carbonaceous		8
Sandstone (?), poorly exposed	12	0
Sandstone, white	2	6
Coal, rusty, probably impure		3
Sandstone and sandy shale, poorly exposed	12	0
Shale, coaly, very carbonaceous		8
	59	9

The Dakota sandstone is exceedingly variable in thickness and character, as is shown by the sections given above. Weathering undoubtedly accounts for some of its variation in color. The only fossils collected in this formation were the fragmentary leaves mentioned on page 28. At many places in Castle Valley evidences of an unconformity were noted at the base of the formation. This may only be apparent, however, because local unconformities as extensive as that which occurs at its base are present within the sandstone itself.

MANCOS SHALE.

GENERAL FEATURES.

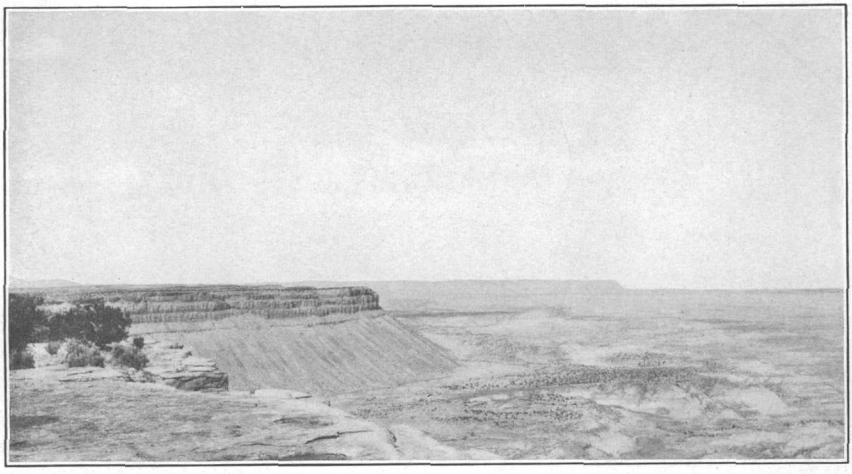
The Mancos shale in Castle Valley consists of three natural subdivisions. The lowest, about 600 feet thick, is described in this report as "Shale below the Ferron sandstone member." Conformably overlying this shale is the Ferron sandstone member, which contains the coal in the southern part of Castle Valley. This member increases in thickness from about 75 feet at the north end of Castle Valley to about 800 feet at its south end. The highest subdivision is described in this report as "Shale above the Ferron sandstone member." It rests conformably on the Ferron sandstone and is about 3,000 feet thick in the vicinity of Emery. At the south end of the field it is impossible to determine its exact thickness on account of extensive faulting.

SHALE BELOW THE FERRON SANDSTONE MEMBER.

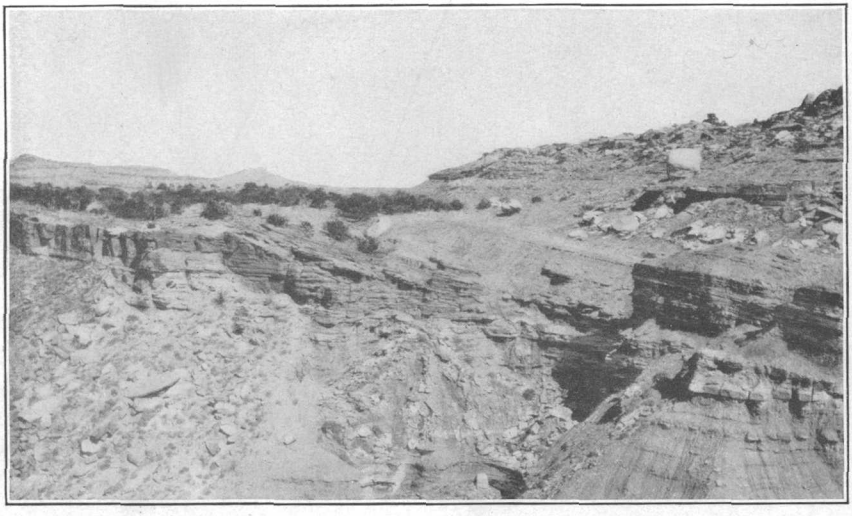
That part of the Mancos shale underlying the Ferron sandstone member ("shale of the San Rafael Swell" of Taff's classification) consists of about 600 feet of bluish-drab shale, which is rather sandy in its lower and upper parts. It probably corresponds to the Blue Gate shale and possibly includes the Tununk sandstone and the Tununk shale, as described by Gilbert[1] in his report on the Henry Mountains. Five collections of fossils were obtained in this part of the Mancos shale. All the species except one are definitely Cretaceous forms and characteristic of the lower part of the Mancos shale or basal Colorado. The species, identified by T. W. Stanton, are listed below:

Prionotropis sp.
Anomia sp.
Inoceramus n. sp., related to I. fragilis Hall and Meek.
Cardium sp.
Lucina sp.
Mactra sp.
Corbula sp.
Astarte? sp.
Ostrea sp.
Gastropod casts of two or more undetermined genera.

[1] Gilbert, G. K., Report on the geology of the Henry Mountains, pp. 4, 5, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1877.



A. FERRON SANDSTONE MEMBER OF THE MANCOS SHALE SOUTHEAST OF EMERY.



B. LOCAL UNCONFORMITY IN THE FERRON SANDSTONE MEMBER OF THE MANCOS SHALE, ABOUT 10 MILES SOUTH OF EMERY.

The greater part of this subdivision of the formation, together with a portion of the Ferron sandstone member, constitutes a "riser" or cliff, in some places 600 feet high, whereas the upper surface of the resistant overlying Ferron sandstone forms a "step" in the topography. Plate III, *A*, shows that part of the Mancos shale above discussed and also the lower part of the Ferron member. This shale weathers into bad lands along the base of the scarp.

FERRON SANDSTONE MEMBER.

The Ferron sandstone member of the Mancos shale is well developed in the vicinity of Ferron and Emery and rests conformably upon the shale above described. It crops out in the upper part of a prominent scarp which ranges from 80 to 1,000 feet in height. This member becomes thicker from a point near Mounds, where it is about 75 feet thick, to Last Chance Creek, 70 miles southwest, where it is about 800 feet thick. Local unconformities occur within the Ferron sandstone, as illustrated by Plate III, *B*. A section measured on Last Chance Creek shows this coal-bearing sandstone portion of the Mancos to be more than 800 feet thick. Eight stratigraphic sections on Plate IV show the gradual increase in thickness of the formation toward the southwest. Concretionary beds near the base of the Ferron sandstone extend from Mounds to Ivie Creek, but south of that stream concretions are not so conspicuous. In some places these spherical concretions are much more abundant than in others, being very large and numerous north of Ferron Creek. Plate V shows a typical exposure of these concretions in the vicinity of Castledale. The Ferron member of the Mancos shale in the Emery field carries the principal coal beds, all of which lie above the concretionary horizon above described. This coal, however, is of little value north of an east-west line through Emery. Carbonaceous material occurs in this sandstone for several miles north of the place (south side of T. 21 S., R. 7 E.) where the first coal of economic importance crops out.

Fossils were collected from the lower part of the Mancos shale and were identified by T. W. Stanton, who considered them indicative of "brackish-water fauna, probably of Colorado age." The fossils from the Ferron sandstone member do not conclusively prove its age, but as the fossils collected stratigraphically above and below it are definitely of Mancos age, there can be no doubt that the Ferron sandstone is also Mancos. The fossils collected on Ivie Creek about 50 feet above the base of the Ferron member, in sec. 17, T. 23 S., R. 6 E., about 8 miles south of Emery, are given below.

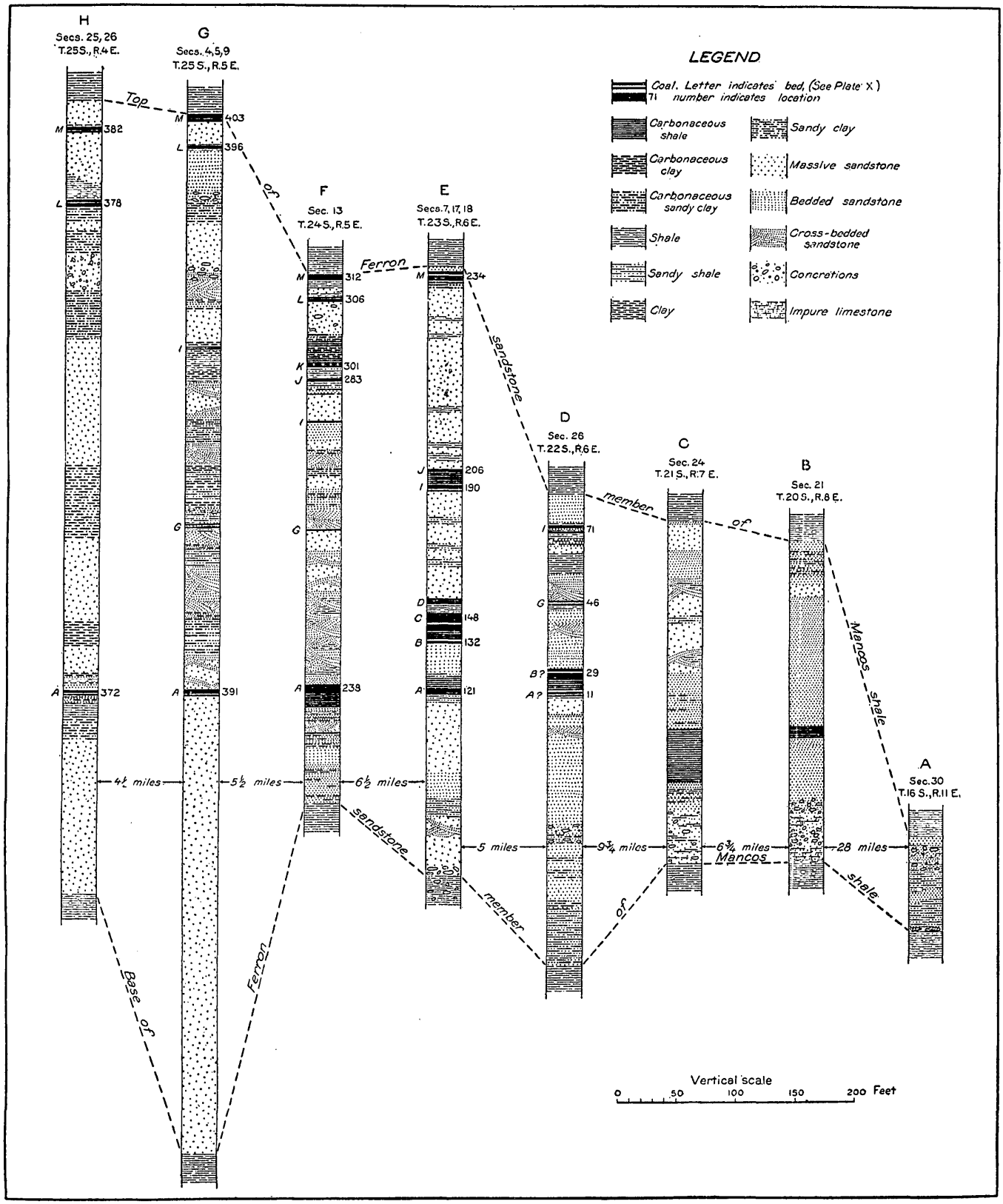
Ostrea sp.
Corbicula sp., related to C. durkeei Meek.
Turritella? sp.
Corbula sp.

The Ferron member corresponds lithologically and stratigraphically to the Blue Gate sandstone in the Henry Mountains, described by Gilbert.[1] The following section of the Ferron sandstone was measured on Ivie Creek in the north half of T. 23 S., R. 6 E., and shows the thickness and distribution of the coals in that locality:

Section of Ferron sandstone member of Mancos shale on Ivie Creek 8 miles south of Emery.

	Ft.	in.
Sandstone, gray; weathers yellowish brown; massive; contains more or less persistent layers of gray to black shale, some of which is carbonaceous. The upper 40 feet of this massive sandstone in places changes very abruptly into a slightly sandy carbonaceous shale	150±	
Bed J, location 206:		
Coal	1	2
Shale, black, carbonaceous, sandy		9
Coal	1	2
Shale, black, carbonaceous, grading upward into drab sandy shale	11	0
Bed I, location 190: Coal, weathered. This bed changes abruptly into a carbonaceous shale a short distance from the point measured	3	6
Shale, brown; weathers gray; carbonaceous, sandy	3	0
Sandstone, gray; weathers yellow and brown; massive. Beds of sandy gray to brown shale as thick as 4 feet are interstratified with the sandstone	86	0
Shale, black, carbonaceous, showing a transition upward into drab shale, which becomes sandy near top	3	0
Bed D, location 148: Coal, blocky	1	6
Shale, clayey, drab; joints iron stained; upper part very gypsiferous and carbonaceous	7	6
Bed C, location 148:		
Coal	8	4
Clay, sandy, yellow, drab at top	1	9
Coal, fair, much weathered	3	8
Sandstone, brown, carbonaceous		½
Coal, fair, much weathered	1	4
Shale, brown, carbonaceous, in places sandy	8	5
Bed B, location 132: Coal, blocky, fair	1	8
Sandstone, gray; weathers brown; medium bedded, very lenticular; in places represented by drab sandy shale	23	0
Shale, brown, carbonaceous, showing a transition upward into gray sandy shale	11	6
Bed A, location 121:		
Coal, fair, weathered	1	2
Shale, brown, carbonaceous		4
Coal, brown, fair		4
Shale, brown, sandy		6

[1] Gilbert, G. K., op. cit., pp. 4, 5.



COLUMNAR SECTIONS OF THE FERRON SANDSTONE MEMBER OF THE MANCOS SHALE IN CASTLE VALLEY, SHOWING VARIATIONS IN THICKNESS FROM NORTHEAST TO SOUTHWEST.

Bed A, location 121—Continued.	Ft.	in.
Coal	1	2
Coal, bony		7
Coal	3	6
Shale, brown, carbonaceous, sandy		10
Sandstone, white, medium grained	1	0
Shale, brown, carbonaceous, sandy		4
Sandstone, lenticular		4
Shale, brown, carbonaceous, sandy; contains a little coal in places	4	0
Sandstone, gray, massive	57	0
Sandstone, shaly and thin bedded at base, medium bedded above	16	0
Sandstone, shaly, carbonaceous; contains thin lenses of coal and at some other places is represented by coal		5
Sandstone, thin bedded, very soft, carbonaceous	4	0
Sandstone, yellowish gray, calcareous, very fossiliferous		10
Shale, drab to yellow, sandy; upper part (1½ feet) very fossiliferous	14	6
Sandstone, yellowish gray; weathers brown; somewhat cross-bedded, ledge maker; contains thin lenses of shale in places; the top of this sandstone forms a structural terrace on which rest gravel and bowlders of basalt	40	0
	475	1½±

The above section shows an unusual thickness of coal. Taff[1] considered this sandstone ("sandstone of the Red Plateau") to be the same formation that caps Cedar Mountain (Red Plateau), 35 miles to the northeast, but the latter formation is about 1,200 feet stratigraphically below the former and probably is equivalent to a conglomerate at the base of the Henrys Fork group of Gilbert's Henry Mountains classification, or about 450 feet below the top of the McElmo formation.[2] As these formations are in some respect similar, and as Taff's work along the east side of Castle Valley was entirely reconnaissance, his conclusion that the coal-bearing sandstone south and east of Emery is the same as the formation capping Cedar Mountain naturally followed.

SHALE ABOVE THE FERRON SANDSTONE MEMBER.

The upper shaly part of the Mancos shale ("shale of Castle Valley" of Taff's classification) is about 3,000 feet thick, as determined a few miles northeast of Emery. It rests with apparent conformity upon the Ferron sandstone member and probably should be correlated with the Masuk shale of Gilbert's section of the

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

[2] Gilbert, G. K., op. cit., p. 4.

Cretaceous of the Henry Mountains region.[1] This subdivision of the Mancos shale is grayish drab in color, and is sandy in its lower and upper parts. The upper part in some places contains lenses of friable yellowish-gray sandstone. Fossils collected in the lower part of the shale above the Ferron sandstone member indicate that this shale is unquestionably of Mancos age. The species identified by T. W. Stanton are typical of the lower part of the Mancos and are as follows:

Inoceramus acutiplicatus Stanton?
Inoceramus labiatus Schlotheim.
Inoceramus sp.
Ostrea congesta Conrad.
Ostrea sp.
Baculites sp.
Fish scales and bones.

The topographic forms resulting from the erosion of this part of the Mancos shale are similar to those of the shale below the Ferron member. This upper shale, together with the overlying Mesaverde formation, constitutes the "riser" of the "step" formed by the overlying Mesaverde that caps the east face of the Wasatch Plateau.

MESAVERDE FORMATION.

The Mesaverde formation in this region consists of yellowish-gray sandstone, sandy shale, and coal beds. The outcrops form the upper part of the prominent east scarp of the Wasatch Plateau. From western Colorado westward along the Book Cliffs to Castle Gate, Utah, and thence southwestward along the Wasatch Plateau, the Mesaverde rocks occupy the same relative position in this extensive cliff. The formation becomes thinner to the south, as is shown by measurements at Sunnyside, Utah, where about 1,650 feet of it is exposed,[2] and at Emery, where the writer by aneroid barometer determined the thickness to be about 1,150 feet. Taff[3] called this coal formation Laramie. Regarding its thickness he said: "In the Book Cliffs the sandstone is estimated to be not less than 1,000 feet thick." Many of the sandstones included in the formation are massive and in places are 200 feet or more in thickness. The prominent coal beds occur mainly in the sandy shale portions of the formation, but as it was not examined in detail for coal little can be said as to the number and thickness of the coal beds present. In some places the coal has been burned, producing slag; in other places the burning has merely oxidized the small quantities of iron in the rocks, giving them a brick-red color. In the vicinity of Emery the principal coal beds are included within about 500 feet of strata, beginning 200 or 300 feet above the base of the formation.

[1] Gilbert, G. K., op. cit., pp. 4, 5.
[2] Unpublished data furnished by F. R. Clark.
[3] Taff, J. A., Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, pp. 291–293, 1906.

CONCRETIONS IN THE FERRON SANDSTONE MEMBER OF THE MANCOS SHALE, ABOUT 6 MILES SOUTHEAST OF CASTLEDALE.

A part of the Mesaverde formation was measured in the canyon of Ferron Creek, as shown below.

Section of part of the Mesaverde formation in Ferron Creek canyon about 12 miles slightly north of west of Ferron.

	Ft.	in.
Sandstone, yellowish gray, mainly massive	20+	
Coal	3	3
Shale, bluish gray, showing transition into carbonaceous shale	2	0
Sandstone, gray, weathers buff, fine grained	4	6
Shale, sandy and shaly sandstone, gray	5	6
Sandstone, gray, weathers buff, medium bedded; contains leaves in upper part	7	6
Shale, black, carbonaceous	1	0
Coal, weathered	4	2
Shale, brown, carbonaceous	2	6
Coal, much weathered	4	6±
Sandstone, gray, massive	25+	
Sandstone, yellowish gray, thin bedded (to level of Ferron Creek)	40+	
	119	11±
Total coal	11	11±

Fossil leaves were collected at this locality and were identified by F. H. Knowlton as *Sequoia reichenbachi* (Geinitz) Heer and fragmentary dicotyledons, which he states are "presumably Montana" in age.

It is probable that this formation is equivalent to the Masuk sandstone, about 500 feet thick, as described by Gilbert,[1] occurring in the Henry Mountains region, 80 miles southeast of Emery, where it is coal bearing and similar to the Mesaverde both lithologically and stratigraphically.

TERTIARY SYSTEM.

EOCENE SERIES.

WASATCH FORMATION.

The Wasatch formation was examined by the writer at only one locality in the area under consideration. This formation consists of alternating beds of soft varicolored sandstone and sandy shale, possibly 1,000 feet thick.

Wherever the contact between the Wasatch formation and the underlying Mesaverde formation has been carefully examined in northeastern and central Utah, evidences of an unconformity of a greater or less degree are unquestionable. On Deep Creek,[2] about

[1] Gilbert, G. K., op. cit., pp. 4, 5.

[2] Lupton, C. T., The Deep Creek district of the Vernal coal field, Uinta County, Utah: U. S. Geol. Survey Bull. 471, p. 585, 1912.

12 miles northwest of Vernal, the Wasatch formation rests upon an eroded surface of the Mancos shale. Near Vernal[1] and northeast of Blacktail Mountain[2] it lies unconformably upon the lower part of the Mesaverde, and northwest of Blacktail Mountain[3] it rests on the higher beds of the Mesaverde. In the vicinity of Castle Valley the unconformity is not so pronounced as it is farther north, along the south flank of Uinta Mountains.

At the north end of Castle Valley, near Sunnyside, about 3,700 feet[4] of strata constitute the Wasatch formation. Its base is marked by about 3 feet of yellowish-gray conglomerate. The pebbles, which are partly subangular and partly well rounded, range from sand grains to pebbles 3 inches in diameter. The matrix is a hard, well-cemented mass of fine quartz grains. The Wasatch near Emery is estimated to be 1,000 feet thick, showing a great decrease in the thickness of this formation toward the south, which is true also of the Mesaverde formation, as mentioned above. The topographic forms resulting from the erosion of the Wasatch formation are smooth slopes which present a striking contrast to the cliffs formed by rocks of the overlying Green River (?) formation and the underlying Mesaverde. No minerals of any economic importance are known to be present in the Wasatch formation of this immediate region; but near Colton and Wales, 75 to 150 miles northwest, thin coal beds are present.

GREEN RIVER (?) FORMATION.

The Green River (?) formation overlies the Wasatch and in this locality consists of about 800 feet of grayish-drab fine-grained calcareous sandstone and sandy shale, which weather white. This formation, which caps the highest part of the Wasatch Plateau west of Emery, crops out in almost vertical cliffs. Although no opportunity was afforded to determine the character of the contact at the base of the Green River (?) formation, yet it is believed to rest conformably on the Wasatch formation above described.

QUATERNARY (?) SYSTEM.

PLEISTOCENE (?) SERIES.

ALLUVIAL FANS.

Former stages of erosion are recorded by the presence of numerous remnants of alluvial fans, probably of Quaternary age. These fans fringe the east face of the Wasatch Plateau for its entire length

[1] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, p. 205, pl. 21, 1910.

[2] Lupton, C. T., The Blacktail (Tabby) Mountain coal field, Wasatch County, Utah: U. S. Geol. Survey Bull. 471, p. 607, 1912.

[3] Idem, pp. 607, 608.

[4] Determined by F. R. Clark.

and are equally numerous along the Book Cliffs, which extend southeastward and eastward into Colorado. The upper surfaces of the fans slope from the plateau at angles ranging from almost horizontal to 15°, being steepest near the cliffs. The drift or wash in these remnants is thickest near the cliffs and becomes thinner as the distance from the upland is increased. The greatest thickness of débris or fan material observed at any one place is about 50 feet.

In most places the fans seem to have been formed about the base of a somewhat dissected cliff from which intermittent streams carry large amounts of material. The positions of the alluvial fans of the first stage of erosion, represented now by remnants of fans, show conclusively that the present courses of the streams have changed but little since the time of the formation of the fans, because nowhere, so far as was observed by the writer, does a perennial stream flow through the ruins of one of these once complete erosion forms. Erosion has so thoroughly dissected these old alluvial fans that in places only a few remnants in the forms of mesas and buttes, with sloping upper surfaces, are left to mark the position of a former large fan. Along the Book Cliffs and Wasatch Plateau alluvial fans are formed with considerable rapidity (in the geologic sense) and are dissected with equal speed, because of the fact that the material on which the drift is deposited (Mancos shale) succumbs to erosion as readily as the semiconsolidated detritus of the fans themselves. The older remnants near the cliffs are from 200 to 300 feet above the surrounding country, but a few miles east of the plateau they are low and grade into the floor of Castle Valley.

Remnants of lower and more recent fans are also present, but they are much more nearly complete. The material being eroded at present is being deposited along the base of the Wasatch Plateau in the form of alluvial fans.

TERRACE GRAVELS.

Remnants of gravel-capped terraces, which probably are of the same age as the remnants of the older and higher alluvial fans above described, occur at several places along the streams that cross Castle Valley. One of the most prominent of these remnants is situated in the E. ½ sec. 26, T. 19 S., R. 8 E. It is in the form of a small mesa or butte, the top of which is a few acres in extent and lies about 250 feet above the level of Ferron Creek. The upper 10 to 15 feet of the mesa is a slightly consolidated conglomerate, the pebbles of which consist of well-rounded fragments of yellowish-gray sandstone, gray and drab limestone, quartzitic sandstone, and black cherty material, and range in size from sand grains to bowlders 1 foot in diameter. Another gravel-capped terrace remnant of probably the same age is

situated on the north side of Ferron Creek near the southwest corner of sec. 34, T. 19 S., R. 8 E. A few miles below the junction of Ferron and Cottonwood creeks, on San Rafael River at the west end of Fullers Bottom, is a terrace remnant capped with gravel, its top about 100 feet above the river level, which is believed to be of the same age as those described above. A terrace remnant at a similar height above the stream is situated on the west side of Ferron Creek about 1 mile above its mouth. Other remnants of probably the same age occur along both sides of the same creek about 5 miles above its mouth, in sec. 36, T. 19 S., R 8 E., and sec. 2, T. 20 S., R. 8 E. The pebbles composing the conglomerate in the tops of these terraces are similar in size and composition to those in the conglomerate capping the small mesa in sec. 26, T. 19 S., R. 8 E., referred to above.

Gravel-capped terrace remnants about 50 feet above the stream bed occur on each side of Huntington Creek in secs. 33 and 34, T. 18 S., R. 9 E., and secs. 3, 4, 8, and 9, T. 19 S., R. 9 E. Similar terrace remnants exist along the west side of Ferron Creek about 1 mile above its mouth, along Muddy Creek in secs. 12 and 13, T. 23 S., R. 6 E., and on the north side of Quitchuppah Creek in secs. 28, 32, and 33, T. 22 S., R. 6 E., north and northwest of the Browning mine.

The most conspicuous gravel-capped terraces in the entire field occur directly south of Ivie Creek in T. 23 S., Rs. 5 and 6 E., and T. 24 S., R. 5 E. Five of these terraces, represented by numbers from 1 to 5 on Plate XII, are in the southeastern part of T. 23 S., R. 5 E., and the highest one (No. 6) lies for the most part in secs. 4 and 9, T. 24 S., R. 5 E. The following table shows the average vertical distance between the terraces:

Approximate average vertical distance between terraces south of Ivie Creek.

No.	Feet.	Datum plane.
6	200	Above No. 5.
5	60	Above No. 4.
4	50	Above No. 3.
3	75	Above No. 2.
2	80	Above No. 1.
1	150	Above Ivie Creek.

Some of the terraces are missing in places, as shown on Plate XII, and all of them have been eroded considerably. Terrace No. 5 is more than 6 miles long, but it includes only a little more area than No. 4. The highest terrace (No. 6) is much eroded and covers approximately 1 square mile. Terraces Nos. 1, 2, and 3 cover comparatively small areas, are narrow, and are irregular in outline, but Nos. 4 and 5 have a much larger extent. In general, these terraces slope to the north at an average of 0.5° or more, but in places the upper surfaces slope as much as 4.5°, as, for example, at Windy Point, in the northern part of sec. 1, T. 24 S., R. 5 E.

Directly north of Ivie Creek the terraces are not present, except in a small area included principally in sec. 33, T. 23 S., R. 5 E.

The material composing the greater part of the gravels which cap the terraces consists principally of subangular to rounded fragments of basalt, the largest of which are 4 or 5 feet in diameter. They are derived from the extensive masses of this rock in the vicinity of Mount Hilgard and Mount Alice and to the southwest. In places as much as 20 feet of this material rests unconformably on the Mancos shale.

QUATERNARY SYSTEM.

RECENT SERIES.

The deposits of Recent age comprise the soil which forms a mantle over the greater part of the floor of Castle Valley and which is very productive wherever moisture is sufficient; the low gravel-covered terraces along streams; the low extensive compound alluvial fans along the base of the Wasatch Plateau and lower scarps; and sand dunes of small extent in T. 21 S., Rs. 7 and 8 E.

IGNEOUS ROCKS.

The east face of a basalt-capped upland which connects Mount Hilgard and Thousand Lake Mountain extends northward across secs. 9 and 4, T. 26 S., R. 4 E., and secs. 33 and 28, T. 25 S., R. 4 E., and then veers slightly to the west. No definite information regarding the thickness of these igneous rocks, which are described at length by Dutton,[1] was obtained. In addition to this basalt, a few dikes of the same material occur in sec. 34, T. 25 S., R. 4 E., and in secs. 2 and 11, T. 25 S., R. 5 E.

STRUCTURE.

GENERAL FEATURES.

The structure of Castle Valley is monoclinal and very simple. In general the strata dip slightly to the northwest, but here and there small local domes are present. The beds are probably a little more steeply inclined at the south end of the field than at any other place. The McElmo and La Plata rocks as a rule dip more steeply than the beds stratigraphically above or below them. The younger Mesaverde, Wasatch, and Green River (?) formations lie almost horizontal. Some faulting has occurred along the east scarp of the Wasatch Plateau, at the south end of the field, and on the west slope of Cedar Mountain or Red Plateau.

[1] Dutton, C. E., Report on the geology of the high plateaus of Utah, pp. 271, 280, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

UPFOLDS AND DOMES.

Small local upfolds and domes exist at several places in Castle Valley. They are, named in order from north to south, the Farnham upfold, northeast of Farnham, a flag station on the Denver & Rio Grande Railroad; the Castledale dome, on Cottonwood Creek, about 3 miles east of Castledale; the Paradise dome, south of Ferron Creek and about 8 miles east of the town of Ferron, in the northeastern part of T. 20 S., R. 8 E.; the Rochester upfold, in the southeastern part of T. 21 S., R. 7 E., 3 miles east of Rochester; and the Last Chance Creek dome, in the eastern part of T. 25 S., R. 5 E., directly east of the principal escarpment.

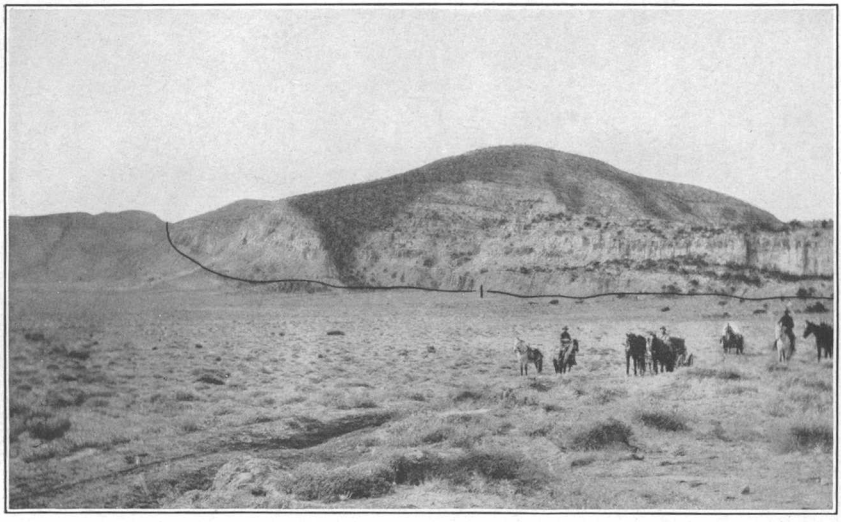
The Farnham upfold, an elliptical anticline situated mainly north of Price River, is 4 or 5 miles long from north to south and about 2 miles wide. Strike faults having displacements of as much as 300 feet, with the upthrown side next to the axis, occur at each side of the fold. On the west side, where the dips are steepest and the displacement is the greatest, step faults are present. Along the east side and north end the dips range from nearly zero to 10° or 15°; on the west side the strata are much more steeply inclined and the dips range from nearly zero some distance from the line of flexure to nearly vertical at one point near the southwest corner of sec. 12, T. 15 S., R. 11 E., where a prominent fault terminates and a flexure begins. The lowest rocks exposed in this eroded upfold belong to the McElmo formation.

The Castledale dome is nearly circular and is about 3 miles in diameter. The beds are horizontal in the center of the uplift but dip as much as 11° at the west side. The dome is slightly dissected by Cottonwood Creek and some of its northern intermittent tributaries.

The Paradise dome is nearly circular and is about 2 miles in diameter. The beds, however, do not dip so steeply as those in the Castledale dome, the maximum dips being 6° W. and 2° E. Erosion has exposed the upper part of the McElmo formation in this dome.

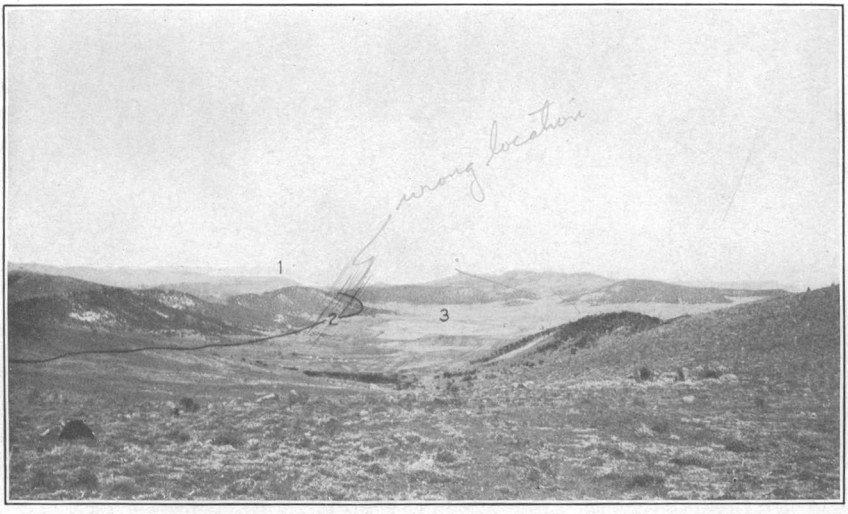
The Rochester upfold is elliptical and is about 2 miles long from northeast to southwest and 1 mile wide. The slight deformation occurring here is apparent only in the Ferron sandstone member of the Mancos shale. The maximum dip of the strata in this upfold is 15° W.; the largest eastern dip is only 6°.

The Last Chance Creek dome is larger than any of the upfolds or domes above described. Only its western and northern limits are shown on Plates X and XII. It was not studied in detail, and the dips shown on the maps are only approximate. These upfolds and domes suggest favorable structure for the accumulation of oil and gas, but there is no definite evidence that they contain these products.



A. EMERY FAULT, NORTH OF IVIE CREEK.

Indicated by heavy black line marked 1. 2, Mesaverde rocks; 3, Mancos shale.



B. PARADISE FAULT, NEAR THE SOUTHWEST END OF THE EMERY COAL FIELD.

1, Youngs Point, a few miles north of Emery; 2, fault; 3, Paradise Lake; 4, Ferron sandstone member of Mancos shale.

Many of them are so small in extent, and one, the Farnham upfold, is so much faulted, that the probabilities that they contain oil or gas in commercial quantities are very remote. Faulting, however, is not always an unfavorable condition for the accumulation of oil and gas in a dome or anticline. The Farnham upfold has been staked for oil once or twice, and it is now reported that a company contemplates drilling there.

FAULTS.

The faults in this area are strike faults—that is, their trend coincides with the strike of the beds—and are situated principally on the west side of Castle Valley near its south end, adjacent to the Wasatch Plateau. Two principal faults, the Emery fault and the Paradise fault, were mapped in considerable detail and are shown on Plates X and XII. Directly west of the Emery fault is a down-dropped block which is broken by numerous minor faults and which is in this report called the faulted zone. Although some of the faults in the faulted zone were mapped, no attempt was made to locate in detail all of them.

The Emery fault is about 20 miles long and extends in a southwesterly direction through T. 22 S., Rs. 5 and 6 E., and T. 23 S., R. 5 E., and about 5 miles south into T. 24 S., R. 5 E. It terminates a short distance south of Deer Peak, in sec. 29, T. 24 S., R. 5 E., where it intersects a short concealed east-west fault, the downthrow of which is on the north side. In the vicinity of Emery the downthrow is comparatively small, but it increases toward the southwest to about 2,000 feet near Ivie Creek, in sec. 5, T. 24 S., R. 5 E. It is believed that the Emery fault is continuous from its north end to a point $1\frac{1}{2}$ miles south of Ivie Creek. From this place to its intersection with the east-west fault referred to above its position is covered with surface wash and talus, so that its continuity is somewhat uncertain. The Emery fault in the vicinity of Ivie Creek is well shown by Plate VI, *A*.

The exact location of the east-west fault near Last Chance Creek is not known, but its existence is assumed in order to explain the structure in this immediate locality. As is indicated on both Plates X and XII, the down-faulted block of Mesaverde rocks which includes the faulted zone lies just west of Deer Peak and extends continuously as far north and northeast as Emery. A mile or more south of the assumed east-west fault beds of the Ferron sandstone member crop out along Last Chance Creek and are unbroken by even minor faults from the prominent escarpment in sec. 9, T. 25 S., R. 5 E., as far west as the Paradise fault, in sec. 1, T. 25 S., R. 4 E. These relations necessitate the assumption of a displacement of 2,500 to 3,000 feet along an east-west line.

On Deer Peak, in sec. 29, T. 24 S., R. 5 E., there are several small strike faults where the Mesaverde strata have been dragged up with the Mancos shale, which lies east of the faults. The prevailing dips are to the west.

The faulted zone west of the Emery fault is a down-dropped block of Mesaverde rocks, which has been broken into smaller blocks principally by numerous strike faults. In places it is as much as 3 miles in width, but elsewhere it is very narrow, and to the north it probably connects with the Pleasant Valley and Joes Valley faults described by Taff.[1] This faulted belt extends parallel to the Emery fault and was studied with especial care along Ivie Creek in secs. 5 and 6, T. 24 S., R. 5 E., where the strata are well exposed. Directly west of the Emery fault in this locality there is a block of Mesaverde strata from 1,000 to 1,500 feet wide, dipping about 31° W., whereas the rocks lying directly west of this block are much more nearly horizontal, dipping only 1° to 10° W. This attitude of the strata is to be expected from the fact that the faulted zone on the west side of the fault has been dropped, but those beds lying immediately west of the fault have been retarded in their descent, thus producing steep dips in the strata near the fault and gradually decreasing dips toward the west away from the fault.

Several other minor faults of slight throw cross Ivie Creek between the Emery fault and the Paradise fault, which in this locality is marked approximately by the edge of the prominent escarpment that exposes several hundred feet of that part of the Mancos shale above the Ferron sandstone member and the overlying Mesaverde strata. The faulted zone becomes less prominent south of Ivie Creek and terminates at the short east-west fault about a mile north of Last Chance Creek. The displacement due to faults within the faulted zone is much less than at the edges of this enormous down-faulted block, where the maximum displacement is approximately 2,000 feet.

The Paradise fault was mapped in detail from Ivie Creek to the south end of the field, in sec. 4, T. 26 S., R. 4 E. Its position north of Ivie Creek is given only approximately. This fault probably connects directly with the Mille Lac (Thousand Lake) fault, which was first described by Gilbert[2] in his report on the Henry Mountains. Plate VI, *B*, shows the Paradise fault near Paradise Lake, at the south end of the field. North of the east-west fault about a mile north of Last Chance Creek the Paradise fault has its downthrow on the east side, but south of that locality the downthrow is on the west side. At Last Chance Creek the strata west of the fault have been dropped 2,000 to 3,000 feet, the displacement

[1] Taff, J. A., The Pleasant Valley coal district, Carbon and Emery counties, Utah: U. S. Geol. Survey Bull. 316, pp. 343–346, pl. 20, 1907.

[2] Gilbert, G. K., op. cit., pl. 2.

equaling the thickness of the Mancos shale above the Ferron sandstone member, as is shown by the fact that the top of that sandstone on the east side of the fault is now at the level of the lower part of the Mesaverde formation on the west side of the fault. It is believed that the displacement at the south end of the field is probably 500 feet more than that at Last Chance Creek.

The faults within the Farnham upfold have been referred to above (p. 40). The principal fault on the west side of the fold extends more than a mile south of Price River. In the northern part of sec. 27, T. 15 S., R. 11 E., it strikes N. 40° E. and has a displacement of about 200 feet, the downthrow being on the east side. North of Price River the maximum throw is at least 300 feet.

A few faults exist on the west slope of Cedar Mountain or Red Plateau, near the north end of the field. One of these has a throw of possibly 200 or 300 feet and is from 2 to 4 miles in length. Other minor faults, mainly of this same type, occur at the south end of Cedar Mountain.

THE COAL.

GENERAL FEATURES.

The coal field herein described (see Pl. X, p. 74) lies east, south, and southwest of Emery. The coal, as shown by its resistance to weathering ("stocking" qualities) and its chemical composition, is a good bituminous coal. All the commercially important coal beds in this field occur in the Ferron sandstone member of the Mancos shale, which was mapped from Mounds southwestward for about 80 miles, to the south end of the field, in the northern part of T. 26 S., R. 4 E. The northernmost coal of importance appearing at the surface in the Ferron sandstone crops out in sec. 26, T. 21 S., R. 7 E. From this locality to the southern edge of the field no one coal bed was found to be continuous for the entire distance of 33 miles, but coal is present in one or more beds at every place examined, except in part of T. 22 S., R. 7 E. (see Pl. X), where the coal-bearing rocks are believed to be barren of coal of economic importance. The Ferron sandstone contains 14 coal beds in the Emery coal field. These beds are designated on Plates VIII, IX, and X by the letters A to L, La, and M. Bed A is the lowest and bed M the highest stratigraphically.

The Dakota sandstone in places contains thin lenses of coal which are of little or no economic importance compared with the coal in the Ferron sandstone member in Castle Valley and in the Wasatch Plateau field, to the west. This coal is discussed in detail under "Coal in the Dakota sandstone" (pp. 74–76).

Good coal occurs in the Mesaverde rocks that crop out in the east face of the Wasatch Plateau immediately west of the Emery coal field, but only one section of this coal (No. 422, near Paradise Lake)

was measured. Plate X (p. 74) shows the outcrop of the coal beds in the Ferron sandstone member and the prospects, mines, and exposures where the coal beds were measured, as well as roads, houses, streams, faults, dikes, geologic boundaries, and the principal sandstone cliffs. The locations at which the coal was measured are indicated by numbers, which are arranged on the map and described in the text by townships in order from north to south. The beds are considered from the base of the coal group upward, except in the description of the coal in T. 21 S., R. 7 E., where a coal bed is described whose correlation with any coal in the township to the south is unknown. The areas of clinker indicated on the map represent localities where the coal has been burned along the outcrop. South of Ivie Creek the approximate elevations of numerous points on the coal outcrops as well as elsewhere are shown. A comparison of these altitudes will indicate something of the topography and relief.

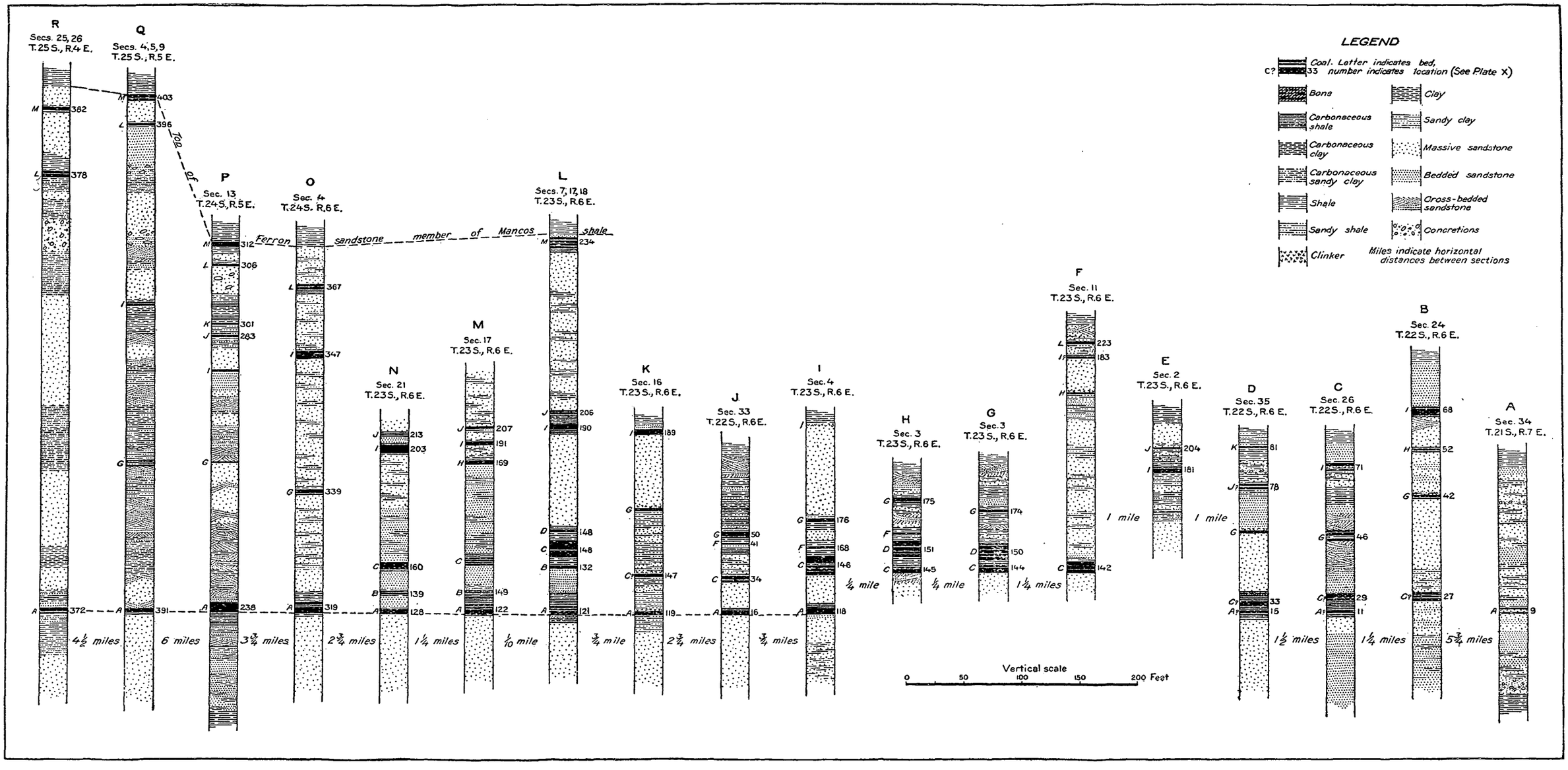
CORRELATION OF COAL BEDS IN FERRON SANDSTONE MEMBER OF MANCOS SHALE.

Plate VII (p. 44) shows 18 graphic sections of beds that contain more or less coal. They are arranged on the plate from right to left in order as they appear, from northeast to southwest, along the outcrop of the coal-bearing formation. These sections show something of the vertical distribution, the variation in occurrence, and the change in the distances between the coal beds in the Emery field. The localities at which these sections were measured are indicated on the map (Pl. X) by letters corresponding to those placed at the tops of the sections on Plate VII. The letters at the left of the sections indicate coal beds. The figures at the right of the sections refer to the coal sections measured at those places, and for the most part shown graphically on Plates VIII and IX. The approximate distances between the places at which the sections were measured are also shown.

Some of the coal beds that occur near the middle of the Ferron sandstone on Ivie Creek (see sections K and L, Pl. VII) are either thin or not exposed at the surface at the south end of the coal field (see sections P, Q, and R, Pl. VII). Many of the sections do not show all the coal beds, but the lack may be due to poor exposures rather than to the absence of certain beds.

Wherever the correlation of the coal beds in the Emery field is doubtful a question mark is placed after the letter at the left of the coal bed. (See Pl. VII.)

Columnar section A, measured in the NW. ¼ SE. ¼ sec. 34, T. 21 S., R. 7 E., shows the presence of only one coal bed (A, coal section No. 9), which is described on page 48.



COLUMNAR SECTIONS SHOWING THE STRATIGRAPHIC POSITION OF COAL BEDS IN THE FERRON SANDSTONE MEMBER OF THE MANCOS SHALE IN THE EMERY COAL FIELD.

Columnar section B, measured in the SW. ¼ NW. ¼ sec. 24, T. 22 S., R. 6 E., shows four coal beds (beds C (?), G, H, and I). Beds C (?) and I are unquestionably of commercial value at this place, but beds G and H are of little economic importance. Coal beds A and B are not exposed at the surface at this locality.

Columnar section C, measured in the NE. ¼ sec. 26, T. 22 S., R. 6 E., shows that the thickness of the rocks between beds C (?) and G is less than it is in section B, but the distance between beds G and I is about the same in both sections. Bed H is not exposed at the place where section C was measured. Bed A (?) contains 1 foot of coal and lies approximately 10 feet below bed C (?), which contains more coal than any of the other beds.

Columnar section D in a stratigraphic distance of 150 feet includes coal beds A (?), C (?), G, J (?), and K. This section was measured in the SW. ¼ SE. ¼ sec. 35, T. 22 S., R. 6 E. Bed C (?) is here also the principal bed.

Columnar section E, measured in the NW. ¼ SW. ¼ sec. 2, T. 23 S., R. 6 E., includes only two coal beds. Bed I was measured near the old Emery mine, at location 181. Bed J, at location 204, is about 15 feet stratigraphically above bed I and is of little value.

Columnar section F was measured in the SE. ¼ NW. ¼ sec. 11, T. 23 S., R. 6 E., and includes coal beds C, H, I (?), and L. Bed I (?) lies about 185 feet above bed C, and bed L is 10 feet above bed I (?). The horizon of bed H is represented by a slight indication of burning at the outcrop. Bed C is the principal bed in this locality. (See coal section 142, Pl. VIII.)

Columnar section G, measured in the NE. ¼ SW. ¼ sec. 3, T. 23 S., R. 6 E., includes coal beds C, D, and G. Bed C is the lowest coal exposed at this place. Bed D lies about 4 feet stratigraphically above bed C, and bed G, which is of little value, lies about 35 feet above bed C.

Columnar section H, measured in the N. ½ S. ½ sec. 3, T. 23 S., R. 6 E., directly across a narrow valley from the place where columnar section G was measured, shows the same coal beds as section G and in addition bed F. The thickness of the rocks between beds D and G in this section is about 10 feet greater than in columnar section G, measured across the valley. The stratigraphic distance between beds C and D is also a few feet greater in section H than in section G. Columnar sections G and H show more coal in their lower parts than any of the other columnar sections measured.

Columnar section I, measured in the NE. ¼ SE. ¼ sec. 4, T. 23 S., R. 6 E., includes coal beds A, C, F, and G and the horizon of bed I at the top. Bed D, however, may be represented by the upper bench of coal in bed C. (See coal section 146, Pl. VIII.) The horizon of

coal bed I, stratigraphically about 85 feet above bed G (location 176), is marked by a band of baked clay and slag.

Coal beds A, C, F, and G are included in columnar section J, measured in the SW. ¼ SE. ¼ sec. 33, T. 22 S., R. 6 E. The stratigraphic distance between coal beds C and F is at least 10 feet greater in this section than in columnar section I. The distance between coal beds F and G in section J is correspondingly less than in section I.

Columnar section K, measured in the W. ½ sec. 16, T. 23 S., R. 6 E., shows the position of coal beds A, C (?), G, and I. Bed G at this place contains 2 feet of unburned coal and much baked clay. The stratigraphic distance between coal beds A and C (?) is about 35 feet, which is practically the same as the distance between these beds in columnar section J, but the distance between beds C (?) and G is from 20 to 25 feet greater in section K than in section J. Bed I is the only coal shown in section K in which the entire coal bed was exposed. Beds A and C (?) are represented merely by bands of ashes and baked clay. Bed C (?) possibly should be correlated with bed B in columnar section L.

Seven coal beds are included in columnar section L, measured in secs. 7, 17, and 18, T. 23 S., R. 6 E. These are beds A, B, C, D, I, J, and M. This section shows more coal beds and a greater total thickness of coal than columnar section K, a fact which is due in part to the poor exposures at the place where section K was measured. It is believed, however, that as many coal beds exist directly north of Ivie Creek at the location of section K as there are at the location where section L was measured. The distances between bed A and bed I are practically the same in sections K and L.

Columnar section M was measured in the NW. ¼ SE. ¼ sec. 17, T. 23 S., R. 6 E., and includes coal beds A, B, C, H, I, and J. The stratigraphic distance between beds A and B is much less at this place than where columnar section L was measured. Coal bed C is represented by a bed of brown carbonaceous shale with a little coal interbedded. Beds H and I contain about the same amount of coal (a little more than 3 feet) and are separated by about 13 feet of strata.

Columnar section N includes five coal beds—beds A, B, C, I, and J—and was measured in the SW. ¼ sec. 21, T. 23 S., R. 6 E. Coal beds B and C are undoubtedly the same as those designated B and C in columnar section M. Beds I and J are definitely correlated with beds I and J in columnar sections L and M. Coal beds D, E, F, G, and H are not exposed at the locality where columnar section N was measured.

Only four coal beds, A, G, I, and L, are included in columnar section O, which was measured in lot 9, sec. 4, T. 24 S., R. 6 E. The others, beds B, C, D, E, F, H, J, and K, are not exposed and are

believed to be of little importance at this locality. Bed A is the most valuable coal bed in this section, and is stratigraphically about 95 feet below bed G. Bed I, which is second in value, lies about 120 feet above bed G, or about 55 feet below bed L.

Columnar section P, measured in the N. ½ sec. 13, T. 24 S., R. 5 E., includes seven coal beds (A, G, I, J, K, L, and M). Coal beds A and M are the most valuable, but the other beds are of no economic importance at the outcrop. Beds B, C, D, E, F, and H are not exposed where this section was measured.

Five coal beds (A, G, I, L, and M) are included in columnar section Q, which was measured in secs. 4, 5, and 9, T. 25 S., R. 5 E. Bed A is about 440 feet stratigraphically below bed L, and bed M about 20 feet above bed L. Beds G and I are of little value. The rocks separating the coal beds consist principally of sandstone and sandy shale. Coal bed M contains the greatest thickness of coal, as indicated on Plate IX by coal section No. 403.

Columnar section R, measured in secs. 25 and 26, T. 25 S., R. 4 E., shows three coal beds (A, L, and M). Beds A and M contain a little less coal here than at the location of columnar section Q, but bed L contains more coal. The distance between coal beds A and L is less and that between beds L and M greater at the location of columnar section R than at the location of section Q.

OCCURRENCE.

COAL IN THE FERRON SANDSTONE MEMBER OF THE MANCOS SHALE.

T. 21 S., R. 7 E.

Ten coal sections were measured in secs. 26, 27, 34, and 35, T. 21 S., R. 7 E., along the outcrop of one coal bed, which probably should be correlated with bed B in the townships to the south. Of these 10 coal sections Nos. 4, 5, 6, 7, and 8 are shown graphically in Plate VIII. The coal, as shown by the graphic sections, ranges in thickness from 1 foot 11 inches to 2 feet 4 inches. At each place the coal is overlain and underlain by shale, except at location 4, where it is overlain by sandstone. At locations 1, 2, 3, 9, and 10, on the north margin of the field, this coal bed is thinner than it is to the south. The sections measured at these locations are not shown graphically, but are as follows:

Sections of coal bed B (?) in T. 21 S., R. 7 E.

[In addition to those shown on Plate VIII.]

No. 1. SW. ¼ SW. ¼ sec. 26.

	Ft.	In.
Sandstone, yellowish gray, massive	35–40	
Shale, carbonaceous, sandy		8
Coal, very impure		11
Sandstone, brownish gray, argillaceous	+	

No. 2. NE. ¼ NW. ¼ sec. 35.

	Ft.	in.
Sandstone, brown, carbonaceous	6	6
Shale, brown, sandy		1
Coal	1	3
Shale, carbonaceous, sandy		6±

No. 3. SE. ¼ NW. ¼ sec. 35.

Sandstone, carbonaceous, grading into brown shale at base	3+	
Coal		8½
Shale, brown, carbonaceous		1+

No. 9. NW. ¼ SE. ¼ sec. 34.

Shale, brown to black, carbonaceous	1	11
Coal, impure		1
Shale, sandy, carbonaceous, includes thin streaks of coal		4
Sandstone, brown, very carbonaceous	3	0
Shale, brown, contains a few thin bands of coal		2½
Coal, very impure		4
Shale carbonaceous		6

No. 10. NE. ¼ SW. ¼ sec. 34.

Sandstone, yellowish gray, thin-bedded, carbonaceous in lower part	3	0
Shale, brown, carbonaceous		10
Coal	1	0
Shale, brown, carbonaceous	1+	

It is believed that the southeastern part of this township marks the northern extent of coal in the Emery coal field. No coal is exposed in the Ferron sandstone farther north in Castle Valley between this township and the Denver & Rio Grande Railroad at Mounds, although in places much carbonaceous shale is present, especially east of Molen, in secs. 16 and 21, T. 20 S., R. 8 E.

T. 22 S., R. 6 E.

Seventy-two sections were measured on the coal beds in T. 22 S., R. 6 E. The following table shows the number of sections obtained on each bed, and columnar sections B, C, and D on Plate VII show the stratigraphic distances between the beds:

Coal beds exposed in T. 22 S., R. 6 E.

	Coal sections.		Coal sections.		Coal sections.
L	82	H	51–59	D	35
K	81	G	42–50	C	17–34
J	78–80	F	37–41	A	11–16
I	60–77	E	36		

Bed A.—Coal bed A ranges in thickness from 1 foot at location 11 to 4 feet 11 inches at location 16, the average thickness being about 1 foot 7 inches. All the measurements made on the bed are shown graphically on Plate VIII, except No. 11, which is as follows:

Section of coal bed A at location 11, in the SE. ¼ sec. 26, T. 22 S., R. 6 E.

	Feet.
Shale, brown, carbonaceous, with thin lenses of coal near base	10
Coal, bony, dull	1
Shale, brown, weathers bluish	4

The shale that forms the roof of the coal in this section is the floor of bed C at location 19. The five graphic sections (Pl. VIII) show similarities in thickness of coal and in the character of the roof and floor, except at location 16, where the coal is much thicker and the roof and floor are sandstone. As in places the correlations are doubtful, the abrupt change in thickness of bed A at location 16 suggests a possibility that this section should be correlated with bed C.

Bed C.—Bed C in this township shows considerable variation in thickness and character along its outcrop from north to south, its thickness ranging from 4 feet at location 25 to about 13 feet at location 30. At location 17, in the SE. ¼ NE. ¼ sec. 25, the bed contains several inches more coal than it does at location 18, where it is about 7½ feet thick, but the arrangement of the partings in general is the same. In a distance of less than a quarter of a mile the lower 2-foot bench of coal at location 17 becomes entirely worthless, and at location 18 it is replaced by carbonaceous shale. Sections at locations 19, 20, and 21 each contain approximately 7 feet of coal, but the upper 3-inch parting at location 19 is not present at locations 20 and 21. At location 22, on the north side of Grassy Valley, in the NE. ¼ NE. ¼ sec. 24, the bed is more broken than it is at locations 20 and 21, and more nearly resembles the section at location 17 than any of the other sections between locations 17 and 22. Bed C at locations 23, 24, and 25 contains less coal than at any of the other locations mentioned, a fact which seems to indicate that the bed thins toward the south; but the section measured at location 26, in the SE. ¼ SW. ¼ sec. 13, about 1½ miles north of location 25, shows a great thickness of coal (7 feet 2 inches) compared with the section at location 25. The character of the roof changes toward the west and north from location 25, so that sandstone rests directly on the coal to a point beyond location 32. Sections at locations 26, 27, and 28 were measured along the outcrop from north to south and show that the bed is thinner on the west side as well as on the east side of Muddy Creek, toward the south. (See Pl. VIII.) This apparent decrease in the thickness ends abruptly, for at location 29, the old

Casper mine, in the SE. ¼ NW. ¼ sec. 26, bed C contains 8 feet 5 inches of coal in two benches. In mining the coal from the Casper mine only the lower bench is removed. A sample for analysis (laboratory No. 12652, p. 80) was taken from this mine. (See Pl. XI, *B*, p. 84.) At location 30, about a quarter of a mile south of the Casper mine, bed C contains 11 feet 3 inches of coal, or 2 feet 10 inches more than at location 29. The bed at location 30 is much broken by partings, but only two of them would be of special disadvantage in mining. At the next point at which the bed was measured (location 31) only 5 feet of coal in two benches is present. Both benches can be mined easily by using the 1-foot shale parting (see Pl. VIII) as a "mining seam." At location 32 the total thickness of the bed is about the same as at location 31, but more coal is present at location 32 because of the decrease in the thickness of the partings. At location 33 the bed is much broken, and probably only the lower portion will be mined. Westward from location 33 to location 34, a distance of about 2 miles, the coal bed continues fairly constant in thickness.

A careful study of the graphic sections of bed C (Pl. VIII) shows the coal to be badly split by partings and irregular in thickness. It is believed, however, that bed C is more constant in thickness than some of the beds farther south, which in places contain more coal than is exposed at any point on bed C in this township. For these reasons bed C probably holds out greater inducements for future development than some of the beds farther south which are apparently thicker.

Bed D.—Coal bed D was measured at only one place, location 35, in the SE. ¼ NE. ¼ sec. 26, where it is represented by 5 inches of coal overlain by sandstone and underlain by brown carbonaceous shale.

Bed E.—Location 36 marks the position of bed E and is the only place in the township where this coal was measured. Bed E contains 9 inches of coal, overlain and underlain by yellowish-gray massive sandstone and is 24 feet 6 inches stratigraphically above bed D.

Bed F.—Five sections of bed F were measured in this township, but the coal is of little value at every place. It is thickest at location 37, in sec. 26, where it contains 1 foot 2 inches of coal overlain by sandstone and underlain by shale, and thinnest at location 38, where thin laminæ of coal interbedded with drab shale are exposed. Five inches of coal, overlain and underlain by brown carbonaceous shale, is exposed at the horizon of bed F at location 39, in the SE. ¼ NW. ¼ sec. 26. About 150 feet north of this place the bed is entirely replaced by massive sandstone, whereas at location 40 bed F contains 6 inches of coal overlain and underlain by brown shale. At location 41 the bed contains 10 inches of fairly good coal overlain and underlain by brown carbonaceous shale.

Bed G.—Nine sections on bed G were measured in this township. It ranges in thickness from 11 inches at location 47 to 4 feet 4 inches at location 50. Five of the sections (Nos. 43, 45, 46, 49, and 50) are shown graphically in Plate VIII. The others are as follows:

Sections of coal bed G in T. 22 S., R. 6 E.

[In addition to those shown on Plate VIII.]

No. 42. SW. ¼ NW. ¼ sec. 24.

	Ft.	in.
Sandstone and shale, brown, carbonaceous; contains a few thin laminæ of coal near base	2	0
Coal, fair, weathered	1	3
Shale, brown, carbonaceous		6

No. 44. SE. ¼ NE. ¼ sec. 26.

Shale, brown, sandy, carbonaceous		7
Coal, fair; contains a few thin laminæ of shale		5
Shale, brown, carbonaceous, sandy, with a few thin lenses of coal	2	0
Coal, weathered		11
Shale, brown, carbonaceous	6+	

No. 47. SE. ¼ SW. ¼ sec. 35.

Shale, sandy, with thin lenses of coal		6
Coal, dull, with a little carbonaceous shale		7
Coal, fair		4
Shale, brown, carbonaceous	1+	
Coal bed		11

The correlation of all these sections with bed G is rather indefinite because of the lenticular character of the thinner coal beds in this part of the field. At location 44 bed G is broken by a 2-foot shale parting which renders the bed practically worthless for mining, but at location 45 the bed is more valuable, as shown by the section in Plate VIII. At location 48 it contains 1 foot 9½ inches of poor coal. Bed G at the last place measured (location 50, in sec. 33) is thicker (see Pl. VIII) than at any other point examined in the township, the principal bench being 3 feet 9 inches thick, with a minor bench above.

Bed H.—The coal in bed H was measured at nine places in this township—at locations 51 to 59—but only three of the coal sections (Nos. 53, 55, and 59) are shown graphically in Plate VIII. The others are described below. The maximum thickness is 3 feet at location 53. At location 51, in sec. 13, there is only 6 inches of coal overlain and underlain by sandstone, and at location 52 the bed contains 7½ inches of coal overlain and underlain by brown carbonaceous shale. The bed at location 53, in the NE. ¼ sec. 26, contains

approximately 3 feet of weathered coal overlain and underlain by sandstone, but this measurement may be incomplete. At location 54, in the E. ½ sec. 26, 1 foot 1 inch of coal, overlain by yellowish-gray sandstone and underlain by brown carbonaceous shale, is exposed on bed H, but at location 55, a short distance to the south, the bed is a little thicker, containing 1 foot 4 inches of coal, overlain and underlain by shale. The coal bed at location 56, in sec. 35, is as follows:

Section of coal bed H at location 56, in the SE. ¼ NE. ¼ sec. 35, T. 22 S., R. 6 E.

	Ft.	in.
Shale, brown, carbonaceous		1
Coal, much weathered, bony at top		9
Shale, brown, carbonaceous		3
Coal, impure, slightly shaly		4
Shale, dark, weathers gray		4
Coal, weathered, stained yellow in places		11
Bone, containing thin lenses of coal	2	0
Coal bed	2	7
Total coal	2	0

The coal at this place is of little economic importance, owing to the partings. At location 57, in sec. 35, 1 foot 2 inches of coal, overlain and underlain by brown carbonaceous shale, is exposed on bed H, and at location 58, in the same section, 1 foot 2 inches of coal is exposed, the upper part of which is slightly shaly. The floor and roof of the bed are brown carbonaceous shale. At location 59, in sec. 34, bed H contains 1 foot 8 inches of good coal, overlain and underlain by brown carbonaceous shale. Owing to the lenticular character of the coal at this horizon, exact correlations are rather difficult to make, but it is believed that the above-described sections are all on coal bed H.

Bed I.—Coal bed I was measured in this township at 18 locations, designated by Nos. 60 to 77, which are arranged in order from north to south along the outcrop. All the sections are shown graphically in Plate VIII, except No. 77, which is described below. The bed ranges in thickness from 1 foot at location 77 to 20 feet at location 75. The Moore mine, at location 60, in sec. 13, is the easternmost point at which bed I is exposed. About a quarter of a mile northwest of location 60 bed I was measured at two points in what is known as the Williams mine. (See Pl. XI, *A*, p. 84.) Coal section 61 gives the thickness of the coal at the mouth of the entry, and section 62 shows its thickness at the back end of the entry, about 200 feet S. 60° E. from location 61. The variation of the bed within a short distance is very striking, as is well illustrated by the graphic sections (Nos. 61 and 62, Pl. VIII). Near the mouth of the mine

the joints of the coal are filled with films of gypsum and sulphur. A sample was collected at location 62, and the analysis (laboratory No. 12613) is given in the table on page 80. Sections 63, 64, and 65, all measured less than a mile south of the Williams mine, suggest that bed I increases in thickness toward the south. At location 66, in sec. 13, only 4 feet 9 inches of coal is exposed, which is 3 feet less than the bed contains at location 65, a quarter of a mile to the north. Coal sections 67 and 68 show an apparent increase in thickness toward the south. Bed I rapidly deteriorates in value from location 69 toward location 71, on account of an increase in the thickness and number of partings and a decrease in the thickness of the coal. At location 72 it is of more value than at location 71, containing 3 feet of coal in one bench, overlain by shale and underlain by clay. The coal section at location 73, which is probably on bed I, seems to indicate that the bed is of little commercial importance toward the south, but at location 74, a short distance south of location 73, the bed has about the same thickness as at locations 66 and 67. It maintains this thickness for some distance along the outcrop, but at location 75, in sec. 33, at the Browning mine, it contains approximately 20 feet of coal, overlain and underlain by brown shale. This is the greatest thickness observed for any one bed in the Emery field. A sample for analysis (laboratory No. 12627, p. 80) was collected from the lower 12 feet of coal, which is the only part of the bed mined at this place. Bed I was measured at location 76, in sec. 33, but contains very much less coal here than at the Browning mine. It is only a little over 3 feet thick at location 76, as indicated in Plate VIII. Possibly the section measured at location 76 may represent a coal bed either slightly above or below bed I, as there has been considerable burning between locations 75 and 76. At location 77, in sec. 34, bed I is probably represented by only 1 foot of coal, overlain by clay of varying colors and underlain by grayish-brown sandstone. It is quite probable that the variegated claylike material overlying the coal is in large part ash, and the total thickness under cover may compare very favorably with that measured at the Browning mine (location 75). About a third of a mile northeast of the Browning mine, in sec. 33, there is an old entry on bed I which was partly filled with water at the time of the field examination. The coal was not measured at this place, but it is believed to be approximately as thick here as at the Browning mine.

Bed J.—Bed J was measured at only three locations (Nos. 78, 79, and 80) in this township. At location 78 it contains 2 feet 3 inches of coal in two benches, separated by 1 foot 2 inches of brown shale, beginning 10 inches below the top of the bed, as shown in Plate VIII.

The roof and floor of the bed are shale. At location 79, in sec. 33, the following section was measured:

Section of coal bed J at location 79, in the NE. ¼ SE. ¼ sec. 33, T. 22 S., R. 6 E.

	Ft.	in.
Sandstone, argillaceous		5
Coal, slightly shaly		5
Shale, brown	1	4
Coal		3½
Shale, brown and gray		10
Coal bed	2	½
Total coal		8½

At location 80, in sec. 33, 1 foot 3 inches of coal is exposed on bed J, which is overlain by sandstone and underlain by clay. At this place bed J is 8 feet stratigraphically above bed I.

Bed K.—Bed K is believed to be represented in this township by only one measurement, in sec. 35, where 8 inches of coal is exposed at this horizon.

Bed L.—Bed L was measured at only one place in this township, where the section is as follows:

Section of coal bed L at location 82, in the SW. ¼ NW. ¼ sec. 33, T. 22 S., R. 6 E.

	Ft.	in.
Sandstone, yellow and brown	10	0
Coal, with thin lenses of shale		4
Shale		4
Coal	1	0
Shale, gray and brown	4	0
Coal bed	1	8
Total coal	1	4

In many places in this township correlation of the coal sections is very definite, but in others it is rather doubtful, owing to the facts that some of the beds are thin and lenticular and that "burning" and talus cover have obscured the outcrops. It is believed that the correlations given above are as nearly correct as it is possible to make without drilling.

T. 22 S., R. 7 E.

In T. 22 S., R. 7 E., 34 sections were measured—Nos. 84 to 97 on coal bed C, 98 to 109 on bed F, and 110 to 117 on bed I.

Bed C.—Bed C ranges in thickness from 5 inches at location 89 to 8 feet 5 inches at location 87. Seven of the measurements made on bed C (Nos. 85, 86, 87, 88, 90, 91, and 92) are shown graphically on Plate VIII. The others are given in detail below:

Section of coal bed C at location 84, in the NE. ¼ SW. ¼ sec. 30, T. 22 S., R. 7 E.

	Ft.	in.
Sandstone, massive; weathers gray	10+	
Coal		4
Sandstone		2½
Coal	1	0
Sandstone		4
Coal bed	1	6½
Total coal	1	4

The coal at locations 85 and 86 is between 5 and 7 feet thick, but at location 87 the bed shows a marked increase in the amount of coal and also in the number of thin shale partings. At location 88, in lot 1, sec. 19, a short distance west of location 87, the total thickness of the coal bed is practically the same as at location 87, but the character and arrangement of the benches are entirely different, as indicated on Plate VIII.

Coal sections at locations 89 to 97, inclusive, in the northeastern part of the township, are correlated with bed C, because they seem to be at the same horizon as bed C elsewhere. At location 89 the bed contains only 5 inches of coal, overlain by sandstone and underlain by shale, but at locations 90, 91, and 92 the thickness ranges from 1 foot 8 inches to 2 feet 2 inches, being greatest at location 91. (See Pl. VIII.) At location 93, in sec. 10, 1 foot 1 inch of coal is exposed on bed C, but at location 94, in the same section, only 7 inches of weathered coal is exposed. Sandstone overlies and shale underlies the bed at locations 93 and 94. At location 95 the following section was measured:

Section of coal bed at C at location 95, in the NE. ¼ NE. ¼ sec. 10, T. 22 S., R. 7 E.

Sandstone, gray.	Inches.
Coal	3
Shale, black carbonaceous	1
Coal, slightly bony	7
Shale, black carbonaceous	10
Coal bed	11
Total coal	10

At location 96, in sec. 10, 1 foot 3 inches of coal was measured, and at location 97, in sec. 3, the bed is only 11 inches thick. The bed at each location is overlain by sandstone and underlain by shale.

Bed F.—In the southwestern part of this township bed F was measured at 12 places, which are indicated on the map (Pl. X) and on the plate of coal sections (Pl. VIII) by Nos. 98 to 109, inclusive. The character of the floor and roof and the thickness and character of the bed in this township are well shown in the graphic sections.

Bed F in this region is reasonably constant in thickness, ranging from 1 foot 9 inches at location 105 to 4 feet 10 inches at location 109, and is only locally split by partings. At location 103 the coal occurs in two benches, the lower of which probably is the same as the lower bench at location 104 and is of no economic importance. The upper bench contains 2 feet 3 inches of coal.

Bed I.—The identification of bed I in this township is uncertain, although coal sections measured at locations 110 to 117, in secs. 7 and 18, are tentatively correlated with bed I for the reason that they occur at about the same stratigraphic position as bed I elsewhere throughout the field. In this township the bed varies in thickness from 10 inches at location 115 to 1 foot 7 inches at location 112. At the Cox prospect, location 110, it contains 1 foot 4 inches of coal, overlain by sandstone and underlain by shale. Bed I in this locality is definitely known to be lenticular because it is entirely replaced by massive yellowish-gray sandstone a short distance east of this prospect. Eleven inches of coal, overlain and underlain by brown carbonaceous shale, is exposed at location 111. The coal bed at location 112 is shown graphically on Plate VIII. In the NE. ¼ SE. ¼ sec. 7, at location 113, 1 foot 1 inch of coal with shale floor and roof is exposed. At location 115, 10 inches of coal is exposed, and at location 116, in sec. 18, 1 foot 1 inch of coal, overlain by sandstone and underlain by shale, is exposed on the south side of a road leading east from Emery. Bed I contains about 1 foot of coal at location 117, in sec. 18, where sandstone underlies and shale overlies the coal.

T. 23 S., R. 6 E.

Thirteen coal beds are exposed in T. 23 S., R. 6 E., and 120 measurements of the thickness of the coal in the different beds were made. The following table shows the number of sections obtained on each bed:

Coal beds exposed in T. 23 S., R. 6 E.

	Coal sections.		Coal sections.
M	233–237	F	153–159, 162–168
L	219–232	E	152
K	216–218	D	148, 150, 151
J	204–215	C	133–138, 140–148, 160, 161
I	180–203	B	132, 139, 149
H	169, 177–179	A	118–131
G	170–176		

The usual order of the description of coal in each township, namely, by beds from the north side of the township along the outcrop to the south side, is varied for this township, the beds south of Ivie Creek, except bed I, being described before those north of that stream.

Bed A.—The thickness of bed A was measured at 14 places in this township, designated on the map (Pl. X) by Nos. 118 to 131. All these sections except Nos. 119 and 127 are shown graphically on Plate VIII. The bed ranges in thickness from 1 foot 11 inches at location 124 to 10 feet 1 inch at location 118. The overlying sandstone at locations 118 and 120 forms an excellent roof. At location 119, in sec. 16, no coal is exposed on bed A, but its horizon could be definitely traced by a streak of brown shale and sandy clay at a distance of 15 feet above the lowermost massive sandstone scarp. At location 121, in sec. 17, coal is exposed on what is believed to be bed A, but the bed is very much broken at this place and closely resembles, in the number of partings, the coal bed at location 118. The roof is brown carbonaceous shale grading upward into sandy shale and that into sandstone. At location 122, in sec. 17, the bed contains 6 feet 8 inches of coal in three benches. At location 124, in sec. 20, it contains only 1 foot 4 inches of coal in two benches, separated by 7 inches of carbonaceous shale. The correlation of coal section 124 with others here referred to bed A is doubtful on account of the greatly reduced thickness of the coal, but its stratigraphic distance above the lower sandstone scarp indicates that it is at the horizon of bed A, as heretofore stated. At location 127, in the NE. ¼ NW. ¼ sec. 21, bed A consists mainly of carbonaceous shale interbedded with some coal. The bed is about 8 feet thick, of which about 2½ feet is coal in several thin layers.

Bed B.—The coal that is assigned to bed B was measured in this township at only three places, locations 132 and 149, in sec. 17, and 139, in sec. 21. At location 132 the bed contains 1 foot 8 inches of coal, overlain by shale and underlain by sandstone, and at location 139 it contains 1 foot 9 inches of coal in two benches, separated by a 1-inch shale parting 5 inches below the top of the bed. At location 149, in the NW. ¼ SE. ¼ sec. 17, the bed is represented by only 9 inches of coal, overlain by carbonaceous shale and underlain by yellowish-gray bone.

Bed C.—Bed C was measured at 17 places in this township, indicated on the map (Pl. X) by Nos. 133 to 138, 140 to 148, 160, and 161. All the sections are shown graphically on Plate VIII, except No. 147. If the suggested correlation is correct, bed C in sec. 20 is probably lenticular and of little value. At location 134 a lens of coal of undetermined extent is of workable thickness, but at location 136 the coal is impure and of no immediate importance. Between locations 137 and 140, in secs. 21 and 28, the sections measured at the outcrop indicate that the bed is comparatively free from partings and constant in thickness, ranging from 1 foot 10 inches to 2 feet 6 inches or more except at locations 160 and 161, where an

unusual amount of coal is present. The upper 1 foot 3 inch bench at location 161 possibly corresponds to the bed as represented by coal sections 137, 138, and 140. At location 141, on an outlier in sec. 34, bed C contains 6 feet of coal in two benches, which is more than double the thickness of coal at any location on this bed in this township previously described, except 134.

In the northern part of the township bed C contains generally more coal than is exposed in the southern part. Between locations 142, in sec. 11, and 145, in sec. 3, the bed ranges from about 6 to 9½ feet, including partings which, though usually thin, separate the bed into two or more benches. These partings will probably give no serious trouble in mining. If locations 145 and 146 are at the same horizon, bed C increases in thickness very rapidly westward from location 145. The section at location 146, about a quarter of a mile distant, shows more than double the amount of coal exposed at location 145. Bed C in secs. 16 and 17 is extremely lenticular in its occurrence according to sections measured at locations 147 and 148. At location 147 no coal is exposed at the horizon of this bed, but only a carbonaceous shale band, whereas at location 148, a mile to the west, 13 feet 4 inches of coal in three benches is exposed on bed C. (See Pl. VIII.)

Bed D.—Bed D was measured at locations 148, 150, and 151, in sec. 3. At location 150 the bed contains 12 feet 6 inches of coal in six benches, and at location 151 it contains only 11 feet 1 inch in five benches. The arrangement of the benches and partings between them is shown graphically on Plate VIII. Only 1 foot 6 inches of coal is contained in bed D at location 148.

Bed E.—Location 152, in sec. 3, is the only place at which bed E was measured in this township. It contains only 10½ inches of coal overlain and underlain by shale.

Bed F.—Bed F was measured at 14 places in this township, shown on the map (Pl. X) by Nos. 153 to 159 and 162 to 168. Plate VIII gives the coal sections measured at these locations, except Nos. 153, 155, and 168. This coal is of little value along the outcrop through the western part of sec. 20 and through sec. 29, as may be inferred from the following coal sections: At location 153, in sec. 20, 1 foot 1 inch of coal on bed F contains several thin bands of shale; at location 154, near the center of sec. 29, the bed contains 1 foot 10 inches of coal (see Pl. VIII); and at location 155, near the north line of sec. 29, it contains only 8 inches of coal with a floor and roof of brown shale. Bed F along its outcrop through the eastern part of sec. 20, through sec. 21, and a small portion of sec. 28, at locations 156 to 159, contains a much greater thickness of coal (from 8½ to 9½ feet) than is exposed at any other places examined in this township. (See Pl. VIII.) The total thickness of coal south of location 162 is

greatly reduced by the splitting of the bed into two benches, the lower of which, according to the exposures, is of very little economic importance.

The exposures in secs. 3 and 4 suggest that bed F is very lenticular. At location 167, 2 feet 10 inches of coal is exposed in one bench, whereas at location 168, a few hundred feet to the west, only 6 inches of coal is exposed. The bed is overlain by shale and underlain by sandstone.

Bed G.—Bed G was examined at seven exposures in this township. The locations are shown on the map (Pl. X) and the sections are shown graphically on Plate VIII by Nos. 170 to 176.

At locations 170 and 171, near the line between secs. 29 and 32, bed G contains about 1½ feet of coal, but at location 172, near the center of sec. 29, it contains only 7 inches of coal, overlain and underlain by carbonaceous shale. At location 173, near the north line of sec. 29, bed G contains 2 feet 1 inch of coal in two benches. As may be inferred from the coal sections above given, bed G in secs. 29 and 32 is of little value, being very lenticular. No exposures were seen on the bed between locations 174 in sec. 3 and 173 in sec. 29, probably owing to poor exposures along the outcrop between those places. At locations 174 to 176, inclusive, in secs. 3 and 4 (see Pl. VIII), this bed is more constant in thickness and more persistent in occurrence than it is farther south.

Bed H.—The coal in bed H in this township was measured at locations 169, 177, 178, and 179, secs. 17, 20, and 29. The coal sections are shown graphically on Plate VIII. According to these sections, the bed shows a slight tendency to increase in thickness toward the south. It ranges from 1 foot 4 inches at location 177 to 3 feet 3 inches at location 169. No other exposures at this horizon were found, so that little is known of the occurrence of the bed in this township.

Bed I.—Bed I in this township was measured at 24 places, which are represented on the map (Pl. X) by Nos. 180 to 203. As may be inferred by a careful study of the graphic sections (Pl. VIII), bed I is very lenticular and exhibits very abrupt changes in thickness even between near-by sections. The range in thickness is from 1 foot 3 inches at location 180 to 14 feet 11 inches at location 198. At location 180, in sec. 3, the coal is overlain by gray clay shale and underlain by brown shale which contains streaks of coal. At location 181, in sec. 2, 5 feet 5 inches of coal, overlain and underlain by carbonaceous shale, is exposed on bed I. This section was measured near the Emery mine (abandoned), which at the time of the examination was closed by caving. A sample for analysis (laboratory No. 2386) was collected at the Emery mine by J. A. Taff.[1]

[1] Taff, J. A., Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, p. 294, 1906.

The measurements in this southern half of secs. 2 and 3 at locations 181, 182, 186, and 187 and in sec. 8 at location 188, all of which are believed to be on bed I, suggest a nearly east-west zone where the coal is at least twice as thick as it is on either the north or the south. South of secs. 3, 4, and 8, according to coal sections that are supposed to be on bed I, the coal is much thinner (at locations 183, 184, 185, and 189) as far south as the south line of secs. 16 and 17. Southward from this line, however, a thin lens of coal on bed I is separated from a comparatively thick one (see Pls. VIII and X) by Dog Creek, a southern tributary of Ivie Creek, flowing through secs. 31, 32, 29, 21, 20, and 16. In making the above tentative suggestion it is assumed that the correlation shown on Plate VIII is correct, but this is questionable at several locations, owing mainly to the abrupt changes in the thickness of the coal and to poor exposures between places examined. The correlation of the sections referred to bed I is based on the relation of the outcrops to other known traceable beds.

It is also possible that the entire thickness of coal on bed I is not exposed at locations 183, 184, and 185. At location 193, in sec. 20, coal "bloom" was exposed about 6 feet below the base of bed I, but it was not possible to determine the source of this "bloom." The difference in the thickness of coal between sections at locations 194, in sec. 20, and 195, in sec. 29, is due to a change in thickness of the bed, as there is no doubt about the correlation of these sections. South of location 196 bed I is concealed by alluvial deposits for a distance of a mile or more. The next measurement of the bed was made at a good exposure at location 197, in sec. 32. A sample of coal for analysis (laboratory No. 14903, p. 80) was collected from this surface exposure.

Two thin coal beds (8 inches and 4 inches thick) crop out at distances of 17 and 28 feet, respectively, above bed I at location 199, in sec. 32. The 8-inch bed probably should be correlated with coal bed J. The southernmost section showing the full thickness of coal on bed I in this township was measured at location 203, in sec. 21. The scarcity of measurements in this vicinity is due mainly to a lack of exposures at this horizon. A 1 foot 1 inch bed of coal is exposed at location 199, on the south side of a knoll near the south quarter corner of sec. 28, and is believed to represent the lower bench of bed I, the upper bench not being represented.

Bed J.—Bed J was measured at 12 places in this township, the locations of which are designated by Nos. 204 to 215. It is of little economic importance, being thin (ranging from a few inches of shale containing thin bands of coal at location 210 to 2 feet 4 inches of coal at location 206) and locally split by shale partings into two or more benches. Coal sections at locations 206 to 209, 211, and 215 are shown on Plate VIII; the others are fully described below.

At location 204, in sec. 2, bed J, which is 1 foot 1 inch thick, is overlain by 7 feet 8 inches of sandstone and shale, which in turn are overlain by a local lens of coal only 7½ inches thick. The stratigraphic distance between beds I and J at this point is 7 feet. The scarcity of sections on this coal bed is due partly to its lenticular character, partly to the extensive burning of the underlying coal bed (bed I), and partly to the presence of hill wash that covers the outcrop of the bed in places.

Little is known of this bed between locations 204 and 206, except at location 205, where it contains 1 foot 1 inch of coal in one bench, overlain and underlain by shale.

Between locations 206, in sec. 17, and 209, in sec. 20, the exposures are not so far apart and the graphic sections probably represent about the true thickness of coal. At location 210, in sec. 29, bed J is made up of brown shale containing thin bands of coal and bone and is of no economic importance. Practically nothing is known of the thickness of the coal along the outcrop between locations 210, in sec. 29, and 215, in sec. 32, a distance of about 4½ miles. Much of the coal between these points has been burned along its outcrop, and to this is probably due the scarcity of the exposures. The coal sections at locations 211 to 214, inclusive, were measured along the outcrop around an isolated tract in secs. 20, 21, and 29. The thickest of these four sections is at location 211, in sec. 29, where the coal is 1 foot 10 inches thick. The coal seems to be thinner toward the north and east from location 211. The bed contains 1 foot 2 inches of coal, underlain and overlain by shale, at location 212, in sec. 20; 9 inches of coal, with roof and floor of carbonaceous shale, at location 213, in sec. 21; and only 7 inches, with shale above and below the coal, at location 214, in sec. 29. As these measurements are well distributed and nearly surround the isolated tract, they suggest that probably bed J is of very little economic importance under this small area.

Bed K.—Three measurements on bed K were obtained in this township, the locations of which are shown on Plate X by Nos. 216 to 218. At location 216, in sec. 9, the bed contains 1 foot 2 inches of coal, with brown shale above and below it; and at locations 217, in sec. 29, and 218, in sec. 31, it contains only 4 inches of coal. Bed K in this township is thus of no economic value, as at location 216 only a very small area is underlain by the coal, and at locations 217 and 218 it is too thin to be mined. About 20 feet stratigraphically above bed K, at location 218, is a bed of carbonaceous shale containing a little coal.

Bed L.—Bed L in this township was measured at 14 places, which are designated on Plate X by Nos. 219 to 232. Plate VIII shows the sections, except Nos. 219, 222, 224, 225, 226, and 230, which are described below. The range in thickness is from 6½ inches at location

219 to 4 feet at location 228. The correlation shown on Plate VIII is doubtful in places, but it is believed that the sections here referred to bed L all occur at the same stratigraphic horizon.

Bed L in the northern part of the township, between Muddy and Quitchuppah creeks, underlies only a few isolated tracts. It is thin and much broken by partings and is of little economic importance, as is well shown by the following sections. At location 219, in sec. 3, near the horizon of bed L there are two thin beds of coal—the lower 6½ inches thick and the upper 7 inches thick—separated by about 8½ feet of sandstone, clay, and shale. The sections at locations 220 and 221 are shown graphically on Plate VIII. At location 222, in sec. 2, 9½ inches of coal on bed L is exposed in two benches separated by a 3-inch parting of drab shale. The bed is here overlain and underlain by shale.

The section at location 223 is shown on Plate VIII, except that the coal in its upper part contains several ¼-inch beds or lenses of brown shale. The following three measurements in the SE. ¼ sec. 3 suggest that bed L is of little value in a small outlier in that vicinity. At location 224 it contains only 1 foot 2½ inches of coal in two benches, separated by 1 foot 3½ inches of shale. The bed is here overlain by shale and underlain by brown clay. At location 225 it contains 1 foot 1½ inches of coal, overlain by clay and underlain by shale, and at location 226 it contains only 1 foot of coal, overlain by sandstone and underlain by shale.

The exposures in the southwestern part of the township, at locations 227 to 232, suggest that bed L is of more economic importance here than elsewhere in this township. In this area it contains from 1 foot 6 inches to 4 feet of coal. At some places the coal is badly weathered and films of gypsum fill the joints and bedding planes. The sections are all shown on Plate VIII, except that at location 230, where the coal was very poorly exposed, but where, it is believed, from 3 to 4 feet of coal is present. The bed is here overlain by sandstone and underlain by shale.

Bed M.—Bed M was measured in this township at five locations, which are indicated on Plate X by Nos. 233 to 237. Two of the sections, at locations 234 and 236, are shown graphically on Plate VIII, and the others are described below. At location 233, in sec. 11, 6 inches of coal, overlain and underlain by brown carbonaceous shale, is believed to represent bed M. The section at location 234, in sec. 7 (see Pl. VIII), shows that the bed has materially changed in character and thickness from that exposed at location 233. The change is even more striking between the near-by sections at locations 234 to 237, inclusive. At location 235, in sec. 7, the bed is practically worthless, consisting mainly of brown sandy carbonaceous shale with thin streaks of coal. At location 236, in sec. 18, it is of

more value, containing 3 feet 3 inches of coal. At location 237, in sec. 19, 1 foot of coal believed to represent bed M is exposed, with roof and floor of brown shale.

T. 24 S., R. 5 E.

The 8 coal beds exposed in T. 24 S., R. 5 E., was measured at 80 places. The table below shows the beds that are present and the numbers of the coal sections measured.

Coal beds exposed in T. 24 S., R. 5 E.

	Coal sections.		Coal sections.		Coal sections.
M	311–317	J	282–299	G	246
L	305–310	I	264–281	A	238–245
K	300–304	H	247–263		

Bed A.—The coal in bed A in this township has been more or less burned along its outcrop. The rocks overlying the coal bed south of the main branch of Willow Creek and north of the principal south branch of Willow Creek are considerably baked, and the horizon of the bed is represented by a dark-red band along the hillside, whereas north of Willow Creek the burning has been so complete that no coal remains at the surface on bed A. South of Willow Creek, however, there are a few unburned wedges or remnants of the coal which give the probable range in thickness of the coal in this township. The sections measured on bed A at locations 238 to 245 are shown graphically on Plate IX.

South of Willow Creek bed A in this township varies greatly in thickness from place to place, ranging from 9 feet 10 inches at location 241 to 14 feet 6 inches at location 240. The coal was measured in sec. 13 at location 238, where the outcrop crosses Willow Creek. The top of the bed at this place was not fully exposed, being overlain by soil, gravel, and bowlders, but it is believed that all the coal of value is shown graphically in the section on Plate IX. Southward from location 238 for a distance of about a mile the exposures on bed A are very poor, and the next measurement was obtained at location 239, in sec. 24. The base of the bed was not definitely determined, but at least 12 feet of coal is present at this place. A thin streak of bony coal, not shown on Plate IX, occurs about 2 feet below the top of the bed at location 239. At location 240, in sec. 24, about a quarter of a mile south of location 239, the bed contains 14 feet 2 inches of fairly good coal in two benches. It is believed that the entire bed is exposed here, which suggests that probably the two previous measurements given underestimate the amount of coal in the bed. Near location 242, in sec. 26, the coal bed was burning at the time of the field examination. A sample for analysis (laboratory No. 15061, p. 80) was collected from the surface prospect at location

243, in sec. 26. The sample was considerably weathered and can not give an adequate idea of the character of the coal under thick cover. Coal bed A was not measured along the outcrop toward the east, southeast, south, and southwest for a distance of 1½ to 2 miles from location 244, in sec. 24, but at location 245, in sec. 25, it contains 12 feet 9 inches of fairly good coal in two benches. South of this point in this township no sections were measured on this bed, but according to the section at location 387, in sec. 3, T. 25 S., R. 5 E., it contains 7 feet 2 inches of coal. This bed probably contains coal of workable thickness southward from location 245.

Bed G.—Bed G was measured in this township only at location 246, in sec. 24, where 5 inches of weathered coal, overlain and underlain by brown shale, is exposed.

Bed H.—Bed H was measured in this township at 17 locations, which are designated on the map (Pl. X) by Nos. 247 to 263. Six of the sections are shown on Plate IX; the others are described below. Bed H overlies bed G in this township at a stratigraphic distance of approximately 50 feet. It ranges in thickness from 8 inches at location 262 to 2 feet 7 inches at location 255. The three northernmost exposures on this bed, at locations 247, 248, and 249, in sec. 13, show it to contain about 1 foot of coal. The graphic sections on Plate IX show the thickness and character of the bed at locations 250, in sec. 13, and 251, in sec. 12. At location 252, in sec. 13, it contains 1 foot of coal, slightly bony at the base, overlain by shale and underlain by clay. The character and thickness of the bed at locations 253, in sec. 11, and 254 and 255, in sec. 14, are shown by the graphic sections on Plate IX. The distance between beds H and I at location 255 is 6 feet. About two-thirds of a mile farther east, at location 256, in sec. 13, this bed contains 1 foot 3 inches of coal, overlain and underlain by shale; and at location 257, in sec. 14, the coal bed is represented by brown to black carbonaceous shale. About a mile south of location 257 bed H at locations 258 and 259, in sec. 23, contains 1 foot 3 inches of coal, overlain by clay and underlain by shale. In the NE. ¼ SE. ¼ sec. 23, at location 260, on the west side of a deep canyon, 1 foot of coal, overlain by clay and underlain by shale, is exposed on bed H. The coal section at location 261 is shown graphically on Plate IX. Near the south boundary of sec. 23, at location 262, only 8 inches of coal is exposed on bed H which seems to be of little economic importance farther south and southwest. The southernmost place at which this bed was measured in the township is in the SW. ¼ NW. ¼ sec. 26, at location 263, where 9 inches of coal, overlain and underlain by shale, is exposed.

Bed I.—Bed I was measured in this township at 18 locations, which are designated on the map (Pl. X) by Nos. 264 to 281. Part of the sections measured are represented graphically on Plate IX;

the others are described below. The bed throughout this township is less than 2 feet in thickness, except at location 272, in sec. 11, where it is 3 feet 6 inches thick. At location 264, in sec. 13, 1 foot of coal, overlain and underlain by clay, is exposed on bed I. The sections measured at locations 265, 266, and 267, in sec. 13, are shown graphically on Plate IX. In the NE. ¼ NE. ¼ sec. 13, 1 foot 1 inch of coal, overlain by bone and shale and underlain by shale, is believed to represent bed I. The following section of this bed was made at location 268, in sec. 13:

Section of coal bed I at location 268 in the NW. ¼ NE. ¼ sec. 13, T. 24 S., R. 5 E.

	Ft.	in.
Clay, dark brown.		
Bone		2
Coal, bony, brownish black		5
Coal, weathered, stained yellow in places		8
Clay, dark reddish brown		5±
Shale, dark blue.		
Total coal	1	1

Five inches of coal, overlain and underlain by dark-brown shale, supposed to be on bed I, is exposed at location 269, in sec. 12. The coal section at location 270, in sec. 12, is shown graphically on Plate IX. At location 271, in sec. 13, the bed contains only 9 inches of dull, weathered coal, which is overlain by bone and underlain by shale. Bed I at location 272, in sec. 11, is 3 feet 6 inches thick (see Pl. IX), containing more coal than was seen at any other exposure on this bed in this township. The bed is represented by 1 foot 2 inches of coal, overlain and underlain by clay, at location 273, in sec. 14, on the south side of Willow Creek. Plate IX shows the thickness and character of bed I at location 274, in sec. 13. At location 275, in sec. 14, 1 foot 2 inches of coal is exposed, and at location 276, in sec. 23, 1 foot of weathered coal, overlain by shale and underlain by clay, represents the bed. At location 277, about 1,000 feet northeast of location 276, 1 foot of coal, overlain by clay and underlain by shale, is exposed on bed I. The coal section at location 278, in sec. 23, is shown graphically on Plate IX. The bed was measured at location 279, about a quarter of a mile farther southwest, where 1 foot of coal is exposed. Only 6 inches of coal is exposed at location 280, in sec. 23. The southernmost measurement on bed I in this township was made in sec. 26, at location 281, where 9 inches of coal, overlain by shale and underlain by dark-gray clayey sandstone, is exposed.

Bed J.—Bed J was measured in this township at 18 locations, Nos. 282 to 299. (See Pl. X.) Most of the sections are shown graphically on Plate IX. The maximum thickness is 3 feet 2 inches at location 291. At location 282, in the SE. ¼ NE. ¼ sec. 13, 9 inches of coal, overlain by clay and underlain by bone, is exposed on bed J. The

sections at locations 283 to 289, in secs. 11, 12, and 13 (see Pl. IX), show the bed to be rather irregular in thickness (from 1 foot 3 inches to 2 feet 10 inches) between these points and to occur in one bench. The upper bed of coal exposed at locations 285 and 286 (see Pl. IX) should probably be correlated with bed K. At location 290, in sec. 11, 2 feet 6 inches of coal, overlain by sandstone and underlain by dark-brown carbonaceous shale, represents bed J. The sections at locations 291 in sec. 14, and 292, in sec. 13, show the bed to be thicker than at the locations described above. (See Pl. IX.) The stratigraphic distance between beds I and J at location 293 is 9 feet. Bed J between locations 293, in sec. 14, and 296, in sec. 23, is thin and of little economic importance. At location 293 it contains 1 foot 1 inch of coal; at 294, 1 foot 2 inches; at 295, 1 foot; and at 296, only 9 inches. The roof and floor of the bed in this locality are generally shale and clay, respectively. The sections at locations 297, in sec. 23, to 299, in sec. 26, inclusive (see Pl. IX), show bed J to be of little economic importance and to deteriorate in value toward the south. It is exposed in two beds, neither of which is thick enough to be profitably mined.

Bed K.—Bed K was examined in this township at locations 300 to 304, which are indicated on the map (Pl. X). Only one section (at location 304) is shown on Plate IX; the others are briefly described below. Bed K in this township lies about 11 feet stratigraphically above the top of bed J and reaches a maximum thickness of only 1 foot 7 inches at location 304. It follows that the bed in this township is of little economic importance. There are, however, two lenses of coal, probably of small lateral extent, which are of some value, one in the vicinity of location 302, in sec. 13, and the other in the vicinity of location 304, in sec. 23. At locations 300 and 301, both in sec. 13, bed K contains 10 inches of coal. At the former place the roof and floor are bone and at the latter the roof is clay and the floor is shale. An exposure about a quarter of a mile west of location 301, believed to represent bed K, shows 1 foot 1 inch of coal having a roof and floor of carbonaceous shale. A short distance farther west 1 foot 2 inches of coal, supposedly on bed K, is exposed. At location 302, in sec. 13, there is 1 foot 2 inches of coal having clay above and bone below it. At location 303, in sec. 12, the bed contains only 8 inches of coal having a shale floor and roof.

Bed L.—Bed L was measured in this township at six locations, designated on the map (Pl. X) by Nos. 305 to 310. Three of the sections are shown on Plate IX. The bed in this township is approximately 55 feet stratigraphically above bed K and 15 feet stratigraphically below bed M. Bed L, like bed K, is of little economic importance in this township, although several exposures show a thickness of coal greater than 1 foot 3 inches. The sections at loca-

tions 305 and 306, both in sec. 13, show more than 1 foot 4 inches of coal. (See Pl. IX.) Two other exposures on bed L, one about 100 to 200 feet west of location 306 and the other at location 307, in sec. 13, each contain 11 inches of coal having a bone roof and a shale floor. At location 308, in sec. 23, the bed contains 1 foot of coal, the lower 4 inches of which is slightly bony. At location 309, in sec. 25, only 8 inches of coal is exposed. The bed at both locations is overlain and underlain by shale. In the SE. ¼ SE. ¼ sec. 24, on the east side of the ridge, 5 inches of coal is exposed which is believed to represent bed L. The southernmost exposure of bed L in this township is on the north side of Last Chance Creek, at location 310, in sec. 31, where 1 foot 8 inches of coal, overlain and underlain by dark-brown shale, is exposed.

Bed M.—Bed M in this township was measured at seven locations, which are represented on the map (Pl. X) by Nos. 311 to 317. The sections at locations 311 to 314, in secs. 13, 14, and 23, are shown on Plate IX; the remainder are described below. The maximum thickness is 5 feet 2 inches, at location 313 in sec. 14. The bed is represented by 11 inches of coal, with shale above and below, at location 315 in the SE. ¼ SW. ¼ sec. 23. At location 316, on the south fork of Willow Creek in the SE. ¼ SE. ¼ sec. 27, bed M is represented by 7 inches of bone and bony coal of no economic value. The southernmost place where this bed was measured in this township is in the SE. ¼ SW. ¼ sec. 25, at location 317, where 1 foot 1 inch of coal, overlain by clay and underlain by sandstone, is exposed. Overlying the bed at this place there is approximately 70 feet of the lower part of the shale above the Ferron sandstone.

T. 24 S., R. 6 E.

Beds A, C, F, G, H, I, J, K, L, and M are represented in T. 24 S., R. 6 E., by a total of 53 measurements, designated on the map (Pl. X) by locations 318 to 370. All the sections containing more than 1 foot 4 inches of coal are shown graphically on Plate IX by corresponding numbers. The following table indicates the numbers of the sections measured on each bed:

Coal beds exposed in T. 24 S., R. 6 E.

	Coal sections.		Coal sections.		Coal sections.
M	370	I	347–355	C	328–332
L	366–369	H	342–346	A	318–327
K	364–365	G	338–341		
J	356–363	F	333–337		

Bed A.—Bed A, which is the lowest one in the section, was measured in this township at 10 locations, which are represented on Plate X by Nos. 318 to 327. The details of the sections are shown graphi-

cally on Plate IX. The bed ranges in thickness from 1 foot 5 inches at location 325 to 13 feet 5 inches at location 319. A good example of the apparent abrupt change in thickness of bed A is furnished by coal sections 131 (Pl. VIII) and 318 (Pl. IX). The former section, showing 2 feet 3 inches of coal, was measured in sec. 33, T. 23 S., R. 6 E., and the latter, showing 8 feet 1 inch of coal, was measured in lot 8, sec. 5, T. 24 S., R. 6 E., only about 1 mile distant. There appears to be no constant rate of change in bed A in any particular direction. At location 319, in lot 9, sec. 4, east of location 318, the bed attains its greatest thickness (13 feet 5 inches) observed in this township. Less than half as much coal (5 feet 1 inch) is exposed at location 320, in lot 14, sec. 5, whereas at location 321, in lot 16, sec. 6, 9 feet 6 inches is exposed. Southwestward from location 321, however, to location 327, in sec. 18, the bed is much thinner and is badly split by partings at locations 322, 323, and 324. At various places along the north side of Willow Creek valley, in sec. 18, the horizon of bed A is marked by a considerable thickness of baked clay which locally contains some slag or fused material. When the thickness of coal in bed A at location 238, in the SW. ¼ NW. ¼ sec. 13, T. 24 S., R. 5 E., is compared with the sections last given above, it seems doubtful if the entire thickness of the coal bed is exposed at locations 322 to 327. It is believed from a careful study of the coal in this locality that bed A is valuable for several miles along the outcrop southward from Ivie Creek and probably is of some value as far south as Last Chance Creek. If it may be assumed that bed A is continuous and fairly constant in thickness, the sections measured at locations 322 to 327 probably represent only a part of bed A or possibly a "split" from it. The bed probably underlies portions of lots 3 and 4, in sec. 19, for at locations 244 and 245, in secs. 24 and 25, respectively, T. 24 S., R. 5 E., only a short distance to the west, bed A contains 12 to 14 feet of coal.

Bed C.—Coal sections 328 to 332 (see Pl. IX) represent bed C in this township and are arranged on Plate X in order from north to south along the outcrop. This bed at location 328, in sec. 8, contains 10 inches of coal, overlain by shale and clay and underlain by clay. The bed is variable in thickness and is badly split by partings in secs. 7, 8, and 18, as is shown graphically on Plate IX by sections 329 to 331. The greatest thickness is 7 feet 4 inches, at location 332, in sec. 18. Bed C in this locality is 35 feet stratigraphically above bed A.

Bed F.—Bed F was measured in this township at five locations, which are designated on Plate X by Nos. 333 to 337. The sections at locations 335 to 337 are shown graphically on Plate IX. The bed is of little economic importance in this township, as the benches of coal are thin and the intervening partings unusually thick, except

at location 337, where the bed is possibly of value, being 3 feet 6 inches thick, including partings. The section measured at location 333 is as follows:

Section of thin coal beds at the horizon of bed F at location 333, in lot 1, sec. 5, T. 24 S., R. 6 E.

	Ft.	in.
Sandstone, massive, yellowish gray; contains clay-ball concretions	30+	
Coal, blocky		6
Shale, brown, carbonaceous	2	0
Shale, brown to black; contains thin streaks of coal	2	0
Coal, impure, of variable thickness		8±
Sandstone, argillaceous and carbonaceous, brown at top; becomes less argillaceous and thin bedded near bottom	7	0
Clay, drab, grading down into brown shale	1	10
Coal, bright		7
Shale, brown, carbonaceous		6+

The base of the section at location 333 is about 60 feet above the top of bed A at location 318. An outcrop of bed G, near location 340, in sec. 5, shows that bed F contains only brown carbonaceous shale. The distance between beds F and G at this place is 42 feet. At location 334, in lot 15, sec. 6, about 4 miles along the outcrop but approximately 1¼ miles in a straight line southwest from location 333, bed F contains only 8 inches of coal, having a brown carbonaceous shale floor and roof. The distance between beds F and A at location 334 is 55 feet, as compared with 60 feet at location 333. The sections at locations 335 to 337 (see Pl. IX) shows the thickness and the character of the coal and the character of the floor and roof of bed F in secs. 7, 8, and 18.

Bed G.—Bed G is represented in this township by coal sections 338 to 341, which are described below. Three benches of coal aggregating 2 feet 8 inches are exposed at location 338, in lot 10, sec. 4. The thickness of each bench of coal and the thickness and character of the partings are shown on Plate IX. Coal section 339, measured in lot 9, sec. 4, contains 2 feet 3 inches of coal in two benches, separated by 4 inches of brown shale that begins 9 inches below the top of the bed. Brown carbonaceous shale both overlies and underlies the coal. Bed G at this place is approximately 90 feet stratigraphically above the top of bed A (Pl. IX, coal section 319). At location 340, in lot 11, sec. 5, 11 inches of coal, overlain by clay and underlain by brown shale, represents bed G, which is 65 feet below the base of bed I (Pl. IX, coal section 349). At location 341, in lot 10, sec. 5, 1 foot 1 inch of coal, overlain and underlain by brown carbonaceous shale, represents bed G, and this is the southernmost measurement obtained on this bed in this township.

Bed H.—Bed H in this township was measured at five exposures, which are designated on Plate X by Nos. 342 to 346. The exposures at locations 342 to 345 are all in sec. 6, and the character and thickness of the coal are shown on Plate IX. Southward from sec. 6 the bed was examined in the NE. ¼ SW. ¼ sec. 18, near the east end of a high ridge, where it contains only 9 inches of coal, having a shale floor and roof. The southernmost exposure examined in this township is at location 346, in sec. 18, where there is 1 foot 3 inches of coal, overlain by clay and underlain by shale.

The stratigraphic distance between beds H and A at location 347, in sec. 4, is 210 feet.

Bed I.—Coal bed I and the associated rocks were examined at nine locations, which are designated on Plate X by Nos. 347 to 355. All these sections except Nos. 350, 352, and 354 are shown graphically on Plate IX. This coal bed, if the correlation of the exposures here suggested is correct, is in this township extremely variable in thickness, as well as in the number and arrangement of the benches. The graphic sections show very well its variable character. The coal bed in secs. 4 and 5, at locations 347 to 349, seems to be relatively constant in thickness, except for the lower two benches at location 348 (see Pl. IX), which may represent a split from bed I or a local lens of small lateral extent. Bed I in the vicinity of location 356 (on bed J), in sec. 5, is represented by a band of carbonaceous shale. Toward the west, in sec. 6, at locations 350 to 353, it is of no economic value. At location 350, in lot 10, sec. 6, an exposure believed to represent bed I contains only 4 inches of coal, having a carbonaceous shale floor and roof. The section at location 351 is shown on Plate IX. At location 352, in the center of sec. 6, the bed contains 1 foot 3 inches of coal having a roof and floor of carbonaceous shale, but at location 353, only a few hundred feet to the southeast, there is only 3 inches of coal. (See Pl. IX.) No exposure was examined on bed I between the SE. ¼ sec. 6 and the SW. ¼ sec. 18. At location 354, in the N. ½ SW. ¼ sec. 18, this bed contains 11 inches of coal, having a carbonaceous shale roof and floor. The section at location 355 is shown on Plate IX.

Bed J.—Bed J in this township was measured by eight locations (Pl. X, Nos. 356 to 363), and all the sections except Nos. 361 to 363 are shown graphically on Plate IX. The exposures examined occur in secs. 5 and 6, except one at location 363, in sec. 18. The bed is of value along its outcrop from location 356 to a point between locations 359 and 360, but eastward and southward from location 360 it is of no economic value in this township. At location 361, in the NW. ¼ SE. ¼ sec. 6, the horizon of bed J is represented by a highly carbonaceous dark-brown shale 1 foot 6 inches thick. In the NW. ¼ SE. ¼ sec. 6, at location 362, 10 inches of coal, overlain by sandstone

and underlain by clay, is exposed at the horizon of the bed. The southernmost measurement on bed J in this township was made at location 363, in the NW. ¼ SW. ¼ sec. 18, where it contains 1 foot 2 inches of coal, overlain and underlain by dark carbonaceous shale. The stratigraphic distance between beds J and I in the vicinity of location 356 is 20 feet, whereas the corresponding distance in the vicinity of location 357 is only 6 feet 6 inches.

Bed K.—Bed K in this township was measured at three exposures, two of which are designated on the map (Pl. X) by Nos. 364 and 365. At location 364, in lot 10, sec. 6, it contains 1 foot 2 inches of coal, overlain and underlain by brown shale. In the NW. ¼ SW. ¼ sec. 18, 10 inches of coal, overlain by shale and sandstone and underlain by bone and sandstone, is believed to represent bed K. At location 365, also in the NW. ¼ SW. ¼ sec. 18, 8 inches of coal, overlain and underlain by bony shale, is exposed.

Bed L.—Bed L was measured at four places in this township (Pl. X, location 366 to 369). The sections are shown graphically on Plate IX. The outcrop of bed L incloses an isolated tract in secs. 4 and 5 (see Pl. X), and the bed at the exposures examined contains about 3 feet of coal. The other exposures examined on bed L are so far apart that little can be said about the character and thickness of the coal between them. Two of the exposures examined are not indicated on the map. In the NE. ¼ SW. ¼ sec. 18, near the east end of a high ridge, 9 inches of coal is exposed; and at about a quarter of a mile to the west 1 foot 8 inches of coal is exposed at the same horizon.

The stratigraphic distance between beds L and I at location 367, in sec. 4, is 57 feet and between beds J and L at location 369, in sec. 18, is 49 feet.

Bed M.—Coal section 370, measured in lot 1, sec. 7, shows that bed M contains 7 feet 11 inches of coal in two benches, the upper one 4 feet 5 inches thick, separated by 2 inches of bone. Shale both overlies and underlies the coal at this place. It is quite probable that bed M underlies the small outlying hill in the northwestern part of sec. 7 and also an irregular strip along the west side of sec. 6, where its horizon is covered by alluvium. It is known to be present also in the outlier, whose eastern part extends into sec. 18.

T. 25 S., R. 4 E.

Only three coal beds (A, L, and M) are known to be exposed in T. 25 S., R. 4 E.

Bed A.—Bed A was measured at three locations in this township, designated on Plates IX and X by Nos. 371 to 373. At each of the three exposures, which are in sec. 25, it contains about 2 feet of coal,

but southwestward from sec. 25 no outcrop was seen, and little is known of the bed in secs. 26, 34, and 35.

Bed L.—Bed L in this township was measured at seven locations (Pl. IX and X, Nos. 374 to 380). The bed ranges in thickness from 1 foot 8 inches to 5 feet 10 inches, being thinnest at locations 376 and 377 and thickest at location 378. So far as the exposures reveal the thickness and character of the coal, bed L is very irregular, as is shown graphically on Plate IX. In the SW. ¼ SE. ¼ sec. 34, at location 380, a total of 3 feet 6 inches of coal is present in three beds in a thickness of about 12 feet of strata. The two lower beds are of little value, as they are thin and widely separated by clay and bone. The upper bed, 2 feet 6 inches thick, is probably all that would be removed in mining.

Bed M.—Six measurements were obtained on bed M in this township, and are designated on Plate X by Nos. 381 to 386. All these sections are shown graphically on Plate IX, except No. 384 and the upper two benches of No. 381. In sec. 13, at location 381, 3 feet 8 inches of coal is exposed in a section of rocks 13 feet 4 inches in thickness. The two upper beds are each 6 inches thick and are separated by 4 feet of yellowish-gray sandstone. The middle bed is separated from the lowest by 5 feet 6 inches of brown shale. It is quite probable that only the lower bed of coal, which is 2 feet 8 inches thick (see Pl. IX) will be mined. At location 384 about 800 feet slightly west of south of location 383, in the NW. ¼ NW. ¼ sec. 35, 1 foot 3 inches of coal, overlain by sandstone and underlain by brown shale, represents this bed. Overlying bed M at this locality there is more sandy material than was noted in this part of the columnar section at any other place in the Emery coal field. Usually bed M is overlain directly by yellowish-drab sandy shale, becoming less sandy toward the top. One or two thin beds of limestone also were noted in the overlying rocks within a distance of 100 feet above this coal bed. At location 386 1 foot 11 inches of coal is present in 7 feet 11 inches of strata. The upper bed is 1 foot 4 inches thick and the lower one 7 inches thick. They are separated by 6 feet of light-gray to dark clay and shale.

T. 25 S., R. 5 E.

In T. 25 S., R. 5 E., 21 measurements were obtained on four coal beds. The following table shows the numbers of the coal sections measured on each bed:

Coal beds exposed in T. 25 S., R. 5 E.

	Coal sections.		Coal sections.
M	403–407	L	396–401
La	402	A	387–395

Bed A.—Coal bed A was examined in this township at nine locations (Pl. X, Nos. 387 to 395). The sections are shown graphically on Plate IX, except those at locations 393 to 395. Southwestward from sec. 3 into sec. 9 bed A shows a gradual decrease in thickness, ranging from 7 feet 2 inches at location 387 to 2 feet 6 inches at location 392. No exposures were observed in secs. 16 and 17, but farther southwest the bed is of no economic value, being too thin. In the NW. ¼ NE. ¼ sec. 20, at location 393, bed A contains only 5 inches of good coal, which is overlain and underlain by several feet of brown carbonaceous shale, containing in places thin streaks of coal. The bed is represented by 10 inches of coal with a little bone, overlain and underlain by dark-brown shale, at location 394, in the NW. ¼ NE. ¼ sec. 30. At location 395, in sec. 30, about a quarter of a mile southwest of location 394, bed A contains only 11 inches of coal, overlain by clay and underlain by shale.

Bed L.—Bed L was measured in this township at six places—Nos. 396 to 401 (see Pls. IX and X), inclusive. The graphic sections on Plate IX show the character and thickness of the bed and probably roughly represent its true condition, as the exposures are rather uniformly distributed over the northwestern part of the township. At location 398, in sec. 6, a bed which lies 10 feet below the bed shown in the plate of graphic sections (Pl. IX) contains only 3 inches of coal.

Bed La.—Only one exposure, at location 402, in sec. 3, was examined at the horizon of bed La in this township. It is believed that the coal exposed here is but a local lens or probably a split from either bed M or bed L. This section is given on Plate IX.

Bed M.—Coal bed M was measured in this township at five locations, which are designated on Plates IX and X by Nos. 403 to 407. The exposures examined are not well distributed and so perhaps do not truly represent bed M in the entire township. The bed is probably irregular in thickness and occurrence, however, as may be inferred from the sections at locations 403 to 405, which are very near together in secs. 4 and 5. At locations 406, in sec. 18, and 407, in sec. 30, the bed is more than 5 feet thick, but little is known of the coal between these exposures or between locations 406, in sec. 18, and 405, in sec. 5. It is believed, however, that only the middle bench of coal at location 404 is exposed at location 405.

T. 26 S., R. 4 E.

The coal beds of T. 26 S., R. 4 E., which are present only in secs. 2, 3, and 4, were measured at five locations—Nos. 408 to 412.

Bed A.—Bed A was measured at three places in this township, which are represented on Plates IX and X by Nos. 408 to 410. At location 409, in sec. 3, a prospect tunnel about 15 feet in length had

been made. The coal here was very much broken and distorted. The lower 3-foot bench of the lower bed was sampled for analysis (laboratory No. 15060, p. 80) at the back end of this entry. The lower coal bed, as shown on Plate IX by coal section 409, may be present elsewhere, but at locations 408 and 410 there is no evidence of its existence.

Bed B.—At location 411, in the SE. ¼ NW. ¼ sec. 3, 1 foot 1 inch of coal, overlain by clay and underlain by shale, represents bed B. The coal at this place is about 12 feet stratigraphically above bed A.

Bed L.—At location 412, in the SE. ¼ NE. ¼ sec. 4, 4 feet 4 inches of coal, overlain and underlain by shale, represents what is believed to be bed L. On account of considerable cover in places and the disturbed condition of the strata it was not practicable to obtain other measurements on any of the coal beds in this township.

COAL IN THE DAKOTA SANDSTONE.

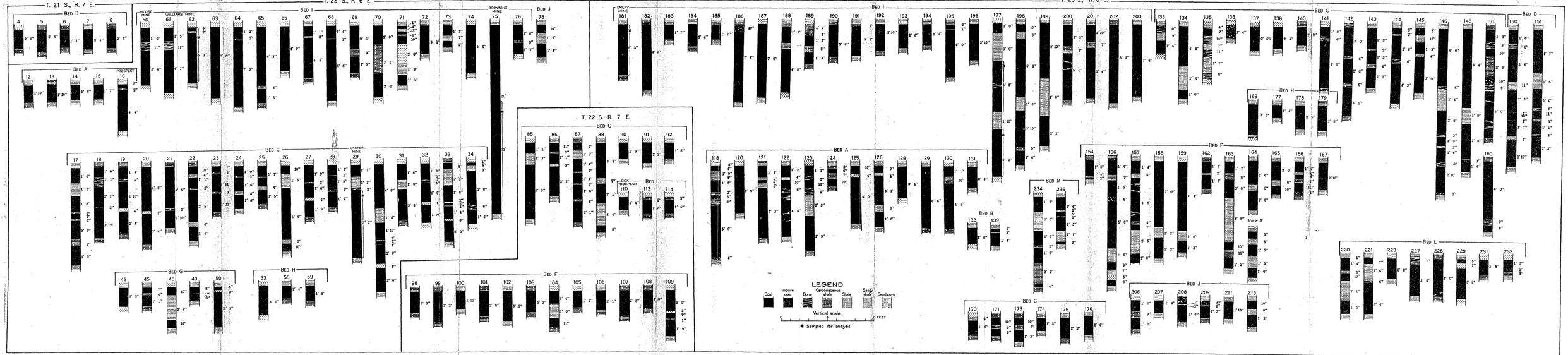
The coal in the Dakota sandstone is of some economic importance in central and eastern Utah south of the Book Cliffs,[1] but along the east side of Castle Valley it is of little value at present, and, considering the extensive deposits of coal in the Mesaverde formation in the Wasatch Plateau and Book Cliffs fields and in the Ferron sandstone member of the Mancos shale in the Emery field, it seems doubtful if the coal of Dakota age in this region will ever be mined, except possibly in a small way for domestic use by ranchers.

Sections of coal beds of Dakota age are described below in order from north to south. The locations examined are indicated on Plate XII. The northernmost exposure of coal in the Dakota sandstone examined in Castle Valley is in the SE. ¼ NW. ¼ sec. 24, T. 17 S., R. 10 E., at location 413, where there is 3 inches of coal, overlain by 2 feet or more of black carbonaceous shale and underlain by 5 feet or more of the same material. Several prospect pits, some of which are 8 feet or more in depth, have been opened in the vicinity of location 413. No evidence of coal exists at the outcrop of the Dakota, although exposures are good for about 15 miles to the southwest, but on the west side of Huntington Creek, in the NW. ¼ SW. ¼ sec. 9, T. 19 S., R. 9 E., at location 414 the following section shows the character of the rocks:

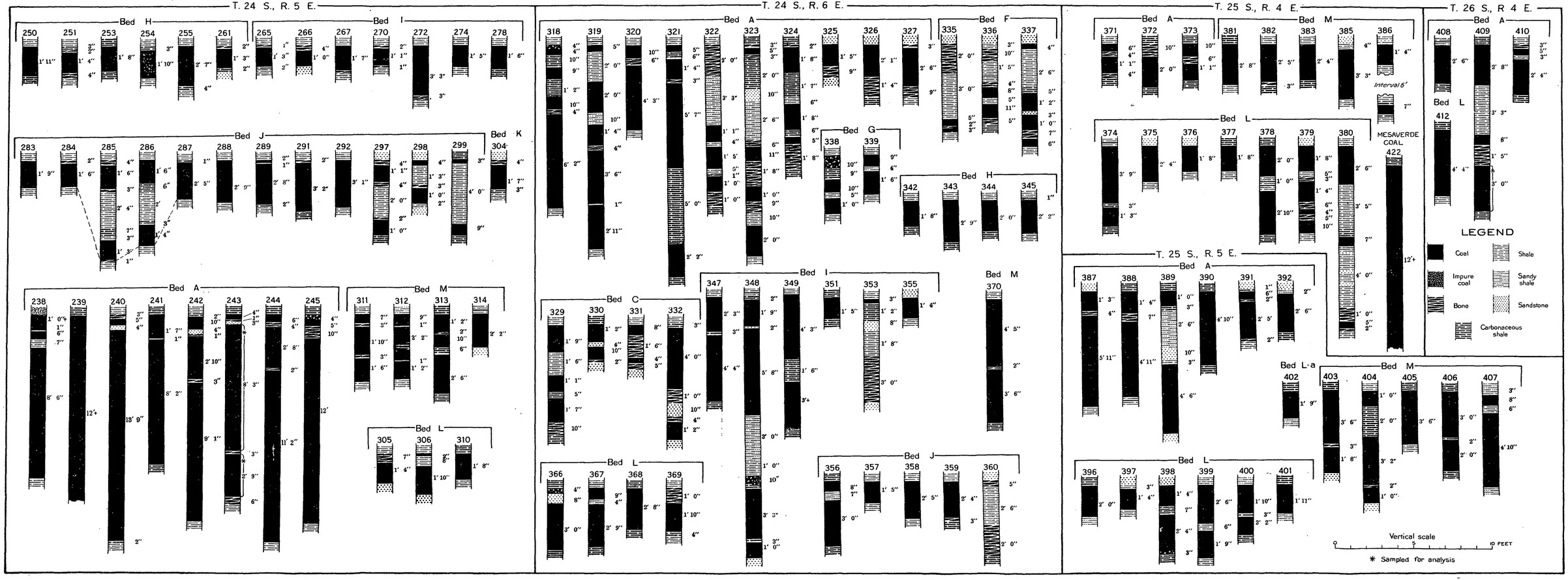
Section of coal-bearing strata in Dakota sandstone at location 414, in sec. 9, T. 19 S., R. 9 E.

	Ft.	in.
Sandstone, yellow, carbonaceous	1	0
Shale, black, very carbonaceous; contains thin streaks of coal at base	1	6
Sandstone, yellow, carbonaceous	5	0
	7	6

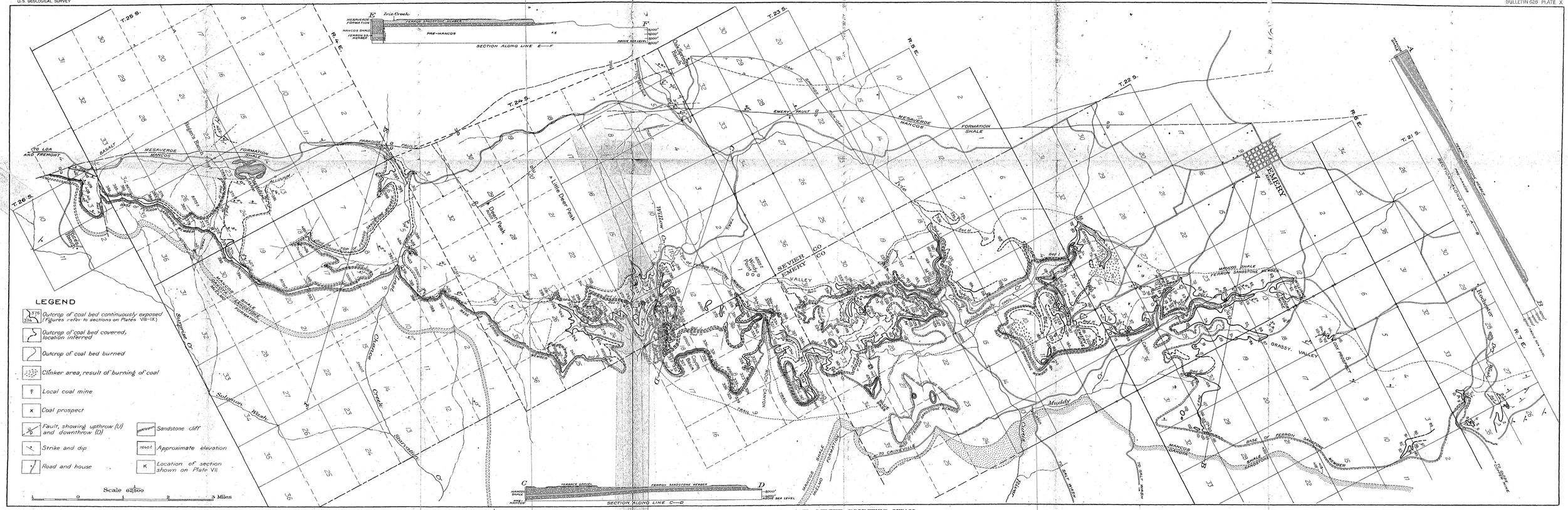
[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field, between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, pp. 12–13, 1909.



SECTIONS OF COAL BEDS IN T. 21S., R. 7 E., T. 22 S., RS. 6 AND 7 E., AND T. 23 S., R. 6 E., EMERY COUNTY, UTAH



SECTIONS OF COAL BEDS IN T. 24 S., RS. 5 AND 6 E., T. 25 S., RS. 4 AND 5 E., AND T. 26 S., R. 4 E., SEVIER AND EMERY COUNTIES, UTAH



MAP OF EMERY COAL FIELD, EMERY AND SEVIER COUNTIES, UTAH

About 5 miles southeast of Castledale an exposure on the south side of Cottonwood Creek, in the SE. ¼ NW. ¼ sec. 17, T. 19 S., R. 9 E., at location 415, shows a lens of shale and coal interbedded, which ranges in thickness from a knife-edge to 3 feet. The lens is overlain and underlain by yellowish-gray iron-stained sandstone. About a quarter of a mile south of this place, at location 416, a prospect has been opened on a bed of bone 2 feet 5 inches thick, the top 11 inches of which contains thin layers of good coal. Three miles southwest of location 416, in the SW. ¼ NE. ¼ sec. 36, T. 19 S., R. 8 E., at location 417 on the north side of Ferron Creek, coal "bloom," which results from the weathering of a very thin bed (about half an inch) of coal, is plentiful. Southwest from this place for 18 or 20 miles the outcrop of the Dakota shows no evidence of coal, but at location 418, in the NE. ¼ NW. ¼ sec. 22, T. 22 S., R. 7 E., about 6 miles southeast of Emery, a bed of coal 1 foot 6 inches thick is exposed and contains streaks of brown carbonaceous shale. A few hundred feet to the southwest the following section was obtained:

Section of coal bed in the Dakota sandstone at location 419, in the NE. ¼ NW. ¼ sec. 22, T. 22 S., R. 7 E.

	Ft.	in.
Sandstone, brown, shaly, carbonaceous		6
Coal, bright, weathered; joints contain gypsum		9
Shale, carbonaceous; contains thin streaks of coal		3½
Coal, slightly bony		6½
Shale, brown, carbonaceous		4
Coal, bony		1½
Shale, brownish gray, carbonaceous	2	6
Coal bed	2	½
Total coal	1	5

The total amount of coal here would warrant mining where fuel is scarce, yet it seems doubtful if this bed will be utilized even as a source of domestic fuel, because much thicker beds of purer coal are present a few miles farther southwest in the Ferron sandstone member of the Mancos shale. The total coal at location 420, as shown by the following section, is practically the same as at location 419:

Section of coal bed in the Dakota sandstone at location 420, in the NW. ¼ NE. ¼ sec. 28, T. 22 S., R. 7 E.

	Ft.	in.
Conglomerate, in places replaced by sandstone		8
Coal, much weathered; contains gypsum in joints		8
Sandstone, gray, lenticular, conglomeratic		3
Coal, much weathered		7
Coal, bony, impure		2
Shale, brownish black, sandy.		
Coal bed	2	½
Total cost	1	5

Coal in the Dakota sandstone was also examined in the SE. ¼ SE. ¼ sec. 25, T. 25 S., R. 4 E., at location 421, but is of little value here, as elsewhere in Castle Valley.

Section of coal in the Dakota sandstone at location 421, in the SE. ¼ SE. ¼ sec. 25, T. 25 S., R. 4 E.

	Ft.	in.
Shale, brown, carbonaceous	1	0
Coal, apparently quite pure		8
Shale, brown, carbonaceous		8
Sandstone (?), poorly exposed	12	0
Sandstone, white	2	6
Coal, rusty, probably impure		3
Sandstone and sandy shale, poorly exposed	12	0
	29	1

COAL IN THE MESAVERDE FORMATION.

Coal of Mesaverde age is exposed in the NW. ¼ NE. ¼ sec. 22, T. 25 S., R. 4 E., at location 422. It was impossible to determine the exact thickness of the coal, owing to a fault that cuts the rocks a few feet from the exposure and has somewhat disturbed the adjacent strata. The fault has a vertical throw of about 75 feet, the downthrow being on the southwest side. At location 422 (see Pl. IX) 12 feet of coal was measured without exposing the base of the bed, but it is believed that very little coal remained unexposed at this place. The coal is overlain by 1 foot of brown shale and that by about 75 feet of sandstone and clay interbedded. Although this bed was not traced in either direction from location 422, it is believed to be the only exposure of coal of Mesaverde age included in the area shown in Plate X.

COAL IN THE MANCOS SHALE NEAR HENRY MOUNTAINS.

A belt barren of coal, 30 or 40 miles in width, separates the Emery coal field from the coal-bearing rocks of the same age in the vicinity of the Henry Mountains, to the southeast. The rocks exposed in the intervening area belong to the Vermilion Cliff, La Plata, McElmo, and Dakota formations. Gilbert[1] states: "The best outcrop was seen in the bank of the south branch of Lewis Creek where it crosses the upturned edge of the Blue Gate sandstone. The seam has a thickness of 4 feet only and is not well disposed for mining."

The writer in October, 1911, while visiting on a reconnaissance trip to the north end of the Henry Mountains, measured a flat-lying coal bed in Gilbert's Blue Gate sandstone near the center of sec. 19, T. 31 S., R. 10 E., about 2½ miles west of the base of Mount Ellen.

[1] Gilbert, G. K., Report on the geology of the Henry Mountains, p. 145, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1877.

The sandstone in which the coal occurs is believed to be the same as the Ferron sandstone member of the Mancos shale, to judge from its stratigraphic position and lithology. The section of the coal bed and associated rocks is given below:

Section of coal bed measured near center of sec. 19, T. 31 S., R. 10 E.

	Ft.	in.
Sandstone, gray, soft, massive	15+	
Sandstone, yellow and somber-colored	2	0
Coal, bright	2	1
Shale, sandy, with a little coal		1½
Coal, bright, blocky		7½
Bone		3
Coal, bright (no partings)	6	6
Sandstone, gray, argillaceous	1+	
Coal bed	9	7
Total coal	9	2½

This coal is apparently a low-grade bituminous coal and is similar to that in the vicinity of Emery described in this report. The outcrop of this bed was not traced, hence nothing definite can be said as to its extent.

Several other exposures of coal along Fremont River between the Emery field and the Henry Mountains were examined. A 2-foot bed of coal crops out on the north side of Fremont River 4 or 5 miles west of Giles. This coal occurs in the upper part of what Gilbert called the Tununk sandstone or in the lower part of his Blue Gate shale, which, with but little doubt, corresponds to that part of the Mancos shale lying beneath the Ferron sandstone member in Castle Valley. Coal is also reported near Hanksville, which is near the junction of Curtis and Fremont rivers. Coal of good quality has been mined at "The Factory," a prominent topographic feature about 6 miles north of Giles.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The coal of the Emery field is pitch-black in color, but here and there thin layers of grayish-black bonelike coal are present. The coal when rubbed on unglazed porcelain gives a black streak and when pulverized in a mortar gives a black powder with possibly a slightly brownish tinge. In general the coal is bedded and has a bright vitreous luster, but parts of the same bed differ widely in appearance. In places the coal is distinctly banded, showing thin alternating bright and dull layers, while a few inches above or below the banded part the coal may be massive and either bright or

dull, and other layers a few inches thick have a dull luster and resemble cannel coal in texture. The jointing and cleavage of the coal vary somewhat, being columnar in most places but cubical in others. The fracture of the coal is remarkably even. In texture it ranges from laminated to dense, and in coherence it is comparatively brittle. The coal is hard and when struck with a hammer emits a metallic sound. When burned it gives a bituminous odor and a short yellowish-red smoky flame. The resulting ash is fine grained and gray in color. It is not known definitely whether or not the coal will coke, but when the Pishel[1] coking test was applied it showed slight coking qualities. In places where the coal is somewhat weathered, the surfaces of joints and bedding planes are partly covered with thin films of sulphur and alkaline salts. Globules of resin are present in small amounts. That the coal has good stocking qualities is inferred from the reports of ranchers and others who use it and from the condition of the walls of country banks and prospect drifts that have been exposed to weathering for many years.

CHEMICAL PROPERTIES.

Three samples for analysis were collected in the Emery coal field during the field season of 1911. Two of these (laboratory Nos. 12613 and 12627) were taken from coal bed I. Sample 12613 was collected from what is locally known as the Williams mine, at location 62, in the SE. ¼ SW. ¼ sec. 12, T. 22 S., R. 6 E., on the north side of Muddy Creek; sample 12627 was taken at the Browning mine, at location 75, in the NE ¼ SW. ¼ sec. 33 of the same township on Quitchuppah Creek. Taff, in 1905, collected a sample (laboratory No. 2386, also shown in table, p. 80) from the Emery mine (location 181, in sec. 2, T. 23 S., R. 6 E.), which is also on bed I. The other sample taken in 1911 (laboratory No. 12652) represents coal bed C and was collected at the Casper mine, at location 29, in the SE. ¼ NW. ¼ sec. 26, T. 22 S., R. 6 E., on a minor western tributary of Muddy Creek.

Three additional samples for analysis were collected during the field season of 1912 in the part of the coal field south of Ivie Creek, but owing to the lack of prospecting these samples are considerably weathered. At location 197, in the SW. ¼ SW. ¼ sec. 32, T. 23 S., R. 6 E., a sample (laboratory No. 14903) was collected under a sandstone ledge at a surface prospect on coal bed I. Laboratory No. 15061 represents a sample collected at location 243, in the SE. ¼ NE. ¼ sec. 26, T. 24 S., R. 5 E., from a surface prospect on coal bed A. In the SW. ¼ NW. ¼ sec. 3, T. 26 S., R. 4 E., at location 409, a sample (laboratory No. 15090) was collected from the lower 3

[1] Pishel, M. A., A practical test for coking coals: Econ. Geology, vol. 3, pp. 265–275, 1908.

feet of coal in a short prospect drift on bed A. As the drift is only about 15 feet long and was opened several years ago the sample undoubtedly represents weathered coal.

An effort was made to obtain samples as nearly unweathered as possible by removing a foot or more of the surface of the coal. It is believed, however, that notwithstanding the care taken, analyses 12613 and 12652 represent slightly weathered coal. These samples were collected from mines in which air could circulate freely, but sample 12627, collected from the Browning mine, which was closed so that circulation of the air was at a minimum, is considered to be practically unweathered. An ultimate analysis, which shows accurately the amount of each chemical element in the coal, was made of sample 12627 in addition to the proximate analysis and calorific determinations. The analyses of the other samples collected are only proximate but include calorific determinations with the exception of No. 2386, collected by Taff in 1905.

A proximate analysis is much simpler than an ultimate analysis. In the former the coal is treated in such a way as to determine the amounts of moisture, volatile matter (gases), fixed carbon, and ash. Usually the amount of sulphur contained in the coal is ascertained. In the ultimate analysis the exact amounts of the elements constituting the coal are determined. A calorific determination of the coal is usually made in both kinds of analyses in order to ascertain its heating value, which is expressed in terms of calories[1] and British thermal units.[2]

In sampling a coal bed a fresh face of the coal is chosen where possible and all surface impurities are removed. A channel is cut perpendicularly across the face of the coal bed from roof to floor of such size as to yield not less than 5 pounds for each foot of coal in the bed. Partings more than three-eighths of an inch in thickness are discarded. An oilcloth is generally used to catch the coal as it falls from the channel and to prevent moisture and impurities from being mixed with the sample. The coal is then pulverized, thoroughly mixed, quartered, opposite quarters discarded, and the remainder remixed. This process is continued until the sample is reduced to about 1 quart, which is sent in an air-tight can to the chemical laboratory of the Bureau of Mines at Pittsburgh for analysis.

The accompanying table of analyses shows the composition of all the samples collected in the field and the heating value of all except one (No. 2386).

[1] A calorie is the quantity of heat required to raise the temperature of a gram of pure water 1° C. at or about 4° C.

[2] A British thermal unit (B. t. u.) is the quantity of heat required to raise the temperature of 1 pound of water 1° F. at or near the temperature of maximum density (39.1° F.).

Analyses of coal samples from the Emery coal field, Emery and Sevier counties, Utah.

[Made at the Pittsburgh laboratory of the Bureau of Mines, A. C. Fieldner, chief chemist.]

Bed.	Location.				No. on plates.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
	Quarter.	Sec.	T. S.	R. E.					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
I	SW	12	22	6	62	12613	0.9	A	4.0	41.8	42.6	11.6	4.7					6,660	11,990
								B	3.1	42.2	43.0	11.7	4.7					6,720	12,100
								C		43.6	44.3	12.1	4.9					6,935	12,480
								D		49.6	50.4		5.5					7,890	14,200
I	SW	33	22	6	75	12627	.3	A	4.0	40.9	49.2	5.93	.39	5.52	73.02	1.25	13.89	7,205	12,960
								B	3.6	41.0	49.4	5.95	.39	5.51	73.24	1.25	13.66	7,225	13,000
								C		42.6	51.2	6.17	.41	5.29	76.01	1.30	10.82	7,500	13,500
								D		45.4	54.6		.44	5.64	81.01	1.39	11.52	7,990	14,380
I	SW	2	23	6	181	2386	.8	A	5.1	36.7	50.4	7.8	2.1						
								B	4.3	37.0	50.9	7.8	2.1						
								C		38.7	53.1	8.2	2.2						
								D		42.1	57.9		2.4						
I	SW	32	23	6	197	14903	8.5	A	16.7	34.3	41.9	7.1	1.1					5,275	9,500
								B	8.9	37.5	45.8	7.8	1.2					5,765	10,380
								C		41.2	50.3	8.5	1.3					6,330	11,400
								D		45.0	55.0		1.5					6,920	12,460
C	NW	26	22	6	29	12652	1.8	A	5.2	39.1	41.6	14.1	.8					6,265	11,270
								B	3.5	39.8	42.4	14.3	.8					6,380	11,480
								C		41.2	43.9	14.9	.9					6,605	11,890
								D		48.4	51.6		1.0					7,765	13,970
A	NE	26	24	5	243	15061	11.6	A	18.4	33.9	42.2	5.5	.4					5,270	9,490
								B	7.7	38.3	47.7	6.3	.5					5,960	10,730
								C		41.5	51.7	6.8	.5					6,460	11,630
								D		44.5	55.5		.5					6,930	12,480
A	NW	3	26	4	409	15090	17.0	A	23.6	32.6	33.2	10.6	2.9					4,345	7,820
								B	7.9	39.3	40.1	12.7	3.5					5,235	9,430
								C		42.7	43.5	13.8	3.8					5,685	10,230
								D		49.5	50.5		4.4					6,600	11,880

12613. Collected at the back end of the Williams mine (location 62, Pls. VIII and X), in the SE. ¼ SW. ¼ sec. 12, T. 22 S., R. 6 E. The coal was possibly slightly weathered.

12627. Browning mine (location 75, Pls. VIII and X), in the NE. ¼ SW. ¼ sec. 33, T. 22 S., R. 6 E. The sample was taken from the lower 12 feet of coal bed I, which is 20 feet thick at this place. The sample probably represented practically fresh coal.

2386. Collected by J. A. Taff[1] in 1905 from the Emery mine (location 181), in the NW. ¼ SW. ¼ sec. 2, T. 23 S., R. 6 E., at the back end of a 50-foot drift which was inaccessible in 1911.

14903. Surface prospect (location 197, Pls. VIII and X) in the SW. ¼ SW. ¼ sec. 32, T. 23 S., R. 6 E. This sample was collected under a sandstone ledge which protected the coal somewhat. About 2 feet of the outer coal was removed in order to obtain a more nearly fresh sample. It is believed, however, that this sample was much weathered.

12652. Casper mine (location 29, Pls. VIII and X), in the SE. ¼ NW. ¼ sec. 26, T. 22 S., R. 6 E. The sample was collected from the lower 7 feet 2 inches of the bed at a point about 250 feet northwest from the mouth of the entry. The coal was probably slightly weathered.

15061. Surface prospect (location 243, Pls. IX and X) in the SE. ¼ NE. ¼ sec. 26, T. 24 S., R. 5 E. The sample was collected from the lower 11 feet 3 inches of the bed, excluding the 3-inch bone parting about 2 feet 9 inches above the base of the coal. The coal at this place if unweathered would probably compare favorably in calorific value with laboratory No. 12627.

15090. Prospect (location 409, Pls. IX and X) in the SW. ¼ NW. ¼ sec. 3, T. 26, S., R. 4 E. The sample was collected at the back end of a 15-foot drift from the lower 3-foot bench of coal. The analysis shows that it is much weathered and contains an excess of moisture.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it came from the mine. This form is not well suited for comparisons, for the amount of moisture in the sample as it comes from the mine is largely a matter of accident and consequently analyses of the same coal expressed in this form may vary widely. Analyses B represents the condition of the sample after it has been dried at a temperature slightly above normal room temperature until its weight becomes constant. This form of analysis is best adapted for general purposes of comparison. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated. Analysis D represents the coal after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance free from the most important impurities. Forms C and D are obtained from the others by recalculation.

In the analytical work it is not possible to determine the proximate constituents of coal or lignite with the same degree of accuracy as the ultimate constituents. Therefore the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place

[1] Taff, J. A., Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, pp. 294, 301, 1906.

only; whereas in the ultimate analysis ash, sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. The determination of the calorific value to individual units is not reliable, hence in the column headed "Calories" the values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest tens, as the British thermal unit is about one-half the value of a calorie.

It seems to the writer that if the samples had been unweathered each analysis would show a heating value on the air-dried basis equal to or greater than that represented by laboratory No. 12627 (13,000 British thermal units). Striking variations may be noted in the amount of ash and sulphur in the above table of analyses. The ash on the air-dried basis varies from 5.95 (No. 12627) to 14.3 (No. 12652) and averages 9.2; the sulphur ranges from 0.39 (No. 12627) to 4.7 (No. 12613), averaging 1.88.

For comparison, the following table of analyses of coals from adjacent fields in Colorado, Utah, and Wyoming, is given:

Analyses of coals from Colorado, Utah, and Wyoming.[a]

Locality.	Laboratory No.	Air-drying loss.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	British thermal units.
10 miles northwest of Palisades, Colo	3545	4.4	10.0	32.7	51.0	6.3	0.66	6,310	11,360
5 miles north of Thompsons, Utah	3856	2.3	4.1	32.6	43.8	19.5	.60	6,030	10,850
Emery, Utah	12627	.3	3.6	41.0	49.4	6.0	.39	7,225	13,000
Sunnyside, Utah	12632	3.4	2.7	40.0	50.5	6.8	1.79	7,385	13,290
Clear Creek, Utah	542	3.1	4.0	43.2	47.3	5.5	.58	.....	.....
Iron County, Utah	3762	2.3	6.4	37.3	47.3	9.0	5.99	.....	.....
Blacktail Mountain, Utah	10998	9.0	6.1	42.3	45.1	6.5	.90	6,340	11,410
Uinta County, Wyo	4300	1.6	1.9	36.5	51.4	10.2	.93	7,265	13,080
Rock Springs, Wyo	6772	7.1	4.7	39.7	53.9	1.7	.81	7,310	13,160

[a] These are analyses of air-dried samples and should be compared with form B in the preceding table.

An examination of this table shows that the coal in the Emery coal field compares very favorably with the coals of the near-by fields, with which it will have to compete sometime in the future.

Moisture, sulphur, and ash are injurious constituents of coal and detract from its heating value. On the other hand, reasonably high fixed-carbon content accompanies an enhanced heating value. The analysis of sample 12627, from the Emery field, shows that it contains less moisture than any of the other coals listed, except those from Sunnyside, Utah, and Uinta County, Wyo. (laboratory Nos. 12632 and 4300). It also contains a smaller amount of sulphur than any of the other analyses and 1 per cent less than the average sulphur content of all of them. In ash the Emery coal compares very favorably with the other coal beds shown in the above table in that it contains less than any of the other coals except those from Clear Creek,

Utah, and Rock Springs, Wyo. (laboratory Nos. 542 and 6772), and nearly 1.5 per cent less than the average of all. The above table also shows that the Emery coal contains more fixed carbon than the coal from Thompsons, Clear Creek, Iron County, and Blacktail Mountain, Utah, but a little less than the coals from the other four localities. The fixed carbon in the Emery coal exceeds the average of the fixed carbon content of the coals in the above table by 0.6 per cent. The average of the British thermal units of seven of the coals cited is 12,310. The Emery coal contains about 700 British thermal units more than this average and exceeds all the coals compared except those from Sunnyside, Utah, and Uinta County and Rock Springs, Wyo.

DEVELOPMENT.

MINES AND PROSPECTS.

Several small mines and prospects have been opened on the coal beds of this field, and considerable coal has been removed for local use. These drifts are described below in order from north to south along the outcrops of the various beds.

COX PROSPECT.

The Cox prospect (location 110, Pl. X), in the NE. ¼ SE. ¼ sec. 7, T. 22 S., R. 7 E., is on a lens of coal believed to be at the horizon of coal bed I, which, 300 feet east of the prospect, is replaced by massive sandstone. The prospect consists of a single drift about 20 feet long which extends slightly east of north along the strike of the rocks. Probably not more than 10 or 15 tons of coal has been removed. Owing to the well-preserved sandstone roof, propping is unnecessary.

MOORE MINE.

A drift about 100 feet in length extends N. 15° E. on coal bed I in the NW. ¼ NE. ¼ sec. 13, T. 22 S., R. 6 E., and is known locally as the Moore mine (location 60, Pl. X). It is reported to have been opened in 1905 by Thomas Thompson, of Ferron, Utah. The roof, which is sandstone, is much broken by joints and requires considerable support. At least 150 tons of coal has been mined from this place.

WILLIAMS MINE.

The Williams mine (location 61, Pl. X), also on bed I, is on the east side of Muddy Creek in the SE. ¼ SW. ¼ sec. 12, T. 22 S., R. 6 E. Its entry, from which no rooms have been turned, is about 200 feet long and 12 feet wide and bears S. 60° E. As the coal bed has a fairly good sandstone roof very little propping is necessary. A

sample (laboratory No. 12613) taken at the back end of the entry (location 62) shows a heating value of 12,100 British thermal units on the air-dried basis. Probably 600 or 700 short tons of coal has been removed from this mine. The mouth of the mine is shown in Plate XI, *A*.

CASPER MINE.

One of the oldest mines in this field, known locally as the Casper mine, is on coal bed C on a tributary of Muddy Creek in the SE. ¼ NW. ¼ sec. 26, T. 22 S., R. 6 E. (location 29, Pl. X), about 4 miles southeast of Emery. The coal bed at this place strikes N. 5° or 6° E. and dips about 2° W. Those mining coal here have left pillars here and there between great irregular cavelike rooms, some of which are large enough for a team and wagon to turn in them. It has been the custom to load the wagons in the mine at the faces of the entry and rooms, thus avoiding any mine haul and the construction of a loading tipple. Owing to the irregular shape of the mine cavity, it is difficult to estimate the amount of coal removed, but it is believed that 1,000 to 2,000 tons has been taken from the Casper mine. A sample (laboratory No. 12652), which shows 11,480 British thermal units on the air-dried basis, was collected at a point about 250 feet northwest of the mine mouth. The coal bed has a good sandstone roof and requires very little support. Plate XI, *B*, shows the conditions at the mouth of the Casper mine.

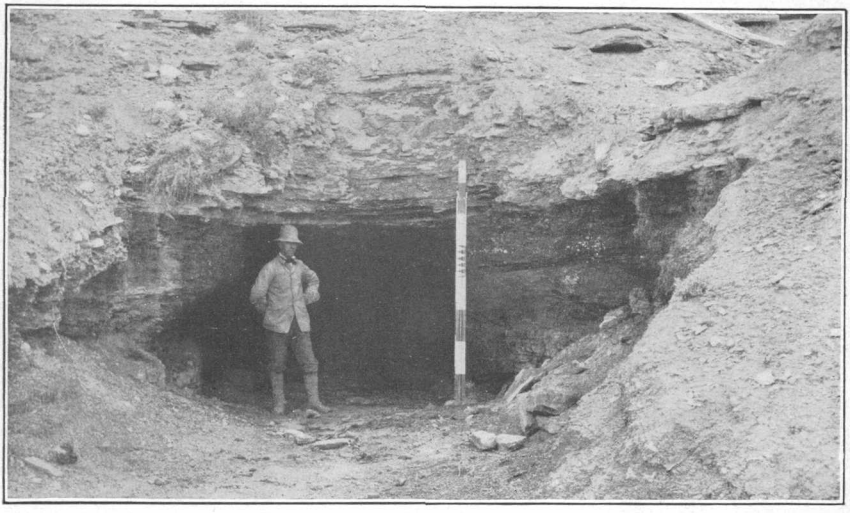
EMERY MINE.

The Emery mine (location 181, Pl. X), in the NW. ¼ SW. ¼ sec. 2, T. 23 S., R. 6 E., was inaccessible in 1911 on account of caving. Some coal is mined from the same bed (bed I) at a surface exposure near the head of a small ravine directly south of the mouth of the old mine. Two entries have been driven—one 20+ feet and the other 50+ feet long. Taff,[1] who collected a sample from this "country bank" in 1905, states: "A drift has been driven 50 feet on the coal and two rooms have been turned." The analysis (laboratory No. 2386) made from the sample collected by Taff at this place is republished in the table of analyses on page 80 in order that all analyses made from coals in the Emery coal field may appear together. It is estimated that at least 1,000 tons of coal has been removed from the Emery mine.

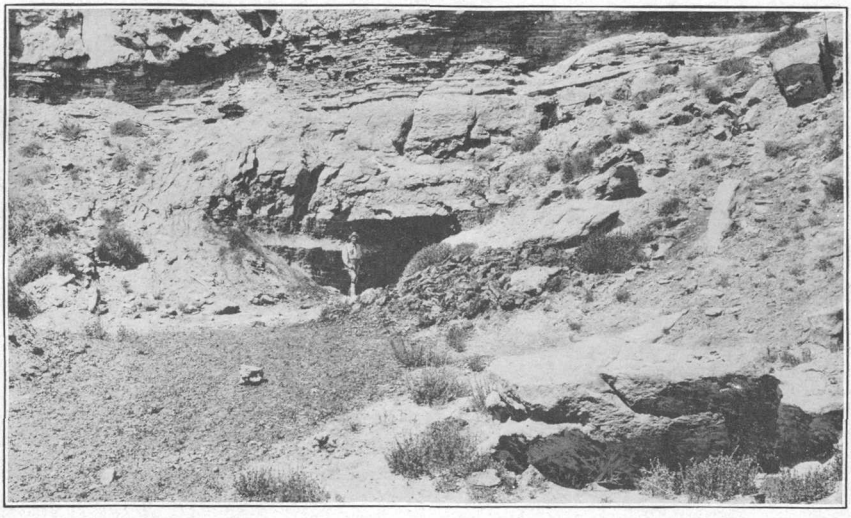
BROWNING MINE.

In 1881 Philip Pugsley opened a prospect on the outcrop of coal bed I in the NE. ¼ SW. ¼ sec. 33, T. 22 S., R. 6 E. (location 75, Pl. X) on the east side of Quitchuppah Creek and directly south of the mouth of Dipping Vat Creek. This mine, which supplies the

[1] Taff, J. A., Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, p. 301, 1906.



A. WILLIAMS MINE, ON COAL BED I, ABOUT 3 MILES EAST OF EMERY.



B. CASPER MINE, ON COAL BED C, ABOUT 4 MILES SOUTHEAST OF EMERY.

greater part of the fuel for the town of Emery and the ranchers living near by, is known locally as the Browning mine because it is under the management of Ira R. Browning, of Castledale. The coal bed at this place is 20 feet thick, as shown by section 75 (Pl. VIII). The entry bears N. 85° E. for a distance of 165 feet. One room, about 40 feet in length, has been turned to the north at a point about 90 feet from the mine mouth. In mining, only the lower 12 feet of coal is removed, the upper part of the bed serving as a roof that requires no support. The coal is brought to the surface by means of a small car on a steel track. The surface equipment consists of wagon scales, a substantial coal bin, and a dwelling house for the use of the miners. During the winter of 1910–11 about 450 tons of coal was sold at the mine at $1.50 a ton. The total amount of coal removed is probably not less than 2,000 short tons. A sample (laboratory No. 12627) was taken from the lower 12 feet of the bed at the back end of the entry. This analysis shows that the coal on the air-dried basis yields 13,000 British thermal units.

OTHER DRIFTS.

In the NW. ¼ NE. ¼ sec. 33, T. 22 S., R. 6 E., on the north side of Dipping Vat Creek, a tributary of Quitchuppah Creek, there is an abandoned drift on coal bed I. The total thickness of the coal could not be measured on account of caving and the presence of water. The drift is 20 to 30 feet long and the coal apparently equals in quality and thickness that exposed in the Browning mine. The strata dip more steeply at this place than at the Browning mine. It is estimated that at least 200 tons of coal has been removed.

A prospect drift (location 16, Pl. X) on coal bed A, in the SW. ¼ SE. ¼ sec. 33, T. 22 S., R. 6 E., on the north side of Quitchuppah Creek, bears nearly north and is about 50 feet long. Probably not more than 30 or 40 tons of coal has been taken from this prospect.

On the east side of Quitchuppah Creek, in the NE. ¼ NE. ¼ sec. 4, T. 23 S., R. 6 E., 75 or 100 feet above the stream level, another prospect, probably on coal bed A, was noted but not visited by the writer. There is also a small surface prospect on coal bed I (location 87, Pl. X) in the NE. ¼ NW. ¼ sec. 19, T. 22 S., R. 7 E. A small prospect drift, about 15 feet long, in the SW. ¼ NW. ¼ sec. 3, T. 26 S., R. 4 E., at location 409, exposes 6 feet 4 inches of coal in two beds. The entry is about 3 feet 8 inches in width and averages 4 feet in height, except at the back end, where a hole has been dug exposing the lower bed, of which the lower 3-foot bench of coal was sampled and is represented by laboratory No. 15090.

Coal has been mined at several places in the Emery field from surface exposures, but the total production of coal from the field probably does not exceed 6,000 short tons.

TRANSPORTATION ROUTES.

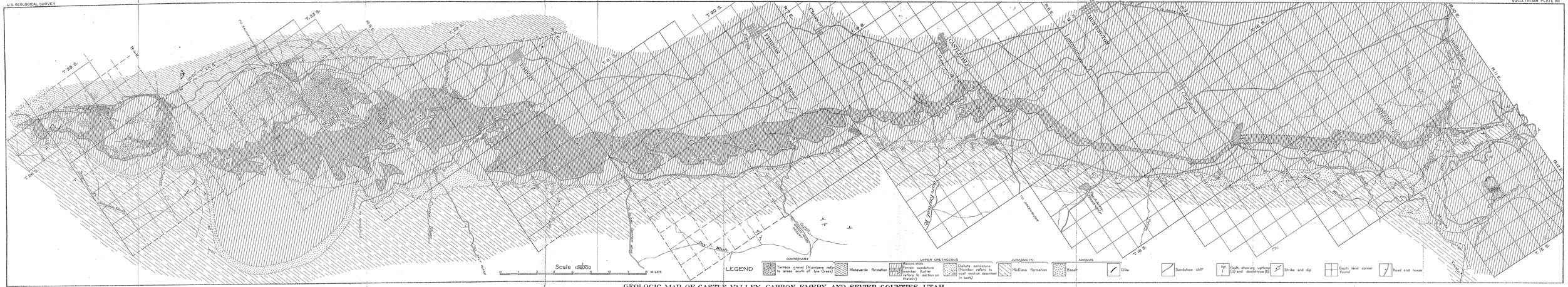
Two railroad routes have been surveyed into this coal field, one from the west and the other from the northeast. The former is considered to be the best by the company that controls the greater amount of coal land in this area, which is in the vicinity of Ivie and Quitchuppah creeks. Already about 20 miles of railroad, which is now in poor condition owing to floods, has been constructed eastward up Salina Canyon from Salina, which is on the Denver & Rio Grande Railroad. The additional construction of about 30 miles of railroad with a comparatively low grade would connect the heart of the coal field with the eastern terminus of the Salina Canyon branch. Such a route would furnish a more direct outlet to the Pacific coast than the route surveyed to the northeast through Castle Valley, joining the main line of the Denver & Rio Grande Railroad at Price or Wellington, and, in addition, would be equally direct to the Salt Lake City region. If the northeastern route is chosen, about 70 miles of railroad must be built over a country that presents practically as great difficulties mile for mile as must be surmounted on the western route, where only 30 miles is required. The Castle Valley Railroad has constructed a spur from Price as far southwest as Mohrland, in T. 16 S., R. 8 E., but only a small portion of this road could be used to advantage, as it is situated mainly high in the foothills adjacent to the Wasatch Plateau.

TONNAGE.

A careful estimate was made of the coal in the Emery coal field. It is assumed in calculating the tonnage that each acre of land underlain by a coal bed 1 foot thick (1 acre-foot) contains 1,800 tons. In the table given below two columns of figures are shown. The one on the left gives the estimated tonnage; the one on the right shows approximately the amount of coal that can be recovered, on the assumption that only 1,000 tons of coal can be mined from each acre-foot. By careful mining, however, much more than this amount may be recovered.

Estimated quantity of coal in Emery coal field, Utah.

Township.	Total coal.	Recoverable coal.
	Short tons.	*Short tons.*
T. 21 S., R. 6 E.	21,463,000	11,923,000
T. 21 S., R. 7 E.	311,000	173,000
T. 22 S., R. 6 E.	427,176,000	237,320,000
T. 22 S., R. 7 E.	21,736,000	12,075,000
T. 23 S., R. 5 E.	214,310,000	119,061,000
T. 23 S., R. 6 E.	355,877,000	197,710,000
T. 24 S., R. 5 E.	268,389,000	149,106,000
T. 24 S., R. 6 E.	33,171,000	18,027,000
T. 25 S., R. 4 E.	30,093,000	16,741,000
T. 25 S., R. 5 E.	54,734,000	30,408,000
T. 26 S., R. 4 E.	1,805,000	1,002,000
	1,429,065,000	793,546,000



GEOLOGIC MAP OF CASTLE VALLEY, CARBON, EMERY, AND SEVIER COUNTIES, UTAH

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