GEOLOGY AND COAL RESOURCES OF THE MEEKER QUADRANGLE, MOFFAT AND RIO BLANCO COUNTIES, COLORADO

By E. T. Hancock and J. B. Eby

INTRODUCTION

FIELD WORK

The investigations on which the greater part of this report is based were carried on by E. T. Hancock, the senior author, during the summer of 1911. They were undertaken by the United States Geological Survey under a comprehensive plan for collecting information about the undeveloped fuel resources of the Western States, both as a step toward the conservation of the coal resources of the United States and as a means of supplying the demand for information concerning the many valuable coal fields of the Western States.

Further work in the field was done during parts of the summers of 1923 and 1924 by J. B. Eby, and the report was revised and amplified in 1924 in order to incorporate the additional data procured. Particular attention was given by Mr. Eby to the stratigraphy of the Williams Fork and Wasatch formations and the geology of the Meeker dome.

The work in 1911 by Mr. Hancock was carried on under the general supervision of M. R. Campbell, and that in 1923 and 1924 by Mr. Eby under the general supervision of W. T. Thom, jr.

Mr. Hancock's mapping of the geology of the Meeker quadrangle was conducted simultaneously with the topographic mapping. Flag locations were made by him, and their position and altitude were accurately determined later during the preparation of the topographic map. Individual coal beds were rarely correlated by tracing, owing to the scarcity of exposures and to the extensive burning of the coal beds along their outcrops, many slopes being covered by brick-red sandstone and shale. The correlations that were made are based mainly on measurements of stratigraphic sections wherever a series of coal beds was exposed along the steep slopes and on the actual or mathematical determination of the stratigraphic position of these beds with reference to key sandstones, of which the Trout Creek was the most persistent and most easily recognized.

EARLIER GEOLOGIC INVESTIGATIONS

The earliest complete maps of Colorado were published in the form of two large atlases that accompany the early reports of the King and Hayden surveys. The area covered by the Meeker quadrangle lies within the region mapped by the Hayden survey in the summer of 1876. The Hayden atlas sheets were published on a scale of 4 miles to the inch, with relief shown in 200-foot contours, and excellently represent the general features of the region. The comparative accuracy of these maps is remarkable, when we consider the unsettled condition of the country, the great extent of territory mapped in a short time, the comparative inaccessibility of the region, and the hostile attitude of the Ute Indians, who then held possession. The area included within the Meeker quadrangle was again surveyed in the summers of 1906 and 1907 by a party under the general supervision of Hoyt S. Gale.[1] The object of the survey was primarily the classification of the public lands and secondarily the compilation of results in such a form as to be useful not only to the general public but to investigators who are making further specialized or detailed study in particular parts of the field.

LOCATION AND ACCESSIBILITY

The Meeker quadrangle is in northwestern Colorado, partly in Rio Blanco County and partly in Moffat County. It lies between meridians 107° 45′ and 108° and parallels 40° and 40° 15′ and includes 228.4 square miles. The quadrangle lies between the Uinta Range and the White River Plateau and includes a portion of the Danforth Hills, the largest single compact mountain group in the foothill province of this region.

The south edge of the Meeker quadrangle is 30 miles north of Rifle, the nearest station on the Denver & Rio Grande Western Railroad, and the quadrangle is approximately 80 miles south of the main line of the Union Pacific Railroad. Craig, the western terminus of the Denver & Salt Lake Railroad, is about 20 miles northeast of the northeast corner of the quadrangle. Should this railroad be extended west to Salt Lake City, the center of the Meeker quadrangle would lie about 25 miles south of its route at Lay, Colo.

Surveys were made in 1887–88 in connection with the construction of the Colorado Midland Railway from Newcastle west to the Colorado-Utah State line. One of the surveys crossed the Meeker quadrangle, following Colorado River, Dry Rifle Creek, the Gov-

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

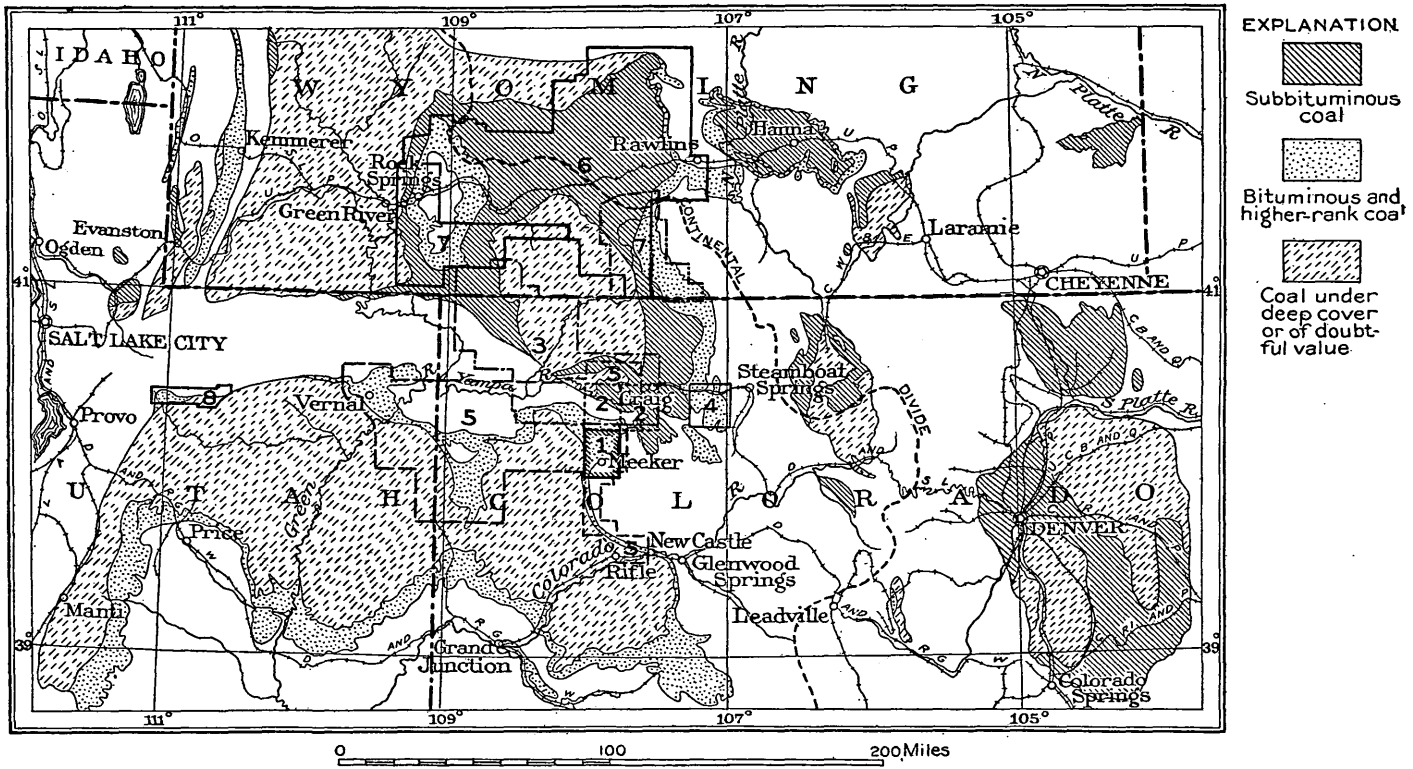


FIGURE 5.—Index map showing the relation of the Meeker quadrangle, Colorado, to the main Yampa coal field and to possibly competing fields. Numbers indicate Geological Survey reports as follows: 1, This report; 2, Bull. 757; 3, Bull. 751; 4, Bull. 748; 5, Bull. 415; 6, Bull. 341; 7, Bull. 381; 8, Bull. 471

ernment road, and White River. The maximum grade and curvature on this route were encountered in ascending Dry Rifle Creek, where for about 9 miles the route had a maximum grade of 3 per cent and curvature of 16°, the remainder of the route from Newcastle to the State line not exceeding 2 per cent grade and 10° curvature. It would appear from these figures that construction of such a road is feasible, and no doubt a route could be found that would be an improvement over the maximum shown.

In regard to the possibility of extending spurs from the valleys of White River and that of Yampa River up to certain points within the main coal area, the following facts are apparent from the topographic map: From the valley of White River at Meeker up to the head of Sulphur Creek Valley in the NW. ¼ sec. 24, T. 2 N., R. 94 W., there is a rise of 800 feet in about 8 miles, which is equivalent to a grade of 1.9 per cent. Again, from Powell Park up Strawberry Creek to the SW. ¼ sec. 6, T. 2 N., R. 94 W., there is a difference in altitude of about 625 feet in a distance of 11 miles, equivalent to a grade slightly in excess of 1 per cent. From White River Valley at Meeker to the base of the Fairfield coal group in Curtis Creek there is an average rise of about 100 feet to the mile, which is equivalent to a grade of 1.9 per cent. Furthermore, there is a difference in altitude of 800 feet between the valley of White River at Meeker and the base of the Fairfield group of coal beds on Coal Creek. The distance by way of the main wagon road is approximately 11 miles, equivalent to an average grade of about 1.4 per cent. The necessary grade from White River Valley to the same point by way of Coal Creek amounts to about 1.9 per cent. It is pointed out in an earlier report[2] that railroad construction down Yampa River from the main line of the Denver & Salt Lake Railroad is feasible and also that the difference in altitude between Yampa River and the valley of Good Spring Creek near the Mount Streeter (old Joseph Collum) mine amounts to 490 feet in a distance of about 10 miles, which is approximately equivalent to a grade of 1 per cent. Furthermore, between the mine and the south line of T. 3 N., R. 93 W., the valley of Good Spring Creek rises at a rate of about 100 feet to the mile, a grade of approximately 1.9 per cent.

From what has been said it would appear that railroad construction to the Meeker area is feasible either north from the main line of the Denver & Rio Grande Western Railroad or south from that of the Denver & Salt Lake Railroad; and further that spurs can be

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

extended from White River Valley or from Yampa River Valley up into the Danforth Hills without involving grades in excess of 2 per cent.

ACKNOWLEDGMENTS

In the summer of 1911 the senior writer was assisted by Joseph H. Gregg, of Meeker. During the progress of the early field work the party was visited by E. G. Woodruff, who had general supervision of the field work in 1911 and to whom the senior writer is indebted for valuable suggestions.

GEOGRAPHY AND TOPOGRAPHY

RELIEF

An inspection of the accompanying topographic map (pl. 19) reveals the existence of three rather pronounced topographic features—the broad valley of Agency Park, the valley of Strawberry Creek, and the Danforth Hills. The quadrangle furnishes an excellent illustration of the intimate relation existing between topographic features and the lithologic character, structure, and distribution of the rocks.

Agency Park.—Agency Park, formerly known as Simpson's Park, lies south of the Danforth Hills, east of the Grand Hogback, and west and north of White River Plateau. The park, about 50 square miles of which is included within the southeast corner of the Meeker quadrangle, consists of a low, broad valley, drained entirely by White River and its tributaries. Lenses of thin-bedded sandstone near the top and base of the shale that underlies the valley are clearly expressed in the topography. For example, the crescent-shaped ridge immediately north of the uplift of Dakota (?) sandstone 3 miles east of Meeker is formed by resistant sandy beds near the base of the Mancos shale. The almost continuous ridge 1 to 2 miles east and south of the line that marks the top of the Mancos indicates the presence of relatively resistant beds a few hundred feet below the top of the shale. Rattlesnake Mesa is a part of this ridge.

Valley of Strawberry Creek.—The valley of Strawberry Creek, a tributary of White River, occupies a considerable area near the western edge of the quadrangle. Strawberry Creek is an intermittent stream that drains the southwest slope of the Danforth Hills and the west slope of the prominent ridge that extends south from the hills. It also drains the east slope of the prominent ridge immediately west of the valley. This stream, together with its tributaries, has carved

its valley from comparatively nonresistant formations composed chiefly of clay or soft clay shale.

Danforth Hills.—The Danforth Hills occupy the greater part of the north half of the Meeker quadrangle. Together with the high ridge that extends south and west of Meeker, they constitute an area which topographically is quite distinct from the areas previously described. The greater part of the area lies at a much higher altitude than either Agency Park or Strawberry Creek Valley. The maximum altitude, 8,720 feet, is on the ridge immediately east of the head of James Creek, on the east line of sec. 12, T. 2 N., R. 93 E.

DRAINAGE

As shown on Plate 19 the southern and western parts of the Meeker quadrangle are drained by White River and its tributaries; the northern and northeastern parts are drained by Good Spring Creek and other tributaries of Yampa River.

CLIMATE

Records kept at Meeker from 1906 to 1915 show a maximum temperature of 90° F. during July, a minimum temperature of 43° below zero in January, and annual precipitation ranging from 11.44 to 20.35 inches.

STRATIGRAPHY

AGE OF THE ROCKS

The strata exposed in the Meeker quadrangle are of Cretaceous and early Tertiary age. Deep-sea, shallow-water, and swampy conditions prevailed during the deposition of these strata, as is indicated by the presence of marine, brackish-water, and fresh-water invertebrate fossils and fossil plants. The sedimentary beds were originally laid down in an approximately horizontal position but have since been folded and in places broken or faulted.

A generalized description of the formations that crop out in the Meeker quadrangle is given below in tabular form for convenience of reference and direct comparison.

Rock formations that crop out in the Meeker quadrangle, Colo.

System and series	Formation		Character	Approximate thickness (feet)
Tertiary (Eocene series)	Wasatch formation.		Mainly massive to thin-bedded sandstone and sandy shale. Some carbonaceous shale and thin coal beds occur near the base of the formation, from 50 to 200 feet above a well-defined conglomerate. Contains a few bodies of silicified and carbonized wood. The massive sandstones resemble those of the underlying Mesaverde formation.	4,180+
	Unconformity			
Cretaceous (Upper Cretaceous series)	Mesaverde group	Williams Fork formation.	Alternating sandstone, sandy shale, and coal beds. The massive sandstones are usually light yellowish brown. The more shaly beds and numerous coal beds are in places covered by a mantle of débris from the overlying sandstones. The coal beds are commonly burned along their outcrops. Includes Lion Canyon sandstone member (0–100 feet thick), about 1,440 feet below the top and about 3,000 feet above the base of the formation.	4,500–5,000
		Iles formation.	Massive ridge-forming sandstone with some shale and a few coal beds. Massive white sandstone (Trout Creek sandstone member) at top.	1,350–1,600
	Mancos shale.		Dark-drab or gray shale, containing layers and lenticular masses of sandstone and sandy strata. One such belt, possibly corresponding to the Morapos sandstone member, occurs about 850 feet below the top of the formation and another about 900 feet lower. Near the base is a unit characterized by fine-grained dark sandstone and some limestone. Basal 150 to 200 feet consists of brown to black platy shale, showing well-developed rectangular joint planes.	5,000
	Dakota(?) sandstone.		Chiefly quartzite and quartzitic sandstone, with a basal conglomerate.	200–250
Cretaceous (?)	Morrison formation.		Greenish sandy shale and indurated clay containing fossil bones of a sauropodous dinosaur (genus *Apatasaurus?*).	50+

CRETACEOUS (?) SYSTEM

MORRISON FORMATION

The Morrison formation crops out beneath the Dakota (?) sandstone in the heart of the Meeker dome, in the SW. ¼ sec. 20, T. 1 N., R. 93 W. Not more than 50 to 100 feet of the upper part of the formation is exposed. The formation consists of greenish sandy shale and indurated clay. The unweathered shale is dark, hard, and sandy, but on weathering it becomes softer and takes on a light-greenish color. The beds exhibit marked rectangular jointing. Vertebrate fossils collected from this formation in the summer of 1924 by the junior author were identified by C. W. Gilmore, of the National Museum, as two incomplete caudal vertebrae that resemble those of the Morrison dinosaur genus *Apatasaurus*.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

Rocks of the Upper Cretaceous series are exposed throughout the greater part of the Meeker quadrangle and include, from the base upward, the Dakota (?) sandstone, the Mancos shale, and the Iles and Williams Fork formations of the Mesaverde group. The total thickness of the four formations is about 10,000 feet. Throughout the time necessary for the deposition of this great thickness of beds there seems to have been uninterrupted sedimentation.

DAKOTA (?) SANDSTONE

The Dakota (?) sandstone crops out only in a small area on the apex of the Meeker dome, immediately north of White River, about 3 miles east of Meeker, and consists of a basal conglomerate overlain by quartzitic sandstone and sandy shale. The thickness of the formation, although difficult to measure, is probably between 200 and 250 feet.

MANCOS SHALE

The Mancos shale lies conformably upon the Dakota (?) sandstone and underlies conformably the Mesaverde group. In this field it is regarded as a single stratigraphic unit, although elsewhere it has been subdivided into several formations, largely on paleontologic evidence. The Mancos of this field includes the Benton, the Niobrara, and a part of the Pierre, according to the classification of the Cretaceous proposed by Meek and Hayden for the upper Missouri River region.

In general the Mancos consists of homogeneous clay shale with local ledges of thin-bedded sandstone, although its basal 150 to 200 feet consists of brown to black platy shale that shows well-developed rectangular joint planes. Interbedded with this slaty shale are beds of clay 2 to 14 inches thick that have the physical character of fire clay. The platy shale belt is well exhibited in the gulch east of Meeker, which coincides closely with the contact line between the Dakota (?) sandstone and Mancos shale. Above this lower platy shale lie shaly and sandy strata of a similar thickness that do not weather as readily as the overlying and underlying beds and hence stand out as a more or less conspicuous ridge, nearly parallel to the curved contact line between the Dakota (?) sandstone and the Mancos shale. Fossils obtained from this sandy zone near the northwest corner of the Axial quadrangle, which lies just north of the Meeker quadrangle, include forms characteristic of the Carlile shale and are as follows:

Inoceramus fragilis Hall and Meek.
Inoceramus sp. near I. deformis Meek.
Prionocyclus wyomingensis Meek.
Scaphites warreni Meek and Hayden.
Shark teeth.

The upper 1,800 feet of the formation contains several zones of thin-bedded sandstone, interbedded with sandy shale. Because of their greater resistance, these beds in general stand out as steep cliffs below the Mancos-Mesaverde contact. Two such cliffs are found along the north and west side of Agency Park. The sandstone in the upper cliff, 800 to 900 feet below the top of the formation, is perhaps equivalent to the Morapos sandstone member of the Monument Butte quadrangle, which lies northeast of the Meeker quadrangle. This sandstone is not persistent and consequently does not form a continuous cliff. Its character is well shown in a photograph taken near the south quarter corner of sec. 1, T. 1 N., R. 94 W. (See pl. 20, *B*.) The sandstone in the lower cliff, 1,600 to 1,900 feet below the Mancos-Mesaverde contact, is more persistent than the sandstone just described and forms an almost continuous ridge from Meeker to a point south of Rattlesnake Mesa. The south or east slope of this ridge is at many places nearly vertical; the north or west slope is more gentle and conforms closely to the dip of the beds. The beds beneath this ridge consist of yellowish-gray sandstone layers that range in general from a quarter of an inch to 6 inches in thickness, though a few are as much as 2 feet thick.

The escarpment that borders Agency Park on the west and north exposes the lower beds of the Mesaverde group and the upper beds of the Mancos shale. The most conspicuous feature of this escarpment is a heavy ledge of sandstone, 25 to 50 feet thick, that is locally called the "rim rock." The Mesaverde-Mancos contact was drawn about 100 feet stratigraphically below its top. Another sandstone, which in many respects resembles the "rim rock," is present at the contact in a number of places. In general it consists of yellowish-brown layers 2 inches to 2 feet thick. The bedding planes in it are generally well developed, and many of the layers are separated into more or less rectangular masses by joint planes. Another conspicuous sandstone, 75 to 100 feet below the contact, locally forms ledges; it is greenish gray and sugary, is almost free from bedding planes, and weathers characteristically into rounded forms. It contains abundant fossils—in fact, most of the invertebrates collected from the upper part of the Mancos have come either from this sandstone or from beds very near it.

It is impossible to measure the thickness of the Mancos shale in this quadrangle, but observations indicate a local thickness of about 5,000 feet. The abandoned test well in sec. 27, T. 3 N., R. 94 W., started in the Iles formation and was put down to a depth of 4,826 feet, the last 4,336 feet of which was drilled in Mancos shale. Sections measured in the vicinity of the Meeker dome and on Flag Creek, 6 miles south of Meeker, indicate a thickness of 5,000 feet or more.

MESAVERDE GROUP

ILES FORMATION

General character.—The Iles formation or lower part of the Mesaverde group overlies the Mancos shale conformably and is conformable below the Williams Fork formation. It crops out as a continuous belt along the west and north side of Agency Park, where by its greater resistance it makes the larger part of the escarpment. (See pl. 20, *A*.) The formation is also exposed in several irregular-shaped patches along the deeper gulches in the northwestern part of the quadrangle, which have been formed by erosional dissection of the Danforth Hills.

The Iles formation consists of massive sandstone, interbedded with shaly sandstone, sandy shale, black carbonaceous shale, and a few coal beds, particularly near its top. It is capped by the Trout Creek sandstone member. The character of the formation is shown by the following stratigraphic section, measured in the bluffs immediately west of Meeker:

Section of the Iles formation immediately west of Meeker

		Ft.	in.
Sandstone, white, massive	Trout Creek sandstone member.	30	
Sandstone, massive, with some interca-lated beds of shale		17	
Sandstone, shaly		7	
Sandstone, white, in thick beds		56	
Sandstone, soft, containing many shaly beds. Where eroded the slopes are gentle compared with those of the beds above and below		218	
Shale, black, carbonaceous		12	
Sandstone, shaly, with yellowish-brown thick beds at base		52	
Coal		2	10
Sandstone, shaly		10	
Coal	probably Meeker coal bed	2	2
Shale, sandy		1	9
Coal		4	8
Shale, sandy		16	
Coal		2	4
Shale, sandy		6	
Coal		1	3
Shale, sandy, with some beds of sandstone 7 to 20 inches thick		45	
Sandstone, burned		29	
Shale, gray, sandy		3	
Dark sandy carbonaceous material, containing ash (burned coal bed)		5	
Shale, black, carbonaceous			6
Coal			8

	Ft.	in.
Sandstone	5	
Shale, gray	9	
Sandstone, yellowish brown, shaly	28	
Shale, gray	13	
Sandstone, shaly, light yellow	41	
Shale, including 4½ inches of coal	4	
Sandstone, yellowish, shaly	17	
Coal		6
Sandstone, shaly, containing iron concretions	34	
Shale, sandy, with some thick sandstone beds	28	
Sandstone, yellowish brown	46	
Shale, bluish, sandy	8	
Sandstone, yellowish brown	7	
Shale, gray, sandy	6	
Sandstone, with iron concretions	7	
Shale, carbonaceous	3	
Sandstone, with iron concretions, shaly, with some thick sandstone beds	110	
Shale, dark gray	16	
Sandstone, yellowish brown	8	
Shale, dark, carbonaceous	9	
Sandstone, yellowish brown	4	
Shale, sandy, with much carbonaceous shale	25	
Sandstone, yellowish brown, in thick beds	7	
Shale, carbonaceous, clayey	5	
Sandstone, shaly, with dark bands of carbonaceous shale	132	
Shale, sandy, with a thick bed of dark carbonaceous shale near the middle	30	
Sandstone, light gray	6	
Sandstone, yellowish, massive, in thick beds	44	
Shale, bluish		6
Sandstone	1	
Shale, dark, carbonaceous	1	
Shale, sandy, with some thick sandstone beds and streaks of dark shale	95	
Sandstone, massive, yellowish, cut by joints into numerous rectangular masses	34	
Shale, sandy, with 1 to 8 inch beds of brownish-yellow sandstone	61	
Sandstone, yellowish brown, in thick beds	2	10
Shale, bluish	3	6
Sandstone, yellowish brown, in thick beds	8	
Shale, black, carbonaceous	1	
Sandstone, light gray, in thick beds	34	
Shale, bluish, sandy	1	
Sandstone, yellowish brown	4	8
Shale, sandy	2	
Sandstone, grayish	3	
Shale, bluish	3	
Sandstone, shaly	10	8
Coal	1	3
Shale, dark brown	1	3
Coal		6

	Ft.	in.
Shale, bluish, sandy, with 20-inch beds of sandstone near top	16	
Shale, bluish, carbonaceous		10
Shale, black, carbonaceous, with some coal		10
Sandstone, thick bedded, brownish, with sandy shale seams	56	
Shale, sandy, with 1 to 6 inch beds of sandstone	18	
Sandstone beds, brownish, with thin seams of sandy shale	72	
Mancos shale.		
	1,607	6

In places the conspicuous "rim rock" sandstone already mentioned is somewhat obscured by the unusual development of the sandstone beds in the upper part of the Mancos shale, particularly along the north side of the Axial Basin, near the east edge of the Axial quadrangle. At many places, also, three heavy sandstone ledges may be seen above the "rim rock," and in some places as many as six are visible. Locally these upper sandstones are more or less uniformly distributed throughout the Iles formation. Elsewhere two or more appear to have united into one bed of unusually great thickness.

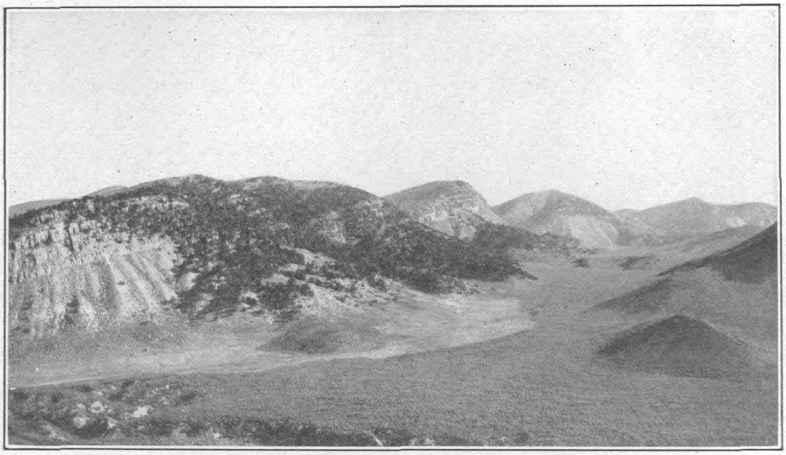
In general sandy shale, shaly sandstone, and coal beds are less abundant in the Iles formation than in the overlying Williams Fork formation.

Lower coal group.—At many localities in the Meeker quadrangle thin beds of coal occur between 100 and 250 feet above the base of the Iles formation, and the name "lower coal group" has been applied to this unit. These coals, which are of little value, are in places associated with thick beds of black carbonaceous shale.

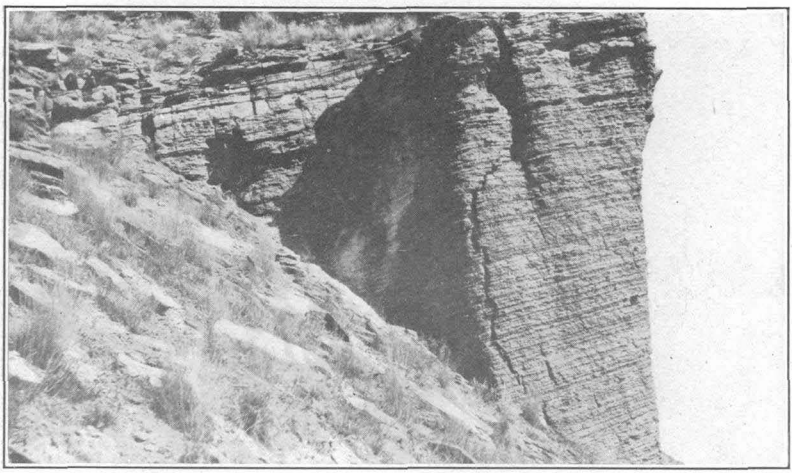
Black Diamond coal group.—The principal coal beds of the Iles formation occur in the upper part, within the interval from 150 to 350 feet below the top of the Trout Creek sandstone. This zone of coal-bearing rocks, called for convenience the Black Diamond coal group, from the Black Diamond coal mine, which works one of the beds, is of considerable value along White River and in Fairfield and Anderson Gulches, as is explained later in the text, but probably is progressively less valuable toward the east edge of the quadrangle.

Trout Creek sandstone member.—The Iles formation is capped by a conspicuous white sandstone that was named by Fenneman and Gale the Trout Creek sandstone, on account of its excellent exposure on Trout Creek on the southeast side of Twentymile Park.[3] Not only is the color of this sandstone characteristic, but its general appearance is rather striking, for it commonly weathers into smooth, rounded surfaces with numerous caverns. It ranges in thickness from 40 to 110 feet and is at some places capped by 6 to 15 feet of

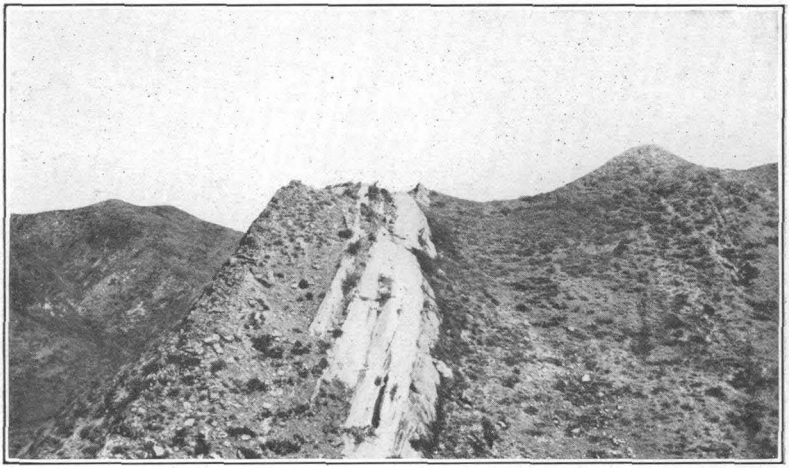
[3] Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.; U. S. Geol. Survey Bull. 297, pp. 18–24, 1906.



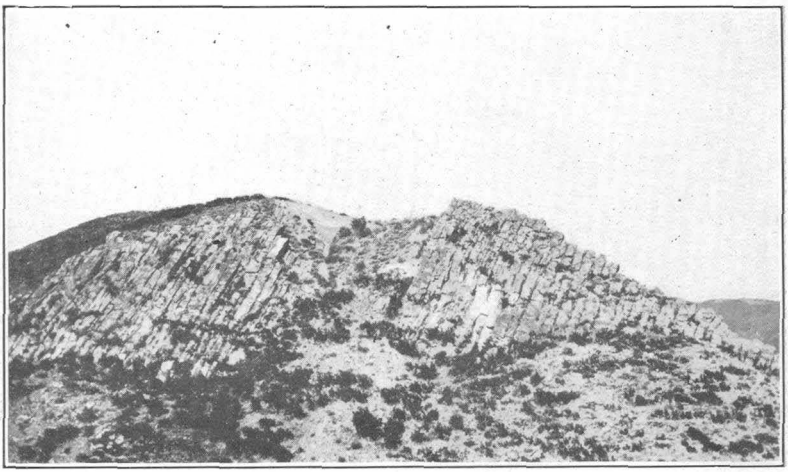
A. ESCARPMENT FORMED BY THE LOWER BEDS OF THE ILES FORMATION, LOOKING NORTHEAST FROM SULPHUR CREEK, COLO.



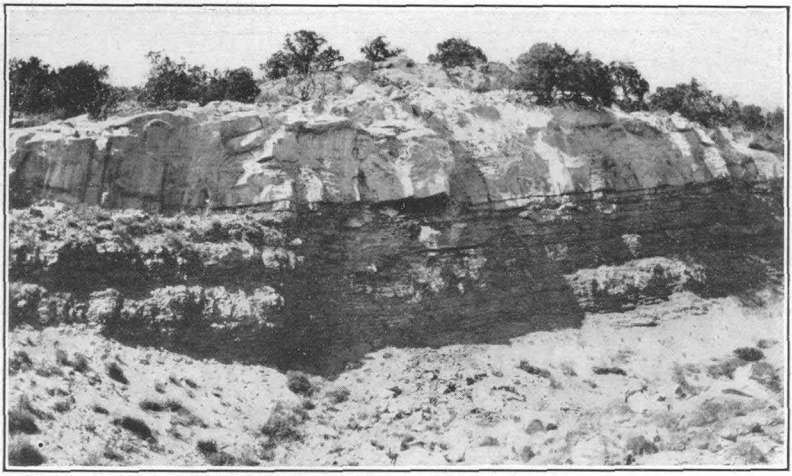
B. THIN-BEDDED SANDSTONE IN MANCOS SHALE, SEC. 1, T. 1 N., R. 94 W., COLORADO



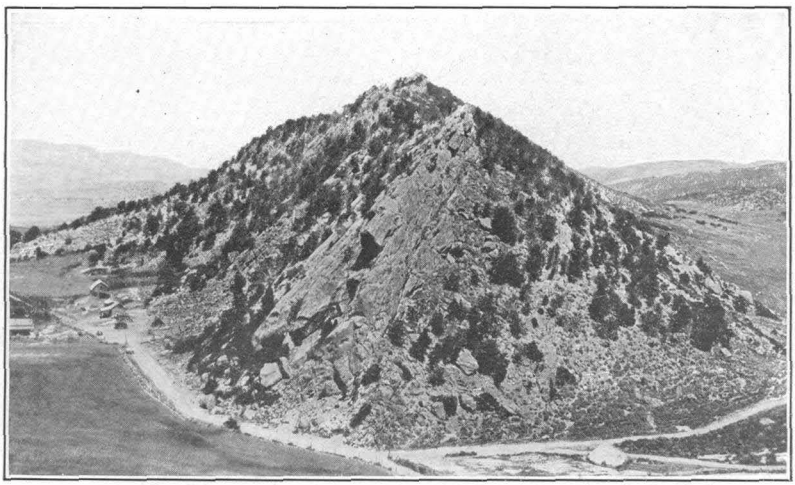
A. TROUT CREEK SANDSTONE AT THE "TRANSFER," COLORADO



B. JOINTING IN THIN-BEDDED SANDSTONE IMMEDIATELY ABOVE THE TROUT CREEK SANDSTONE AT THE "TRANSFER"

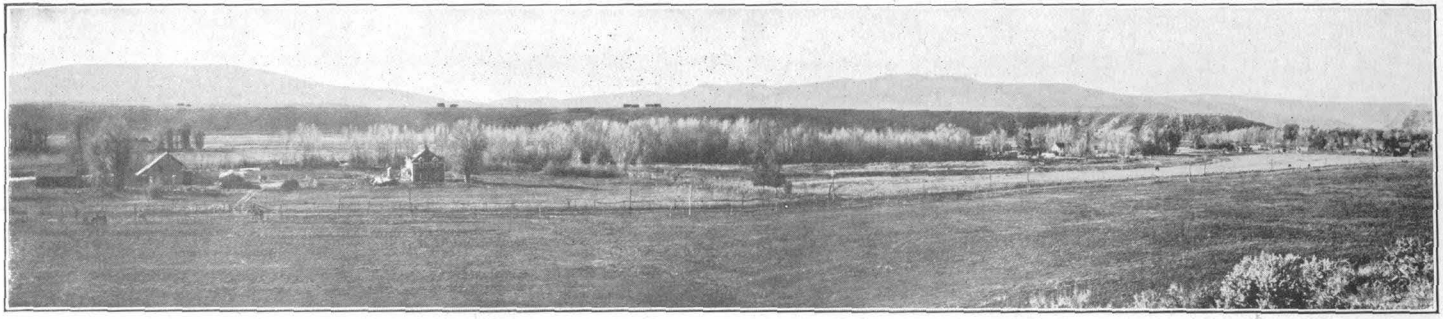


A. TROUT CREEK SANDSTONE IN SEC. 10, T. 2 N., R. 94 W., COLORADO

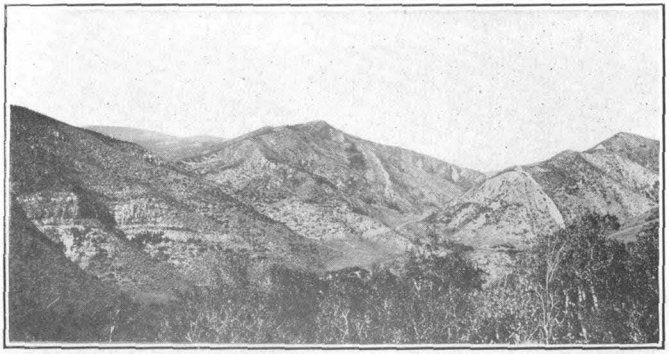


B. SANDSTONE AT BASE OF WASATCH FORMATION AT VALENTINE RANCH, SECS. 7 AND 8, T. 2 N., R. 94 W., COLORADO

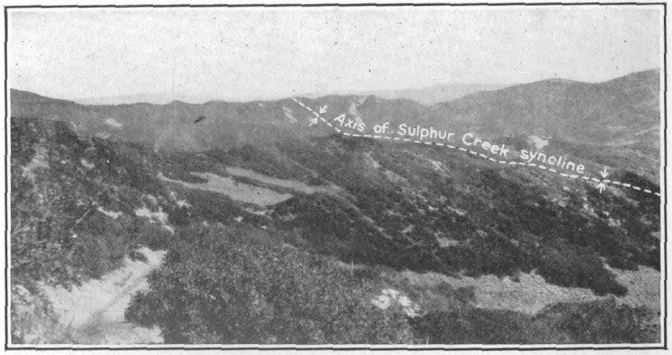
Sandstone dips 58° SW.



A. TERRACE EXTENDING EAST FROM MEEKER, COLO., ALONG THE SOUTH SIDE OF WHITE RIVER

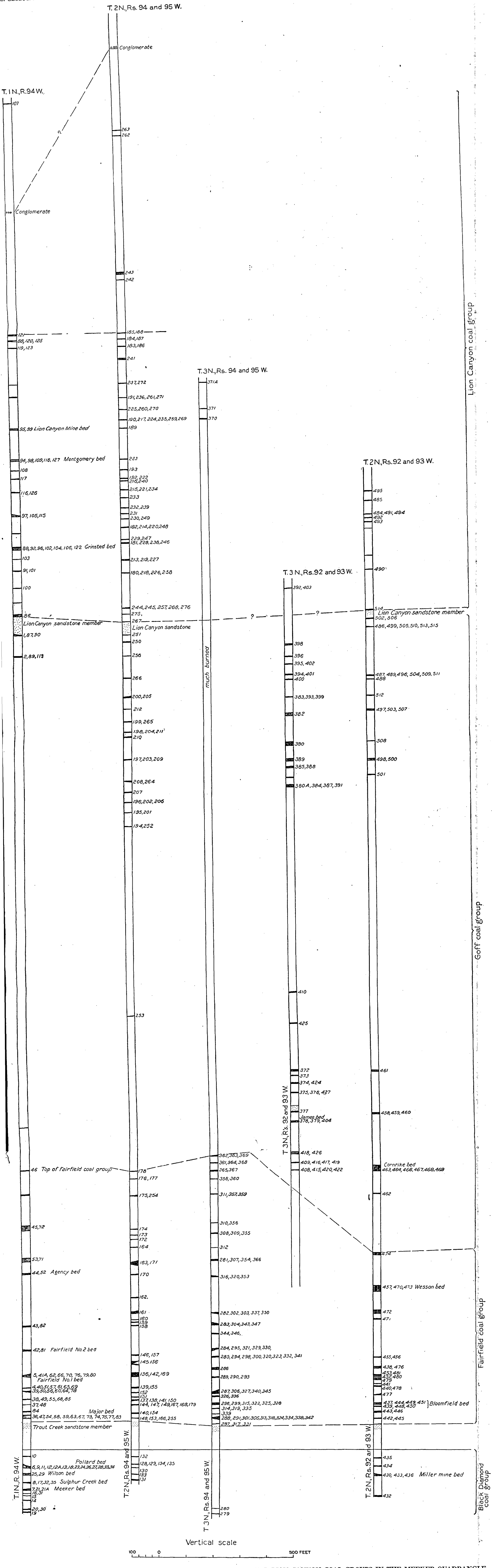


B. SULPHUR CREEK SYNCLINE AS OBSERVED FROM THE "TRANSFER," COLORADO



C. LION CANYON SANDSTONE IN THE SULPHUR CREEK SYNCLINE

Looking east from a point half a mile northwest of the Goff ranch, sec. 23, T. 2 N., R. 94 W., Colorado



STRATIGRAPHIC SECTIONS OF BLACK DIAMOND, FAIRFIELD, GOFF, AND LION CANYON COAL GROUPS IN THE MEEKER QUADRANGLE, COLORADO, SHOWING INTERVALS BETWEEN AND THICKNESSES OF COAL BEDS

thin-bedded sandstone that is locally fossiliferous. Many of these thin beds exhibit jointing to a marked degree. Plate 21, *A*, is a photograph taken looking north at the "Transfer," which is a well-known locality just east of the town of Transfer, on the east edge of the quadrangle. (See pl. 19.) It shows the white sandstone, with its characteristic weathered surface, and also the thin-bedded sandstone immediately above it, all dipping about 70° W. Plate 21, *B*, is a photograph of the upper surface of the same thin-bedded sandstone taken to show its characteristic jointing. Plate 22, *A*, a photograph taken in the NW. ¼ sec. 10, T. 2 N., R. 94 W., also shows the Trout Creek sandstone. At that locality it consists of about 30 feet of massive white sandstone underlain by a similar thickness of thin-bedded yellowish-brown sandstone.

Fossils.—Invertebrate fossils, mostly of marine types, were collected by Hancock from a belt about 400 feet thick at the base of the Iles formation in the Meeker, Axial, and Monument Butte quadrangles. As identified by T. W. Stanton they are:

Cardium speciosum Meek and Hayden.
Ostrea subtrigonalis Evans and Shumard.
Inoceramus pertenuis Meek and Hayden.
Inoceramus sp. fragments.
Tellina sp.
Donax? sp.
Mactra sp.
Shark teeth.
Anomia sp.

The following invertebrates, also chiefly of marine types, were collected from the upper 250 feet of the Iles formation and identified by T. W. Stanton:

Inoceramus sp.
Inoceramus barabini Morton.
Cardium speciosum Meek and Hayden.
Haminea sp.
Ostrea subtrigonalis Evans and Shumard.
Tellina sp.
Mactra sp.

Plants collected from the Iles formation were identified by F. H. Knowlton as follows:

Halymenites major Lesquereux (abundant throughout the lower part of the Mesaverde formation).
Stems and bark of Ficus populoides (?) Knowlton.

The thickness of the Iles formation in the Meeker and Axial quadrangles is 1,350 to 1,600 feet.

WILLIAMS FORK FORMATION

General character.—The Williams Fork formation lies conformably on the Iles formation and unconformably below the Wasatch and consists of an alternating series of massive and shaly sandstones, sandy and black carbonaceous shales, and coal beds. It is 4,500 to 5,000 feet thick, measuring 4,540 feet on White River west of Meeker and about 5,050 feet at the Valentine ranch, near the head

of Strawberry Creek. The following stratigraphic section serves to illustrate its character:

Section of the Williams Fork formation, measured in Anderson Gulch and along north side of White River, Colo.

	Ft.	in.
Conglomerate, probable base of Wasatch formation.		
Heavy ledge of sandstone, forming sharp ridges	20	
Valley, apparently underlain by soft shaly sandstone, mostly concealed	466	
Heavy sandstone ledge forming sharp ridge	25	
Sandstone, soft, chiefly concealed	150	
Coal	1	1
Sandstone, soft	15	
Sandstone, massive; stands up as sharp ridge	23	
Shale, brown, sandy	1	
Coal, Lion Canyon mine bed	6	
Sandstone, shaly, easily disintegrated, chiefly concealed, forming valley	129	
Coal, Montgomery bed	8	6
Sandstone, probably shaly, forming low canyon valley	290	
Coal	4	
Shale, black, carbonaceous	1	
Coal	5	2
Sandstone, light yellow, shaly	88	
Shale, sandy	22	
Coal, Grinsted bed	5	
Sandstone, shaly	42	
Coal	1	8
Sandstone, soft, and sandy shale	40	
Coal	3	6
Sandstone, soft, and sandy shale	60	
Coal (bed of location 100)	1	6
Sandstone, soft, and sandy shale	47	
Shale	6	
Coal	1	4
Sandstone, shaly	45	
Sandstone, light yellowish brown, thick bedded (Lion Canyon sandstone member)	100	
Sandstone, soft, shaly	58	
Sandstone and shale containing coal beds	500	
Sandstone, yellowish brown, massive, containing fossil leaves (approximate base of Goff coal group)	83	
Sandstone, yellowish brown, shaly in places, containing fossil leaves	100	
Sandstone, yellowish brown, with soft shaly beds	847	
Coal	1	6
Sandstone, gray, massive, and thin shaly sandstone	191	
Coal (approximate top of Fairfield coal group)	6	
Shale, soft, sandy, sandstone, and carbonaceous shale	130	
Sandstone, yellowish, massive bed	5	
Shale, soft, sandy, including two thin beds of carbonaceous shale	42	
Sandstone, yellowish, massive bed	5	

	Ft.	in.
Sandstone, soft, shaly, including a thin bed of carbonaceous shale	17	
Sandstone, yellowish, massive	3	
Sandstone, soft, including a thin bed of carbonaceous shale	28	
Coal	6	
Sandstone, soft, shaly, with intercalated beds of shale	92	
Shale, sandy	12	
Sandstone, yellowish brown	3	
Shale, sandy	36	
Sandstone, reddish brown, massive	11	
Shale, soft, sandy	16	
Sandstone, reddish brown, massive, shaly, in thin beds	54	
Shale, sandy, and some massive sandstone beds	200	
Sandstone, reddish, massive and shaly beds	125	
Shale, black, carbonaceous	6	
Sandstone, brown, shaly	20	
Coal, with sandy shale top	1	8
Shale, gray, sandy	10	
Sandstone, changed to a reddish-brown color and rendered brittle by burning. Interbedded with seams of clay changed to white color by burning	36	
White and yellow pulverulent substance. Ash from Fairfield No. 2 bed	1	
Clay, burnt shale	2	
Shale, reddish and grayish, sandy, with streaks of kaolin	10	
Coal, with black carbonaceous shale at top	5	
Shale, blue, sandy	50	
Sandstone, colored reddish brown by burning, rendered brittle	50	
Impure substance resembling burned fire clay	3	
Coal, impure, Fairfield No. 1 bed	5	
Shale, blue, with some thick beds of sandstone	47	
Coal	3	6
Shale, blue, with some thin beds of sandstone	12	
Coal	1	3
Shale, sandy	3	
Coal		6
Sandstone, shaly	5	
Coal	1	3
Sandstone, shaly	22	
Coal, Bloomfield bed	2	10
Sandstone, thin bedded	18	
Coal	1	2
Sandstone, thin beds, with sandy shale	30	
Coal	1	4
Shale, sandy		6
Coal — Major bed	3	
Shale, black, carbonaceous		11
Coal	4	3
Shale, blue; base of Williams Fork formation	6	
Sandstone (Trout Creek).		
	4,542	5

Fairfield coal group.—Numerous coal beds occur throughout the Fairfield coal group, which includes approximately the basal 1,300 feet of the Williams Fork formation and is named for the Fairfield mine. Where the rocks of this coal group are exposed along steep slopes, they are usually reddened by the burning of coal beds. The rocks of the Fairfield group are conspicuously exposed on the north side of the main stage road leading west from Meeker. Outcrop burning of the coal beds has taken place at many places along the west and north sides of Agency Park and has imparted a deep brick-red color to the slopes between the Trout Creek sandstone and the crest of the ridge. The coal beds below the Trout Creek sandstone are rarely burned at the surface. In the northwestern part of the quadrangle erosion has removed the Williams Fork strata, and extensive burning has taken place around the margin of this area.

Goff coal group.—The name Goff coal group is applied to the 700 feet of coal-bearing beds that underlie the Lion Canyon sandstone member of the Williams Fork formation. This coal-bearing group is separated from the Fairfield coal group below by about 1,000 feet of rocks that are almost wholly barren of coal. It is called the Goff group, from the Goff ranch, in sec. 23, T. 2 N., R. 94 W. In T. 2 N., R. 94 W., 15 coal beds belonging to the Goff coal group were measured, and in T. 2 N., R. 93 W., 9 were measured. The intervals and sections found in these two townships are represented on Plates 24, 27, and 30. Several coals that are thought to belong to the Goff coal group were measured in T. 3 N., R. 93 W., and are also shown in Plate 24.

Lion Canyon sandstone member.—About 3,000 feet above the Trout Creek sandstone lies another sandstone to which the name Lion Canyon is here given. This sandstone projects boldly toward the main road immediately east of the mouth of Lion Canyon, and it forms a prominent ledge along the west side of the west fork of Lion Canyon, 3 miles west of Meeker. It almost disappears in the northern part of T. 1 N., R. 94 W., and again becomes very prominent as a ledge maker along the west side of Sulphur Creek Valley. Near the Goff ranch (see pl. 23, *C*) the outcrop of the Lion Canyon sandstone swings east and finally disappears about 1 mile east of the township line. This sandstone was recognized by the occurrence of associated fossil shells in secs. 16 and 6, T. 2 N., R. 94 W., and again about 1,000 feet southwest of the northwest corner of the same township.

Lion Canyon coal group.—The group of coal-bearing beds that crops out in the 1,000 feet of the Williams Fork formation immediately above the Lion Canyon sandstone member is called the Lion Canyon coal group.

Fossils and correlation.—The Williams Fork formation at Meeker is from 4,500 to 5,000 feet thick, whereas on the north side of Axial Basin, about 30 miles to the north, it is only 1,600 feet thick. This great difference in thickness is all the more striking in view of the fact that at these same localities the Iles formation is very similar in lithology and thickness. Two explanations might be offered—that the Williams Fork at Meeker represents actual thickening from the Yampa field, or that the Williams Fork of the Meeker section contains beds of the age of the Williams Fork, Lewis, and "Laramie" of the Yampa section. The first interpretation is set forth by H. S. Gale in Bulletin 415. The second interpretation is suggested by the writers as being more probable.

In support of the second view it may be pointed out that near White River the lower 1,300 feet of the Williams Fork formation is abundantly coal bearing. This unit is overlain in order by 1,000 feet of barren rocks, about 1,800 feet of coal-bearing rocks, and about 1,000 feet of rocks usually barren of coal beds. In general the Fairfield coal group of the Meeker Williams Fork appears to correspond to the coal group of the Yampa Williams Fork, the barren interval between the Fairfield coal group and the Goff coal group to the Lewis shale, and the Lion Canyon coal group to the "Laramie" formation of the Yampa field. The fact that the total thickness of the Mesaverde group at Meeker is almost exactly the same as the combined thickness of the Mesaverde, Lewis, and "Laramie" of the Yampa field is corroborative evidence of the writers' interpretation.

Later work by Sears [4] has shown that the Lewis shale thins from 1,600 feet at Craig to 900 feet at Spring Creek, and it is his opinion that the "Laramie" at Meeker is included in the Williams Fork as mapped in the Meeker quadrangle. Corroborative evidence was procured during recent examinations of the Meeker section by J. B. Reeside, jr., and J. B. Eby. Their work led them to believe that the lower part of the rocks mapped as Wasatch in the Meeker quadrangle are actually equivalent to the post-"Laramie" formation as mapped near Craig, the striking similarity of the lithology of these two groups of rocks supporting this view. They therefore agree with Hancock and Sears that the Williams Fork formation as mapped in the Meeker quadrangle is equivalent to the Williams Fork, Lewis, and "Laramie" formations of the Yampa section. Paleontologic evidence is difficult to obtain, and such as has been found so far is not conclusive in establishing the relationship of these beds in the two areas. Until evidence of this kind can be found to supplement that offered by lithology the problem will await definite settlement.

[4] Sears, J. D., Geology and oil and gas prospects of Moffat County, Colo., and southern Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 751, p. 291, 1925.

The list below shows the different species of invertebrates obtained from a group of strata about 1,100 feet thick, immediately above the Trout Creek sandstone in the Meeker, Axial, and Monument Butte quadrangles, as identified by T. W. Stanton. Some of the invertebrates are brackish and fresh water species, and some are marine.

Anomia micronema Meek.
Cardium speciosum Meek and Hayden.
Corbula sp.
Corbula undifera Meek.
Corbicula cytheriformis Meek and Hayden.
Inoceramus sp.
Inoceramus barabini Morton.
Liopistha undata Meek and Hayden.
Mactra sp.
Modiola sp.
Ostrea glabra Meek and Hayden.
Ostrea subtrigonalis Evans and Shumard.
Sphaerium sp.
Tellina sp.
Unio sp.
Campeloma? sp.
Lunatia sp.
Tulotoma thompsoni White.
Viviparus or Tulotoma.
Lingula sp.

The following brackish-water invertebrates, also identified by Mr. Stanton, were collected immediately above the Lion Canyon sandstone:

Ostrea glabra Meek and Hayden.
Corbicula sp.
Ostrea subtrigonalis Evans and Shumard.
Anomia micronema Meek.
Modiola laticostata (White).
Siliqua? sp.
Panopaea? sp.

The following invertebrates were taken about 150 feet below the Lion Canyon sandstone:

Ostrea subtrigonalis Evans and Shumard.
Modiola sp.
Corbicula cytheriformis Meek and Hayden.
Turritella sp.

The invertebrates in the last two lists belong to types that have a wide stratigraphic range, most of them occurring in the Mesaverde of southern Wyoming and in rocks of similar age in Montana and also in rocks of post-"Laramie" age. On account of their general stratigraphic relations and the absence of any fossils strictly characteristic of the later Cretaceous formations, Stanton has agreed with Gale in referring these rocks in Lion Canyon to the Mesaverde.

The following plants were obtained about half a mile north of the Keystone mine at Newcastle and above the main coal bed. This coal bed is reported by Gale to lie about 4,000 feet above the base of the Mesaverde and would probably correspond stratigraphically with one of the coal beds in the Lion Canyon coal group at Meeker.

Ficus speciosissima Ward.
Myrica torreyi Lesquereux.
Eriocaulon porosum Lesquereux.
Ficus, type of F. planicostata.
Salix sp.

F. H. Knowlton says, concerning these species, that their age is apparently Montana, though only the first species is confined to that horizon.

TERTIARY SYSTEM

EOCENE SERIES

WASATCH FORMATION

The Wasatch formation occupies a considerable area in the western part of the Meeker quadrangle and is the only Tertiary formation present in the area. It is composed of a series of rather steeply dipping beds that rest unconformably upon the upper beds of the Mesaverde group. It consists mainly of a lower unit of sandstone and sandy shale (pl. 22, *B*), with local layers and lenses of interbedded conglomerate and an upper unit of varicolored clay and shale.

The lower sandy beds were examined in detail by J. B. Reeside, jr., and J. B. Eby, and a section measured from the basal conglomerate up to and including the stratigraphically uppermost sandstone exposed on the north side of the White River road, 1,800 feet west of the junction with the Strawberry Creek road, showed a total thickness of 4,180 feet. In lithology and stratigraphic occurrence these beds bear a striking resemblance to the post-"Laramie" beds of the Yampa field, which are most likely of Fort Union age. The thickness of the overlying clay and shale up to the base of the Green River formation, which overlies the Wasatch west of the Meeker quadrangle, was not measured.

Where the formation dips steeply the softer sandstone and sandy shale commonly weather down to narrow valleys, and the lower massive sandstone beds are left as narrow jagged ridges or hogbacks. These beds of sandstone, some of which are conglomeratic, are separated by belts of gray and drab shale that contain locally thin coal beds. Ordinarily the interbedded conglomerate could not be traced more than a few hundred feet along the strike. One rather prominent bed, however, about 3,500 feet above the base of the formation, was traced almost continuously from the south line of the quadrangle northeastward to sec. 22, T. 2 N., R. 94 W., and thence northwestward to the west line of the quadrangle. In some places this conglomerate appears to be only 10 or 15 feet thick. In other places, however, thin beds and lenses of conglomerate are interspersed throughout a bed of coarse sandstone fully 50 feet thick. The pebbles of the conglomerate consist for the most part of flint, vein quartz, red and light-colored quartzite, and acidic and basic igneous rocks—schist and quartz porphyry—and range in size from very coarse sand to pebbles 6 inches in diameter.

Leaves were discovered near the base of the formation. A single collection taken from beds about 300 feet above the basal conglomerate was examined by F. H. Knowlton and said to contain *Aralia* cf. *A. notata* and also fragments of dicotyledonous leaves. According to Knowlton, the species appear to belong to the Fort Union flora.

QUATERNARY SYSTEM

PLEISTOCENE (?) DEPOSITS

A few scattered boulders of small size seen at high altitudes may be remnants of late Tertiary or Pleistocene gravel beds that were once more extensive or they may be true glacial débris. Their rounded shape and apparent lack of well-defined facets, however, cast doubt upon their glacial derivation.

RECENT DEPOSITS

TERRACE GRAVEL

Well-marked terraces were observed along White River in Agency Park. Plate 23, *A*, shows one of these terraces that extends east of Meeker, immediately south of White River. In some places the terrace seems to consist largely of gravel, but in others the gravel is subordinate in amount. Several of the low hills on the north side of the river consist almost entirely of gravel and boulders and are believed to be remnants of the same terrace. The gravel consists chiefly of pebbles of granite, diorite, diabase, amygdaloid, and red, white, and dark-colored quartzite, mingled with boulders of the same materials, many of which are as much as 40 inches in largest diameter. It is quite probable that these gravel deposits accumulated in the valleys of rather voluminous streams. Whether the variation in transporting power of the streams was due to increase in volume of water from the melting of ice or to variations in gradient resulting from the cutting of the natural barrier formed by the monocline of resistant Mesaverde rocks is not apparent.

ALLUVIUM

While White River was establishing its present course a rather extensive flood plain was developed, and from time to time meanders were cut off and filled with Recent deposits. Moreover, the river has frequently overflowed its banks and spread a thin sheet of sediment over the present flood plain.

STRUCTURE

The present attitude of the rocks in the Meeker quadrangle is determined by the deformation which they have undergone since their deposition. Their present surface distribution is the result primarily of erosion. Some of the strata have undergone very little deformation, but others have been tilted at high angles.

ACCURACY AND USE OF STRUCTURE CONTOURS

The structure contours on Plate 19 are lines that connect points of equal altitude on the top of the Trout Creek sandstone and enable the reader to comprehend at a glance the broad structural features of the quadrangle. It therefore follows that as the topographic contours represent the altitude of the surface above mean sea level and the structure contours show the altitude of the Trout Creek sandstone the difference in altitude at any point between the topographic and structure contours is the depth of the Trout Creek sandstone below the surface. The depth to the individual coal beds may be roughly calculated from the dip of the rocks and the topographic and structure contours shown on Plate 19 in connection with the columnar sections on Plate 24.

FOLDS

Sulphur Creek syncline.—One of the most easily recognized structural features in the Meeker quadrangle is the Sulphur Creek syncline. The axis of the syncline passes from the head of Sulphur Creek eastward along the center line of T. 2 N., R. 93 W., as shown by the structure contours on Plate 19. Plate 23, *B*, shows the character of the syncline at the "Transfer." In the right of the picture is the Trout Creek sandstone, which strikes N. 9° W. and dips 70° W. On the left and opposite side of the synclinal axis the beds strike nearly east and dip north at a very small angle. In the vicinity of the Goff ranch the synclinal axis pitches steeply toward the west and the two limbs of the fold spread broadly, one extending northwest along the southwest side of the Danforth Hills anticline and the other extending southwest and finally south, until it becomes the monocline of the Grand Hogback.

Plate 23, *C*, shows a view of the Lion Canyon sandstone in a westward-facing exposure, as seen from a point about half a mile east of the Goff ranch. The large outcrop on the south (right) side of the synclinal axis exposes about 100 feet of the sandstone. Like most other east-west synclinal folds in this region this one has much the steeper dip on the north limb. The south limb of the fold dips north at an angle of 10° to 24° and presents a bold escarpment front toward the low, broad valley of Agency Park. At the "Transfer" the beds northeast of the axis dip west as steeply as 70°. Farther west the beds flatten considerably and have dips as low as 20°. From the Ninemile ranch westward, however, the fold narrows and the dips range from 45° to 50°.

Danforth Hills anticline and Elkhorn syncline.—The Danforth Hills area, which includes most of the northern half of the Meeker quadrangle, is the largest single, compact mountain group in the

foothill province of this region. Within the area is an anticline, the strata along the limbs of which are inclined 5° to 70°. The hills are bounded on all sides except the west by a partly dissected monoclinal ridge of the Iles formation, which presents an escarpment that faces the valleys surrounding the hills.

The axis of the Danforth Hills anticline extends from about the middle point of the west line of T. 3 N., R. 94 W., southeastward and finally eastward to a point almost a mile south of the northeast corner of T. 2 N., R. 93 W. A domelike portion of the anticline that lies in the southern part of T. 3 N., R. 94 W., and the northeastern part of T. 2 N., R. 94 W., is commonly called the Wilson Creek dome or Devils Hole dome. The anticline is joined on the northeast by the Elkhorn syncline, which passes southwestward from the northeast corner of the quadrangle. Near the northeast corner of the quadrangle the beds on the west side of the syncline dip about 10° E.; those on the east side dip 6° W. In passing south the Elkhorn syncline broadens and the dips become very low.

Along the north limb of the Danforth Hills anticline the dips range from 2° to 10°, and the prevailing dip is about 5°. Along the southwest flank of the anticline, on the other hand, in the northwestern part of T. 2 N., R. 94 W., the upper beds of the Williams Fork formation and the lower beds of the Wasatch dip 50° SW. A similar dip prevails almost as far southeast as sec. 22, T. 2 N., R. 94 W., but toward the northeast the angle of dip gradually decreases in approaching the axis of the Danforth Hills anticline. Where the Trout Creek sandstone passes below drainage level in Hanging Rock, Cabin, and Devils Hole Gulches, it dips 20° to 29°. Where the outcrop of sandstone is observed along the mountain slopes this gradual decrease in dip is apparent, but on Magnetic Mountain, Coal Butte, and Devils Hole Mountain the sandstone is almost horizontal. Farther east along the south limb of the anticline a uniform dip of 40° to 50° was observed as far as the Ninemile ranch. Beyond that point the beds flatten.

A deep hole has been drilled in sec. 27, T. 3 N., R. 94 W., on this dome by the Richmond Petroleum Co. It was begun in 1919 and abandoned in 1921, at a depth of 4,825 feet. Showings of oil and gas are reported to have been found at several horizons. The well is reported to have been abandoned in the Mancos shale and thus did not reach the Dakota (?) sandstone. A second well (Freeman No. 1) in the same section was being drilled on June 2, 1928, by the Texas Production Co. Its depth at that time was 5,600 feet.

North end of the Grand Hogback.—The two limbs of the Sulphur Creek syncline spread broadly at its west end, the north limb extending northwestward to form the southwest flank of the Dan-

forth Hills dome and the south limb extending almost due south to form the Grand Hogback monocline. Along the east side of this ridge the massive sandstones of the Iles formation present a bold escarpment front toward the broad lowland of Agency Park. Along the west side the Williams Fork formation dips steeply beneath the Wasatch beds. Throughout its extent the beds along the east side of the ridge dip less steeply than those along the west side. Northward from White River the dip gradually diminishes, and the area of outcrop becomes correspondingly wider. A mile southwest of the point where Sulphur Creek opens out into Agency Park the Trout Creek sandstone dips 18° NW. The upper beds of the Mesaverde and the basal beds of the Wasatch near by exhibit dips that range from 30° to 35°.

Meeker dome.—The lowest rocks exposed in the Meeker quadrangle crop out 3 miles due east of Meeker in a small fold that is here called the Meeker dome. The long axis of the dome lies east and west about 2,500 feet north of the river and plunges gently to the east and west from the apex in the SW. ¼ sec. 20, T. 1 N., R. 93 W. The surface rocks on the north, east, and west sides of the crest of the dome belong to the lowermost Mancos shale, but the trenching of the dome by White River exposes the full thickness of the Dakota (?) sandstone and the top beds of the Morrison formation.

Along the west side of the area of the Dakota (?) outcrop the quartzitic sandstone beds dip away from the apex of the dome at an angle of about 15°. On the south side they dip about 20°, and on the east side from 8° to 12°. The thin-bedded sandstone in the Mancos shale conforms closely in strike with the basal beds of the Mesaverde group and also with the quartzitic sandstone of the Dakota (?) formation and indicates a very gradual increase in dip away from the apex of the uplift.

The dome has a structural closure of 700 to 900 feet. A well to test the oil possibilities of sands below the Dakota (?) was begun in 1924 by the Marland Oil Co. of Colorado but was abandoned in 1925 at a depth of 2,022 feet. Several strong flows of water were encountered.

An old well half a mile southwest of the Marland well was drilled to a depth of 800 feet and abandoned when a strong flow of salt water was encountered. The well was never capped, and the salt water in 1924 was still flowing in a considerable stream.

FAULTS

Near the east side of sec. 10, T. 1 N., R. 94 W., a small valley leads off from Sulphur Creek and cuts back into the escarpment produced by the Iles formation. There the Trout Creek sand-

stone has been faulted, the sandstone north of the fault having been dropped 285 feet with reference to the sandstone south of the fault. A break in the Mesaverde is also shown near the northwest corner of sec. 4 of the same township. There a fairly massive sandstone has been faulted, and the position of the sandstone on the north or downthrown side of the fault indicates a displacement of about 175 feet. The two faults mentioned are mapped as parts of the same fracture, although the field evidence is inconclusive. If the faulting occurred later than the Wasatch deposition the displacement must have been taken up in the soft shale at the base of that formation, for it was impossible to trace the fault in the Wasatch beds. Another fault follows the valley of Sulphur Creek in secs. 3 and 11, T. 1 N., R. 94 W., and has produced a distinct offset in the Trout Creek sandstone in passing from one side of Sulphur Creek to the other, thus indicating a vertical displacement estimated at 510 feet on the northeast side. A fault crosses secs. 34 and 28, T. 2 N., R. 94 W., and has a downthrow of about 275 feet to the southwest, where it cuts the Lion Canyon sandstone. This fault may be a continuation of the one farther southeast on Sulphur Creek, in spite of the different direction of downthrow.

SLUMPING

In this area numerous great masses of sandstone become detached, and, on the removal of their support by the undercutting action of erosion, they gradually move down steep slopes in such a way as to produce a distinct offset in the beds. Many examples of slumping were observed, but the most conspicuous ones were seen along the deep gulches on the southwest side of the Danforth Hills anticline. For example, in the NW. ¼ sec. 10, T. 2 N., R. 94 W., there occurs a break in the Trout Creek sandstone. From the point where the sandstone dips beneath the valley up to a level 200 to 300 feet below the top of the ridge immediately west the sandstone occurs as a high cliff. It abruptly ends, however, but occurs again about 300 feet below, whence it can be traced continuously to the top of the hill near the north line of the section. The conclusion is that the sandstone was fractured and that the portion east of the fracture plane gradually slumped down the hillside as a result of erosion in the valley below. A very similar condition exists in the S. ½ sec. 4 and also near the south line of sec. 30 of the township immediately north. The Trout Creek sandstone has been fractured in a similar manner in each of the three places cited, and the fracturing may have been caused by torsional strains produced by the peculiar folding which the rocks of the region have undergone.

JOINTING

Joints have developed in many of the sandstones to a remarkable extent. They occur most abundantly where the sandstones dip steeply and are as a rule almost at right angles to the strike of the formation. The extent to which jointing occurs in some places is well shown in Plate 21, *B*, where the sandstone dips at an angle of 70° toward the observer.

COAL

DISTRIBUTION

Coal is the chief economic resource of the Meeker quadrangle, and the coal-bearing Mesaverde group underlies the greater part of the quadrangle, as shown by Plate 19. The coal beds found are roughly classifiable into five groups—the Lion Canyon, Goff, Fairfield, Black Diamond, and "lower" groups, named in descending order, which lie respectively in the upper, middle, and basal parts of the Williams Fork formation and in the upper 400 feet and lower 250 feet of the Iles formation. The coal of the lower coal group is of comparatively little value in the Meeker quadrangle as compared with those of the upper four groups, as shown by the composite sections in Plate 24.

As pointed out in the description of the methods of field work, the tracing and exact correlation of individual coal beds was not possible in any extensive way. Plate 24, however, indicates the best approximations that can now be made as to the correlation of the coal outcrops found and the sequence of known coal beds by townships. The numbers beside the coal beds refer to the locations shown on Plate 19. Sections of coal beds measured at most of these locations are shown graphically on Plates 26 to 30. Two or more numbers given beside a single coal bed in the columnar sections imply that the measurements at these locations were presumably made on the same bed, though many of these correlations are tentative.

As the structure contours of Plate 19 indicate, the valuable coal beds of the Meeker quadrangle lie within 3,000 feet of the surface except in a small area in the southwestern part of the quadrangle, where the coal-bearing formations dip so steeply beneath the Wasatch formation that they pass below the depth of 3,000 feet, which is assumed to be the present limit for practicable operation.

PHYSICAL PROPERTIES

The coal from this field in its unweathered condition has a deep black color and commonly displays the rectangular jointing characteristic of bituminous coal, though some of it breaks with a pronounced conchoidal fracture, a property of subbituminous coal. In

places incipient parallel joints have developed in the coal to such an extent that it "slabs off" readily when struck with the miner's pick. As a general rule, the coals that have rectangular joints do not "slack" or crumble rapidly on exposure, whereas the coals that have a conchoidal fracture can not be shipped to distant markets in open-topped cars without much disintegration.

CHEMICAL COMPOSITION OF THE COALS

Samples were obtained of the fresh, unweathered coal wherever possible during the examination, and the table given below includes analyses of samples from most of the mines and prospects of the quadrangle, together with analyses of samples from a few of the larger mines in the surrounding fields.

Each analysis is given in four forms, which are designated A, B, C, and D. A represents the analysis of the sample as received at the laboratory, B the analysis of the sample after being air dried for a certain length of time at a standard temperature, C the calculated analysis of theoretically "moisture-free" or "dry" coal, and D the calculated composition of the coal exclusive of all moisture and ash.

Analyses of samples of coal from the Meeker quadrangle, Colorado

[Made at the Pittsburgh laboratory of the Bureau of Mines]

Mine	Location				Analysis No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
	Quarter	Sec.	T. N.	R. W.				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
Fairfield No. 1 mine	SW.	28	1	94	3482	3.2	A	10.3	34.9	45.2	9.6	0.73	------	------	------	------	------	------
							B	7.4	36.0	46.7	9.9	.75	------	------	------	------	------	------
							C	------	38.9	50.4	10.7	.81	------	------	------	------	------	------
							D	------	43.5	56.5	------	.91	------	------	------	------	------	------
Do	SW.	28	1	94	3498	2.4	A	9.4	38.0	45.4	7.2	.75	5.34	63.39	1.23	22.05	6,290	11,320
							B	7.2	38.9	46.5	7.4	.76	5.20	64.95	1.26	20.41	6,445	11,600
							C	------	40.9	50.1	8.0	.83	4.74	69.97	1.36	15.11	6,945	12,500
							D	------	45.6	54.4	------	.90	5.15	76.05	1.48	16.42	7,550	13,590
Do	SW.	28	1	94	12518	4.0	A	11.0	38.5	44.3	6.2	.85	5.80	64.20	1.32	21.63	6,315	11,360
							B	7.3	40.1	46.1	6.5	.89	5.58	66.87	1.37	18.83	6,580	11,840
							C	------	43.3	49.7	7.0	.96	5.15	72.15	1.48	13.29	7,095	12,770
							D	------	46.5	53.5	------	1.03	5.54	77.55	1.59	14.29	7,625	13,730
Mine of A. H. Adams	SE.	29	1	94	3483	4.4	A	12.5	31.8	50.5	5.2	1.36	------	------	------	------	------	------
							B	8.5	33.2	52.9	5.4	1.42	------	------	------	------	------	------
							C	------	36.3	57.8	5.9	1.55	------	------	------	------	------	------
							D	------	38.6	61.4	------	1.65	------	------	------	------	------	------
Do	SE.	29	1	94	3504	3.3	A	12.0	40.0	45.7	2.3	.51	------	------	------	------	------	------
							B	9.0	41.4	47.3	2.3	.53	------	------	------	------	------	------
							C	------	45.5	52.0	2.5	.58	------	------	------	------	------	------
							D	------	46.7	53.3	------	.60	------	------	------	------	------	------
Sulphur Creek mine	SE.	3	1	94	3845	3.7	A	11.9	33.1	48.3	6.7	.47	5.72	63.89	1.33	21.93	6,300	11,340
							B	8.5	34.4	50.2	6.9	.49	5.51	66.35	1.38	19.36	6,540	11,770
							C	------	37.6	54.8	7.6	.53	4.99	72.52	1.51	12.89	7,150	12,870
							D	------	40.7	59.3	------	.58	5.40	78.45	1.63	13.94	7,735	13,920
Do	SE.	3	1	94	3848	6.1	A	11.2	33.4	48.8	6.6	.57	------	------	------	------	------	------
							B	5.5	35.6	51.9	7.0	.61	------	------	------	------	------	------
							C	------	37.7	54.9	7.4	.64	------	------	------	------	------	------
							D	------	40.7	59.3	------	.69	------	------	------	------	------	------

Analyses of samples of coal from the Meeker quadrangle, Colorado—Continued

[Made at the Pittsburgh laboratory of the Bureau of Mines]

Mine	Location				Analysis No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
	Quarter	Sec.	T. N.	R. W.				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
Sulphur Creek mine	SE.	3	1	94	12773	2.5	A	10.4	36.6	44.7	8.3	.59	5.40	63.38	1.36	20.97	6,255	11,260
							B	8.1	37.5	45.9	8.5	.60	5.25	65.01	1.39	19.24	6,415	11,550
							C	-------	40.8	49.9	9.3	.66	4.73	70.74	1.52	13.09	6,985	12,570
							D	-------	45.0	55.0	-------	.73	5.21	77.96	1.68	14.42	7,695	13,850
Old Wilson mine of T. D. Riley and Arthur Burnham on Sulphur Creek.	NE.	10	1	94	3850	4.2	A	13.4	33.8	47.6	5.2	.52	-------	-------	-------	-------	-------	-------
							B	9.6	35.2	49.8	5.4	.54	-------	-------	-------	-------	-------	-------
							C	-------	39.0	55.0	6.0	.60	-------	-------	-------	-------	-------	-------
							D	-------	41.5	58.5	-------	.64	-------	-------	-------	-------	-------	-------
Black Diamond mine	NW.	15	1	94	3847	3.6	A	12.0	34.2	47.4	6.4	.51	5.72	64.31	1.30	21.83	6,385	11,490
							B	8.7	35.5	49.2	6.6	.53	5.52	66.71	1.35	19.32	6,620	11,920
							C	-------	38.9	53.9	7.2	.58	4.98	73.10	1.48	12.66	7,255	13,060
							D	-------	41.9	58.1	-------	.62	5.37	78.77	1.59	13.65	7,820	14,080
Do	NW.	15	1	94	12776	2.5	A	10.8	37.2	44.0	8.0	.49	5.52	63.98	1.32	20.71	6,230	11,220
							B	8.5	38.2	45.1	8.2	.50	5.37	65.62	1.35	18.98	6,390	11,510
							C	-------	41.8	49.3	8.9	.55	4.84	71.74	1.48	12.44	6,990	12,580
							D	-------	45.9	54.1	-------	.60	5.32	78.79	1.63	13.66	7,675	13,820
Mine of David Pollard	NW.	28	1	94	3849	3.7	A	12.6	34.6	48.6	4.2	.47	-------	-------	-------	-------	-------	-------
							B	9.2	36.0	50.5	4.3	.49	-------	-------	-------	-------	-------	-------
							C	-------	39.6	55.6	4.8	.54	-------	-------	-------	-------	-------	-------
							D	-------	41.6	58.4	-------	.57	-------	-------	-------	-------	-------	-------
Meeker Coal Co. mine	NW.	28	1	94	12426	6.6	A	12.7	35.9	45.6	5.8	.44	5.69	64.92	1.25	21.87	6,330	11,390
							B	6.5	38.5	48.8	6.2	.47	5.31	69.51	1.34	17.13	6,775	12,200
							C	-------	41.1	52.2	6.7	.50	4.90	74.33	1.43	12.16	7,250	13,050
							D	-------	44.1	55.9	-------	.54	5.25	79.65	1.53	13.03	7,765	13,980
Lion Canyon mine	NW.	29	1	94	3532	3.2	A	13.2	39.0	42.4	5.4	.68	-------	-------	-------	-------	-------	-------
							B	10.3	40.3	43.8	5.6	.70	-------	-------	-------	-------	-------	-------
							C	-------	44.9	48.8	6.3	.78	-------	-------	-------	-------	-------	-------
							D	-------	47.9	52.1	-------	.83	-------	-------	-------	-------	-------	-------

Montgomery mine (Old Lion Canyon mine).	NW.	29	1	94	12777	2.0	A	12.4	38.6	42.9	6.1	.71	5.38	62.61	1.33	23.84	5,995	10,790
							B	10.6	39.4	43.7	6.3	.72	5.27	63.89	1.36	22.50	6,115	11,010
							C	-------	44.1	48.9	7.0	.81	4.58	71.45	1.52	14.64	6,840	12,320
							D	-------	47.4	52.6	-------	.87	4.92	76.83	1.63	15.75	7,355	13,240
Miller mine	SW.	29	2	93	3851	2.5	A	8.9	33.5	48.1	9.5	.67	-------	-------	-------	-------	-------	-------
							B	6.5	34.4	49.3	9.8	.69	-------	-------	-------	-------	-------	-------
							C	-------	36.8	52.8	10.4	.74	-------	-------	-------	-------	-------	-------
							D	-------	41.1	58.9	-------	.82	-------	-------	-------	-------	-------	-------
Wesson mine	NE.	30	2	92	3791	4.1	A	13.6	36.2	45.6	4.7	.45	5.71	61.92	1.32	25.94	6,075	10,930
							B	9.9	37.7	47.5	4.9	.47	5.47	64.57	1.38	23.25	6,335	11,400
							C	-------	41.9	52.7	5.4	.52	4.86	71.67	1.53	16.03	7,030	12,650
							D	-------	44.2	55.8	-------	.55	5.14	75.75	1.61	16.95	7,430	13,370
Do	NE.	30	2	92	12705	5.9	A	14.4	38.4	41.2	6.0	.81	5.83	60.64	1.24	25.47	5,890	10,600
							B	9.0	40.8	43.8	6.4	.86	5.49	64.44	1.32	21.50	6,260	11,260
							C	-------	44.9	48.1	7.0	.95	4.94	70.84	1.45	14.80	6,880	12,380
							D	-------	48.3	51.7	-------	1.02	5.31	76.19	1.56	15.92	7,400	13,320
Prospect at location 471 on Spring Creek	NE.	5	2	93	3846	15.1	A	24.9	32.3	38.9	3.9	.49	-------	-------	-------	-------	-------	-------
							B	11.5	38.1	45.8	4.6	.58	-------	-------	-------	-------	-------	-------
							C	-------	43.0	51.8	5.2	.65	-------	-------	-------	-------	-------	-------
							D	-------	45.4	54.6	-------	.69	-------	-------	-------	-------	-------	-------
Cornrike mine	SW.	10	2	93	12695	3.7	A	13.9	42.0	41.9	2.2	.28	6.01	63.91	1.28	26.31	6,260	11,270
							B	10.6	43.6	43.5	2.3	.29	5.82	66.37	1.33	23.90	6,505	11,700
							C	-------	48.8	48.6	2.6	.33	5.19	74.21	1.49	16.21	7,270	13,090
							D	-------	50.1	49.9	-------	.34	5.33	76.17	1.53	16.63	7,465	13,430

Analyses of coals from other fields with which the coals from the Meeker quadrangle may have to compete

[Made at the Pittsburgh laboratory of the Bureau of Mines]

Mine	Location				Analysis No.	Air-drying loss	Form of analysis	Proximate			Ultimate					Heating value	
	Quarter	Sec.	T. N.	R. W.				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
Roby mine, Monument Butte quadrangle, Colorado.	------	------	4	91	17840	2.2	A	14.2	36.3	45.3	4.2	.59	5.82	63.54	1.22	24.65	6,100	10,980
							B	12.2	37.1	46.4	4.3	.60	5.70	64.98	1.25	23.19	6,235	11,220
							C	------	42.3	52.9	4.8	.69	4.94	74.06	1.42	14.02	7,110	12,790
							D	------	44.4	55.6	------	.73	5.19	77.85	1.49	14.74	7,470	13,450
Ed. Collum mine, Axial quadrangle, Colorado.	SW.	13	4	94	14529	2.0	A	14.8	38.7	42.7	3.8	.66	5.87	61.49	1.17	26.99	5,990	10,780
							B	13.1	39.5	43.5	3.9	.67	5.77	62.74	1.19	25.73	6,110	11,000
							C	------	45.4	50.1	4.5	.78	4.96	72.21	1.37	16.19	7,035	12,660
							D	------	47.5	52.5	------	.82	5.19	75.60	1.43	16.96	7,365	13,260
Mount Streeter (Joseph Collum) mine, Axial quadrangle, Colorado.	NE.	2	3	93	14543	2.1	A	11.9	40.6	45.3	2.2	.32	------	------	------	------	6,450	11,610
							B	10.0	41.5	46.2	2.3	.33	------	------	------	------	6,590	11,860
							C	------	46.1	51.4	2.5	.36	------	------	------	------	7,320	13,180
							D	------	47.3	52.7	------	.37	------	------	------	------	7,510	13,520
Do	------	------	------	------	93309	1.8	A	10.4	38.0	49.2	2.4	.3	------	------	------	------	6,570	11,820
							B	8.8	38.7	50.1	2.4	.3	------	------	------	------	6,685	12,030
							C	------	42.4	54.9	2.7	.3	------	------	------	------	7,320	13,180
							D	------	43.5	56.5	------	.3	------	------	------	------	7,520	13,540
Do	------	------	------	------	93310	1.7	A	10.2	40.1	46.9	2.8	.3	------	------	------	------	6,570	11,830
							B	8.6	40.8	47.7	2.9	.3	------	------	------	------	6,685	12,030
							C	------	44.6	52.3	3.1	.3	------	------	------	------	7,320	13,170
							D	------	46.1	53.9	------	.3	------	------	------	------	7,550	13,590
Mount Streeter (Joseph Collum) mine (composite of samples 93309 and 93310).	------	------	------	------	93311	1.7	A	10.6	38.5	48.4	2.5	.2	5.9	66.8	1.2	23.4	6,570	11,830
							B	9.0	39.2	49.2	2.6	.3	5.8	68.0	1.2	22.1	6,690	12,040
							C	------	43.1	54.1	2.8	.3	5.3	74.7	1.4	15.5	7,350	13,230
							D	------	44.3	55.7	------	.3	5.4	76.8	1.4	16.1	7,560	13,610

Producers No. 1 mine, Monument Butte quadrangle, Colorado.	SE.	9	6	91	93306	2.3	A	14.4	31.2	49.8	4.6	.5					5,995	10,790
							B	12.4	31.9	51.0	4.7	.5					6,130	11,030
							C		36.4	58.2	5.4	.6					7,000	12,600
							D		38.5	61.5		.6					7,395	13,310
Do					93307	2.7	A	13.8	31.7	49.6	4.9	.5					6,045	10,880
							B	11.4	32.5	51.0	5.1	.5					6,210	11,180
							C		36.7	57.6	5.7	.6					7,010	12,620
							D		39.0	61.0		.6					7,440	13,390
Producers No. 1 mine (composite of samples, Nos. 93306 and 93307).					93308	2.5	A	13.8	31.4	50.2	4.6	.5	5.8	62.7	1.6	24.8	6,055	10,900
							B	11.6	32.2	51.5	4.7	.5	5.7	64.2	1.6	23.3	6,205	11,170
							C		36.4	58.3	5.3	.6	4.9	72.7	1.8	14.7	7,020	12,640
							D		38.5	61.5		.6	5.2	76.8	1.9	15.5	7,415	13,350
Eberly mine, Monument Butte quadrangle, Colorado.	SE.	9	6	91	93315	4.3	A	15.0	32.2	47.8	5.0	.5					5,900	10,620
							B	11.1	33.6	50.0	5.3	.5					6,165	11,100
							C		37.8	56.3	5.9	.6					6,940	12,490
							D		40.2	59.8		.6					7,370	13,270
Mount Evans mine, Monument Butte quadrangle, Colorado.	SE.	9	6	91	93316	3.7	A	15.1	30.6	48.6	5.7	.3					5,910	10,640
							B	11.8	31.8	50.5	5.9	.4					6,140	11,050
							C		36.0	57.3	6.7	.4					6,960	12,530
							D		38.6	61.4		.4					7,455	13,420
Mine No. 1, Colorado & Utah Coal Co., Mount Harris, Colo. (composite from 3 mine samples).	SW.	15	6	87	22740	2.7	A	10.4	37.9	45.5	6.22	.42	5.85	64.87	1.59	21.05	6,370	11,470
							B	7.9	39.0	46.7	6.39	.43	5.70	66.68	1.63	19.17	6,550	11,790
							C		42.3	50.8	6.94	.47	5.24	72.39	1.77	13.19	7,110	12,800
							D		45.4	54.6		.51	5.63	77.79	1.90	14.17	7,640	13,750
Argo mine of Moffat Coal Co., Oak Creek, Colo. (composite from 4 mine samples).	NW.	31	4	85	31134	3.5	A	8.6	39.1	48.0	4.25	.41	5.75	69.41	1.50	18.68	6,790	12,220
							B	5.3	40.5	49.8	4.40	.43	5.56	71.93	1.55	16.13	7,035	12,660
							C		42.8	52.6	4.65	.45	5.24	75.96	1.64	12.06	7,430	13,370
							D		44.9	55.1		.47	5.50	79.67	1.72	12.64	7,790	14,020
Casper Webber mine, Dunkley Canyon, Dunkley, Colo. (grab sample).	NW.	2	4	87	30862	3.3	A	13.2	35.8	44.9	6.11	.53	5.68	62.75	1.44	23.49	6,095	10,970
							B	10.3	37.0	46.4	6.32	.55	5.49	64.88	1.49	21.27	6,300	11,340
							C		41.3	51.7	7.04	.61	4.85	72.29	1.66	13.55	7,020	12,640
							D		44.4	55.6		.66	5.22	77.76	1.79	14.57	7,555	13,600
Boulder County, Colo. (average of 3 analyses).						14.7	A	20.8	30.2	44.2	4.76	.32	6.08	55.83	1.12	31.89	5,310	95,630
							B	7.2	35.3	51.9	5.60	.37	5.21	65.45	1.31	22.06	6,200	11,220
							C		38.1	55.9	5.96	.40	4.75	70.55	1.45	16.89	6,715	12,080
							D		40.5	59.5		.42	5.05	75.05	1.51	17.97	7,140	12,850
Canon City, Colo. (average of 3 analyses).						5.9	A	11.7	34.0	45.7	8.56	.50	5.28	61.15	.95	23.56	6,065	10,910
							B	6.2	36.2	48.5	9.06	.53	4.92	64.84	1.02	19.63	6,450	11,610
							C		38.6	51.8	9.56	.57	4.52	69.12	1.08	15.15	6,870	12,370
							D		42.7	57.3		.63	5.02	76.44	1.20	16.71	7,605	13,690

Analyses of coals from other fields with which the coals from the Meeker quadrangle may have to compete—Continued

[Made at the Pittsburgh laboratory of the Bureau of Mines]

Mine	Location				Analysis No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
	Quarter	Sec.	T. N.	R. W.				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
Newcastle, Colo. (composite from 2 mine samples; best coal of Newcastle district).	------	------	------	------	12327	3.6	A	7.1	40.8	46.9	5.19	.45	5.65	70.77	1.56	16.38	7,010	12,620
							B	3.6	42.3	48.7	5.38	.47	5.45	73.41	1.62	13.67	7,215	13,090
							C	------	43.9	50.5	5.59	.48	5.23	76.20	1.68	10.82	7,550	13,590
							D	------	46.5	53.5	------	.51	5.54	80.71	1.78	11.46	7,995	14,390
Trinidad field, Colo. (average of 4 analyses).	------	------	------	------	------	1.2	A	3.7	31.9	54.4	9.95	.60	5.24	71.97	1.12	11.12	7,255	12,610
							B	1.4	32.7	55.7	10.17	.61	5.10	73.68	1.15	9.29	7,400	13,360
							C	------	33.2	56.5	10.30	.68	5.04	74.75	1.16	8.12	7,530	13,550
							D	------	37.0	63.0	------	.69	5.61	83.32	1.30	9.08	8,150	15,120
Rock Springs, Wyo. (average of 4 analyses).	------	------	------	------	------	3.6	A	10.6	35.2	50.4	3.77	.82	5.57	66.82	1.24	21.78	6,635	11,940
							B	7.2	36.5	52.3	3.95	.85	5.36	69.30	1.29	19.25	6,890	12,400
							C	------	39.4	56.4	4.20	.91	4.92	74.78	1.39	13.80	7,430	13,370
							D	------	41.1	58.9	------	1.20	5.14	77.84	1.45	14.37	7,755	13,960
Hanna, Wyo. (average of 2 analyses)	------	------	------	------	------	2.2	A	11.5	41.0	40.7	6.80	.37	5.68	61.84	.93	24.38	6,060	10,920
							B	9.5	41.9	41.7	6.90	.38	5.56	63.26	.95	22.95	6,200	11,160
							C	------	46.4	45.9	7.70	.41	4.96	69.92	1.05	15.96	6,855	12,340
							D	------	50.2	49.8	------	.45	5.39	75.74	1.14	17.28	7,425	13,370
Kemmerer, Lincoln County, Wyo., (composite from 4 mine samples; best coal of Kemmerer field).	------	------	------	------	18612	1.8	A	3.9	40.1	49.0	6.97	.60	5.49	72.19	1.22	13.53	7,160	12,890
							B	2.2	40.8	49.9	7.10	.61	5.39	73.51	1.24	12.15	7,290	13,120
							C	------	41.7	51.0	7.26	.62	5.26	75.15	1.27	10.44	7,455	13,420
							D	------	45.0	55.0	------	.67	5.67	81.03	1.37	11.26	8,035	14,470
Castle Gate district, Utah (average of 7 analyses).	------	------	------	------	------	1.8	A	4.3	43.5	45.8	6.42	.46	5.84	72.37	1.45	13.46	7,210	12,690
							B	2.7	44.1	46.7	6.51	.69	5.69	73.52	1.43	12.16	7,345	13,440
							C	------	45.7	47.5	6.82	.70	5.45	75.51	1.44	10.08	7,530	13,550
							D	------	49.0	51.0	------	.77	5.95	80.92	1.57	10.79	8,070	14,520

Comparison of average analyses of coal from Meeker and neighboring fields (air-dried basis)

	Meeker	Axial and Monument Butte	Hanna, Wyo.	Rock Springs, Wyo.	Southern Uinta County, Wyo.	Trinidad, Colo.	Canon City, Colo.
Moisture	8.6	8.6	8.3	7.4	3.5	1.4	6.4
Volatile matter	37.7	37.7	38.4	36.1	38.2	32.7	36.3
Fixed carbon	46.4	48.3	47.4	52.7	50.3	55.7	48.6
Ash	6.2	5.2	5.4	3.7	7.8	10.2	8.7
British thermal units:							
Air-dried coal (form B)	11,610	11,590	11,530	12,360	12,780	13,360	11,610
Moisture and ash-free coal (form D)	13,670	13,360	13,370	13,920	14,430	15,120	13,640

The above tables show that the average analyses for the Meeker, Axial-Monument Butte, Canon City, and Hanna fields correspond very closely. The percentages of moisture, volatile matter, and ash in the Rock Springs coal are slightly less, and the percentage of fixed carbon as well as the heating power is somewhat higher. The coals from southern Uinta County, Wyo., are low in moisture and high in ash as compared with those from northwestern Colorado. The percentage of volatile matter is similar, but that of fixed carbon is higher. As compared with the other coals those from the Trinidad field are low in moisture and high in ash but nevertheless possess a comparatively high heating power.

SPONTANEOUS COMBUSTION

The extent to which the coal of this field has burned near the surface has been repeatedly mentioned. The inception of such burning is sometimes attributed to the oxidation of pyrite, marcasite, or sulphur. Possibly combustion has sometimes been started by lightning. Ignition, however, is probably most often spontaneous, for many low-rank coals when finely divided and exposed to the atmosphere develop sufficient heat to ignite spontaneously. Not enough mining has been done in this field to furnish data regarding the depth to which burning has occurred. Where the air is excluded in all probability the burning does not extend far back from the outcrop. On the other hand, where the beds are thick and the burning causes slumping the fissures formed may admit air that will support combustion to considerable depths. In the Sunnyside field, Utah, the coal in places has been burned to a distance of 1,500 feet back from the outcrop. The extent to which burning has taken place along the outcrops of the coal beds of the Meeker field is strong evidence of the natural combustibility of the coal. It is said that in

mining the thicker beds at Newcastle it sometimes became necessary to remove all or a part of the coal from rooms before their completion, owing to the tendency of the loose coal to heat and take fire. The slack pile at the Fairfield mine, 2½ miles west of Meeker, has been burning intermittently for several years.

QUANTITY OF COAL

From what has already been said in regard to the thickness of the overburden, the extent of burning along the outcrop, and the consequent difficulty of tracing the individual coal beds, it was believed to be desirable to estimate the tonnage of coal in the Meeker quadrangle by groups of coal beds rather than by individual beds. These different coal groups are fully discussed under stratigraphy.

The most complete stratigraphic section across the entire Mesaverde group was measured up the steep slope west of Meeker and across the steeply dipping beds along the north side of White River. That section contains a total of 22 feet of coal in the Black Diamond coal group, 67 feet in the Fairfield coal group, and 44 feet in the combined Lion Canyon and Goff coal groups. Almost exactly the same amount of coal was measured in the Fairfield group along the deep gulch in the west side of sec. 10, T. 2 N., R. 94 W., but, as in the White River section, there is also evidence of considerable coal having been burned along the outcrop. In order to make the estimate conservative, however, there was assumed to be at least 67 feet of coal in the Fairfield group wherever the entire group is present. The different stratigraphic sections measured across the Black Diamond group of coal beds indicate a gradual decrease in its contained coal toward the northern and more especially the eastern parts of the quadrangle, and in the computation of tonnage a reduction was made to conform to these field observations.

From the map it is obvious that the Goff and Lion Canyon coal groups underlie only a portion of Tps. 1 and 2 N., R. 94 W. An assumption of 44 feet of coal was made for these groups wherever present. Where erosion has removed a portion of the formation including the Fairfield group of coal beds a corresponding deduction was made in the amount of coal estimated to be present.

A coal bed 1 foot thick that underlies an acre of ground contains about 1,800 tons of coal. It therefore follows that a horizontal coal bed 1 foot thick that underlies 1 square mile contains $640 \times 1{,}800$, or 1,152,000 tons. If the coal bed is not horizontal but is inclined, a bed that underlies a square mile really exceeds a square mile in area,

a fact illustrated in Figure 6. The total tonnage of coal in a given number of square miles is determinable from the following formula:

$$\frac{\text{number of miles}^2}{\text{cosine of dip angle}} \times 1{,}152{,}000 \times \text{thickness of bed in feet}$$

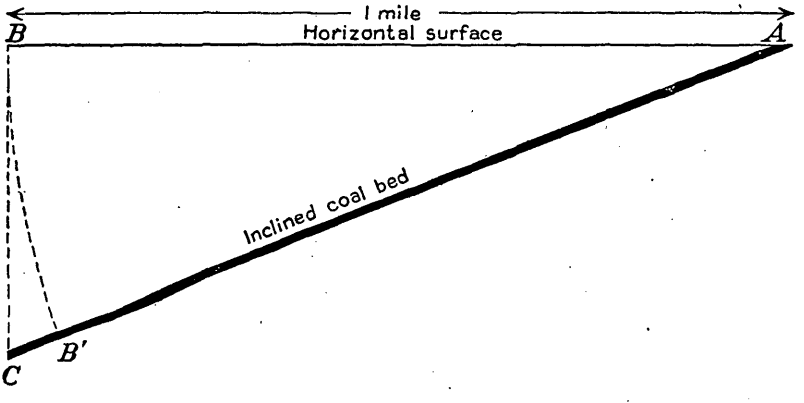


FIGURE 6.—Diagram illustrating relation between surface area and area of underlying inclined coal beds

The total estimated tonnage of coal above a depth of 3,000 feet, in the townships and parts of townships included in the Meeker quadrangle, as computed according to the above formula, amounts to 10,645,000,000 tons, distributed as follows:

Estimated reserves of coal in the Meeker quadrangle, Colorado

	Short tons
T. 1 N., R. 94 W., and parts of T. 1 S., R. 94 W., and T. 1 N., R. 95 W.	1,360,000,000
T. 2 N., R. 94 W., and part of T. 2 N., R. 95 W.	2,285,000,000
T. 3 N., Rs. 94 and 95 W. (part)	1,540,000,000
T. 3 N., Rs. 93 and 92 W. (part)	2,300,000,000
T. 2 N., Rs. 93 and 92 W. (part)	3,160,000,000

No commercially valuable coal is known in T. 1 N., R. 93 W., and parts of T. 1 N., R. 92 W., and T. 1 S., Rs. 92 and 93 W., in the quadrangle.

TOWNSHIP DESCRIPTIONS

In the following descriptions the local details of the thickness and location of the coal beds examined are given, with additional details of geography or geology, not already covered in the general discussion, which bear directly on the estimation of the coal reserves of the several townships or on the accessibility of these reserves.

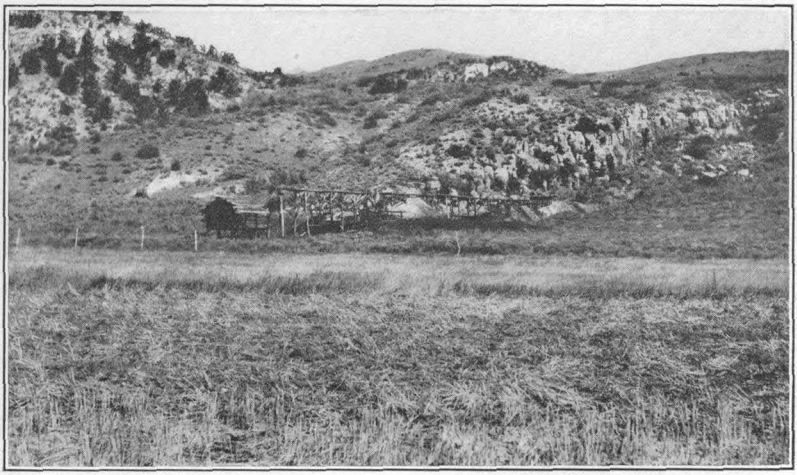
T. 1 S., R. 94 W., AND T. 1 N., RS. 94 AND 95 W.

GEOLOGY

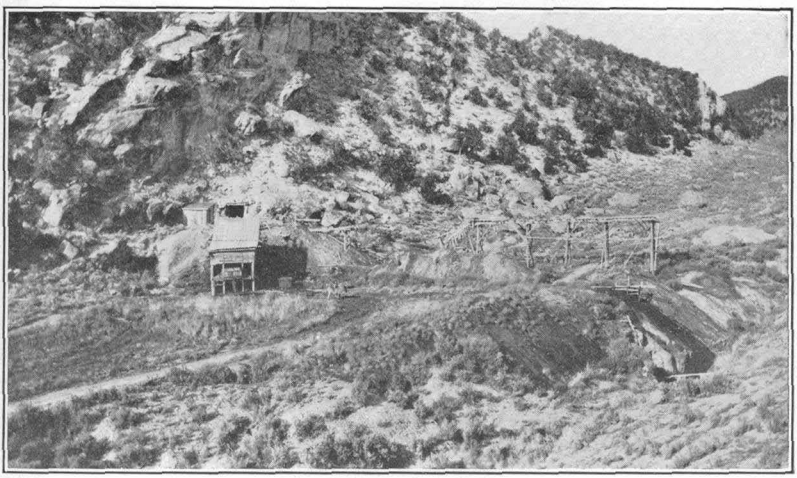
In the southwestern part of the Meeker quadrangle, embracing T. 1 N., R. 94 W., and parts of T. 1 N., R. 95 W., and T. 1 S., R. 94 W., the beds that form the upper sandy units of the Mancos are well developed. They are clearly expressed by the ridges along Fourmile Gulch, north of Meeker.

The Mesaverde group is steeply inclined in these townships, and the massive sandstones of the group produce a series of narrow, jagged ridges, whereas the intervening beds of sandy shale and shaly sandstone are represented by narrow parallel valleys. Some of these valleys are too narrow to be represented on the scale of the topographic map. Others, such as the East and West Forks of Lion Canyon, are clearly shown. The lower beds of the Iles formation are so resistant in comparison with the underlying soft shale that they form a conspicuous escarpment that extends northeastward from the center of the south line of sec. 33, T. 1 N., R. 94 W., to the northeast corner of the township. The Trout Creek sandstone was traced almost continuously from White River northeastward to the valley of Sulphur Creek and thence to the northeast corner of T. 1 N., R. 94 W. The local thicknesses of the Iles and Williams Fork formations are, respectively, about 1,600 and 4,500 to 5,000 feet, and their character is illustrated by the detailed stratigraphic sections on pages 200 to 205. The outcrop of the massive Lion Canyon sandstone member, 3,000 feet above the base of the Williams Fork formation, is a prominent topographic feature near the main road that leads west from Meeker. It forms a bold ledge along the west side of the West Fork of Lion Canyon, almost disappears in the northern part of the township, and again becomes very prominent as a ledge maker along the west side of Sulphur Creek Valley.

These townships are on the west flank of the Meeker dome, and consequently their beds dip away from the dome at different angles toward the west and northwest. Along the Meeker-Rifle road the dip at the base of the lower part of the Mesaverde is about 30°. It is about 35° at the Trout Creek sandstone, 63° at the Lion Canyon sandstone, and about 67° at the conglomerate at the base of the Wasatch formation. Along the Mesaverde rocks from east to west near the center of T. 1 N., R. 94 W., a dip of 20° is noted near the north line of sec. 23. The dip seems to increase to about 30° at the Trout Creek sandstone in sec. 22 and becomes as steep as 45° at the base of the Wasatch near the center of sec. 8. At the north edge of the township the dips are less steep, owing to the spreading out and flattening of the entire Mesaverde group in the Sulphur Creek



A. SULPHUR CREEK MINE, NE. ¼ SEC. 10, T. 1 N., R. 94 W., COLORADO



B. MONTGOMERY MINE, NW. ¼ SEC. 29, T. 1 N., R. 94 W., COLORADO

SECTIONS OF COAL BEDS MEASURED IN T. 1 S., R. 94 W., AND T. 1 N., R. 94 W., COLORADO

syncline. Near the south edge of sec. 1 thin-bedded sandstone that forms the ridge near the top of the Mancos shale dips about 15°. The Trout Creek sandstone at Sulphur Creek seems to have an average dip of about 15°, although some irregularities are caused by the faults shown on Plate 19.

COAL

GENERAL FEATURES

Coal beds belonging to all five coal groups are present within the part of the Meeker quadrangle included in T. 1 S., R. 94 W., and T. 1 N., Rs. 94 and 95 W. The locations of measured sections of these coal beds are shown on Plate 19, and the thickness of the more valuable beds is shown graphically on Plate 26. Locations of measured sections of coal beds are numbered serially from south to north, by coal groups.

Lower coal group.—Within this part of the Meeker quadrangle the lower coal group is represented by a few thin beds of coal and some fairly thick beds of carbonaceous shale that pass laterally into local coal beds of some value. These beds are associated with the lowest massive sandstones in the bluffs on both sides of the gulch that leads to the Black Diamond mine (location 24), in sec. 15, T. 1 N., R. 94 W.

Black Diamond coal group.—The Black Diamond coal group commonly contains four to six coal beds in this part of the quadrangle, and these beds have been rather extensively developed owing to their accessibility. Locations 4 to 35, on Plate 19, mark places at which beds of the Black Diamond group were examined, and the thickness of the more valuable of the beds measured is shown graphically in Plate 26. The vertical distribution of the coal beds found and their tentative correlation are shown in Plate 24.

The southernmost exposure of coal definitely known to belong to the Black Diamond group is that at the Grace Adams mine (location 6), which was opened on the lowest bench of the three-fold bed measured at location 9. (See pl. 26.) Location 11, in the northern part of sec. 28, T. 1 N., R. 94 W., is at the old Pollard mine, which was caved when visited in 1911. The old Fairfield mine, at location 12, had also been abandoned, because of the dangerous condition of the roof, according to report. This mine is said to have been opened by F. W. Fairfield, of Meeker, in 1884 or 1885, and to have had a main drift that extended 1,000 feet northeastward at the time of its abandonment.

Sections 21 and 21–A (pl. 26) show two measurements made of the Meeker coal bed worked at the Meeker Coal Co.'s mine at location

21, in the northwest corner of sec. 22, T. 1 N., R. 94 W. Location 21 was made at the mouth of the incline and location 21–A at the easternmost opening of the mine. Laboratory sample No. 12426, the analysis of which is given on page 218, was taken at location 21–A. The mine when visited in 1911 was operated by John Watson, of Meeker, and was producing 12 to 15 tons of coal a week.

The Black Diamond mine is also opened on the Pollard bed at location 24 (pl. 19) and had entries several hundred feet in length in 1911. The Pollard bed is at least 11 feet thick in this mine and is reported to be 14 feet thick, though no accurate measurement was obtainable, for the mine everywhere had a coal roof or coal floor. Laboratory sample No. 12776 was taken at the face of a drift turned off to the left of the main entry, 175 feet from its mouth. This mine is reported to have produced 870 tons of lump coal and 690 tons of slack in the year ending August 31, 1911. The Pollard bed had also been opened at the abandoned Wilson mine, at location 27, in sec. 10, T. 1 N., R. 94 W.

Plate 25, *A*, shows the Sulphur Creek mine, which was opened on the Sulphur Creek coal bed at location 32, in the southeastern part of sec. 3, T. 1 N., R. 94 W. This mine was owned in 1911 by Arthur Burnham and T. D. Riley, and laboratory samples 3845, 3848, and 12773 were taken in it. Sample 12773 was cut about 450 feet from the entrance, where the section of the part sampled was as follows:

Section of Sulphur Creek coal bed in Sulphur Creek coal mine at location 32, near Meeker, Colo.

	Inches
Coal roof.	
Coal	20
Shaly sandstone parting	¼
Coal	1
Shaly sandstone parting	½
Coal	18
Sandy shale parting	¾
Coal	28½
Black shale bottom.	
Total coal	67½

The coal at this point was much jointed and had a dull earthy appearance on joint planes but was distinctly vitreous in appearance where freshly fractured.

Fairfield coal group.—The Fairfield coal group is believed to be the most valuable in T. 1 N., R. 94 W., and is extensively exposed north of the Meeker-Rifle road near the west line of sec. 28. Most of the beds have been opened up at one time or another, but the old workings have been abandoned, and the entries have been allowed to cave. The only active mine in 1911 was the Fairfield mine, which

was operated by F. W. Fairfield, of Meeker. The beds were uncovered and measured chiefly at the mouths of the old entries. Eleven beds that were measured in secs. 28 and 29 showed a total of 66 feet of coal. The stratigraphic distribution of the coal beds of this group is shown by Plate 24, and map locations 36 to 85 (pl. 19) mark natural or artificial exposures of coal beds belonging to the Fairfield coal group. Graphic sections of the thicker beds of the group are shown on Plate 26.

The Major coal bed is named from the abandoned Major mine at location 36, in sec. 28, where it is about 13 feet thick, and the Fairfield No. 1 bed consists of about 20 feet of coal in two benches at the Fairfield No. 1 mine, at location 41–A, in the SW. ¼ sec. 28. This mine was opened on the lower of the benches and in 1911 extended N. 30° E. for a distance of 40 feet, then down diagonally across the dip, and continued N. 23° E. along the strike of the bed for a distance of about 700 feet. At a point about 110 feet from the mouth of the entry the drift was said to fork, and an opening to the west passed through the roof of the lower bench into the upper coal of the double bed and continued to a point about 650 feet from the mouth of the mine. Laboratory sample No. 12518 was taken 300 feet from the entrance. At this point the following measurement was taken on the bed:

Section of coal bed in Fairfield No. 1 mine, near Meeker, Colo.

	Inches
Coal roof.	
Coal	72
Bone, which locally disappears	4
Coal	4
Shale, black, carbonaceous, floor.	

Only the 72 inches from the roof to the 4-inch bone parting was included in the sample. The coal has a vitreous luster, conchoidal fracture, and rectangular jointing. Along the joint planes are infiltrations of silica that commonly reach a thickness of one-sixteenth of an inch. These veins, together with numerous flakes of pyrite, constitute the chief impurities.

Location 42, also in sec. 28, marks the site of the Fairfield No. 2 mine, which was caved shut when visited in 1911. In some parts of the workings the Fairfield No. 2 bed is reported to have had a thickness of 10 feet.

An entry on the Agency bed at location 44, in sec. 29, was once operated by A. H. Adams as the source of fuel for the old Meeker Indian Agency at Powell Park, and another prospect that was opened by him on a higher bed at location 45 had been abandoned when examined in 1911.

Location 74, in sec. 10, marks an old mine on the Major bed that is reported to have extended to a depth of about 250 feet and to have ended against a fault in a room to the west of the main entry. To a depth of 150 feet the coal was said to be of good quality, but beyond that depth it became softer, which was partly the reason for the abandonment of the mine. No. 75 marks the location of a prospect on a coal bed that measured at the opening 5 feet 6 inches. No. 76 marks another opening on a coal bed near the center of the NW. ¼ SE. ¼ sec. 3. The bed at the opening measured 6 feet 9 inches but is reported to be about 3 feet thick at the end of the drift, which is about 65 feet long.

Another opening on the coals of this immediate vicinity was made at location 77–A, in the SW. ¼ NE. ¼ sec. 3. At the time of the examination this prospect was almost completely caved, but near the entrance 9 feet 2 inches of coal was measured. This coal was underlain by 14 inches of brown shale with some coal, and this in turn by more than 5 feet 8 inches of coal, but the lower part of this bed was not seen. Mr. Arthur Burnham reported that the entry of this old mine ran into the hill 85 feet, where it terminated abruptly against sandstone. He reported that 24 feet of coal was found when the mine was opened. It was his opinion that the bed really belonged far above and was involved in a slump.

Several thick beds of coal that belong to the Fairfield group are exposed in sec. 3, and in spite of the fact that a number of coal beds have burned out along their outcrop in this vicinity, the beds measured here contained a total thickness of more than 50 feet of coal.

Goff and Lion Canyon coal groups.—Coal beds that belong to the Goff and Lion Canyon coal groups were measured at locations 1, 2, 3, and 86 to 127 (see pls. 19 and 24), and the thickness of the more valuable beds is show graphically on Plate 26. Location 88 marks a small prospect opened by H. L. Grinsted, and location 94, on the Montgomery coal bed, is at the mine of the W. S. Montgomery Land & Cattle Co. (See pl. 25, *B*.) In 1911 this mine consisted of a drift that extended about 1,300 feet N. 10° E. and was so graded as to give gravity haulage for the loaded cars. The dip of the bed averaged about 62°, and in driving the entry the coal had been worked out to a height of 20 to 40 feet along the steeply dipping bed. The entry was then braced above by means of stulls and lagging. Laboratory sample No. 12777 consisted of fresh coal taken at a point 474 feet N. 10° E. from the mouth of the entry. At this point the bed measured 7 feet 6 inches between sandstone roof and shale floor and consisted of coal interbedded with numerous layers of bone from one-sixteenth to one-fourth inch thick. None of the partings were sufficiently thick to be hand separated. The coal is reported to hold fire

well but to yield a large quantity of ashes and clinker. About 129 feet stratigraphically above the Montgomery bed lies another bed that was opened at the original Lion Canyon mine, at location 95. Above this bed lay 14 inches of sandy shale beneath a heavy sandstone ledge. The bed itself, which measured 6 feet in thickness, is underlain by sandstone. When visited in the summer of 1923 the mine was being operated by F. E. Long, of Meeker, who mined coal on a small scale for local use. The coal is hauled out by a stationary steam engine at the mine mouth. The mine tunnel slopes in for 200 feet and then extends 1,000 feet northward along the strike of the bed, which dips 60° W. Thirty-nine rooms have been mined out from the hanging wall. The coal at the face of the main tunnel is 7 feet 7 inches thick without parting or evidence of crushing.

Between location 105, in sec. 20, and location 108, in sec. 4, T. 1 N., R. 94 W., where the coals of the Goff and Lion Canyon groups might be expected to crop out, the outcrops had burned or the surface was more or less flat, and the slopes approach true dip slopes. Under these conditions, though coal outcrops were found, it usually was impossible to obtain good sections of the beds.

SUGGESTIONS FOR DEVELOPMENT

The coal beds of the part of the Meeker quadrangle within T. 1 S., R. 94 W., and T. 1 N., Rs. 94 and 95 W., could be opened up on a large scale, either by driving a main tunnel or haulageway toward the northeast from the valley of White River along the strike of the coal or by tunneling eastward from the East Fork of Lion Canyon. In driving the tunnel northeast from the valley of White River along any particular bed a slight deviation to the east from the direction of strike would give the main entry sufficient slope toward the mine mouth for drainage and haulage. The altitude of the Trout Creek sandstone at location 59, in the center of T. 1 N., R. 94 W., is 6,820 feet, and its altitude near White River is about 6,200 feet. Dividing the difference by the sine of the angle of dip of the Trout Creek sandstone indicates that about 1,000 feet of the Major bed could be mined out from a horizontal tunnel along the strike in the center of the township. Again, the altitude of the East Fork of Lion Canyon directly west of the center of the township is 6,700 feet, or 120 feet lower than the Trout Creek sandstone at location 59. Dividing 120 feet by the sine of 35° gives approximately 200 feet as the extent of the Major bed that could be mined out along the dip above a horizontal tunnel run in from the bottom of the East Fork of Lion Canyon at this point. The coal from beds below the level of White River may be taken out by sinking either vertical or inclined shafts and crosscutting to the coal beds.

QUANTITY

The tonnage of coal in the area just described, if we assume 22 feet for the total thickness of coal in the Black Diamond group, 67 feet for the Fairfield group, and 44 feet for the combined Goff and Lion Canyon groups, is 225,000,000 tons in the Black Diamond group, 735,000,000 tons in the Fairfield group, and 400,000,000 tons in the Goff and Lion Canyon groups, which gives a total tonnage of coal above a depth of 3,000 feet of approximately 1,360,000,000 tons.

T. 2 N., RS. 94 AND 95 W.

GEOLOGY

In the west-central part of the Meeker quadrangle, which embraces T. 2 N., R. 94 W., and part of T. 2 N., R. 95 W., the chief topographic feature is the monoclinal ridge that is formed by massive sandstone in the upper part of the Mesaverde group, which extends from sec. 33, T. 2 N., R. 94 W., to sec. 14 and thence northwestward to sec. 6. The Trout Creek sandstone member of the Iles formation is extensively exposed in the northeastern part of T. 2 N., R. 94 W., where the numerous streams have eroded great amphitheaterlike openings along the southwest flank of the Danforth Hills dome, and the sandstone commonly crops out as a conspicuous ledge around the rims of these openings. Near the anticlinal axis the Trout Creek sandstone lies almost horizontal, but to the southwest the dip rapidly increases, so that in a short distance the sandstone passes beneath the bottoms of the gulches. The Lion Canyon sandstone was traced northeastward from a point a few hundred feet west of the southeast corner of sec. 33 and is offset by a fault in secs. 33 and 34. (See pl. 19.) Northeast from the fault it forms a continuous ledge along the steep slope west of Sulphur Creek. A short distance east of the Goff ranch the sandstone attains an unusual thickness, as is shown in Plate 23, *C*. Along the southwest flank of the Danforth Hills dome the Lion Canyon sandstone loses its identity almost entirely. A bed that is believed to be the same sandstone occurs in isolated exposures in the SE. ¼ sec. 15, between the two burns designated by locations 256 and 257 in the NE. ¼ sec. 16, and again near the southeast and northwest corners of sec. 6.

The conglomerate belt that marks the contact of the Wasatch formation with the Mesaverde group was traced continuously from the southwest corner to the northeast corner of sec. 33, and conglomerate was again seen on the opposite side of the fault near the center of the SE. ¼ sec. 28. The main belt of conglomerate was recognized again with certainty on the high ridge in the NW. ¼ sec. 27 and was traced thence to the west edge of the quadrangle, as shown on Plate 19.

This area lies almost wholly within the limits of the Sulphur Creek syncline, as indicated by the structure contours of Plate 19, which represent the altitude of the top of the Trout Creek sandstone above sea level. The interrelationship of the Sulphur Creek syncline and the Danforth Hills dome and the inclination of the beds of these townships are also indicated by these structure contours.

In the NW. ¼ sec. 10 a block of the Trout Creek sandstone lies in an abnormal position. From the point where the sandstone dips beneath the valley, in the NW. ¼ SW. ¼ sec. 10, nearly to location 153 the sandstone can be traced as a high cliff. It has, however, apparently dropped by slumping just southwest of location 153, and the break trends northwestward and has a maximum downthrow of 293 feet toward the northeast. A similar condition exists in the S. ½ sec. 4 and also near location 299, in sec. 30 of the next township to the north.

COAL

GENERAL FEATURES

It was found practically impossible to trace the individual coal beds for any considerable distance along the outcrop in these townships, owing to the extent to which the beds have been burned at the outcrop and also to the large amount of débris that mantles the surface. The best data obtainable in regard to the number of beds, their thickness, and their relation to one another were procured by following the outcrops of certain sandstones and measuring the stratigraphic sections above and below them. The difficulty attending the measurements makes the intervals shown only close approximations to the true intervals, and correlations are correspondingly uncertain. Owing to the lack of development in these townships in 1911 it was necessary to depend entirely on outcrops found and opened up during the progress of the field work.

Lower coal group.—The lower group of coal beds is probably unimportant in this part of the quadrangle and is believed to be completely concealed within it, as probably not more than 800 or 900 feet of the Iles formation is exposed, even on the slopes of Devils Hole Gulch, in secs. 2 and 3, T. 2 N., R. 94 W.

Black Diamond coal group.—Only a few exposures of coal beds that belong to the Black Diamond coal group were found in these townships, and the measurements obtained at most of these locations, Nos. 128 to 134, are shown graphically on Plate 27. At location 135 the bed found is only 8 inches thick.

Fairfield coal group.—The Fairfield coal group is of value in these townships, and coal beds belonging to it were found at locations 137 to 178, 254, and 255. (See pls. 19, 24, and 27.) Coal beds of the group have locally been much affected by burning on the outcrop,

notably between locations 142 and 143 and near the southwest corner of sec. 4, T. 2 N., R. 94 W. Sixteen beds of coal that belong to the group crop out along the gulch in sec. 10, and the 14 beds not affected by burning on the outcrop (locations 153 to 165) contained an aggregate thickness of 45½ feet of coal. In sec. 5, at locations 170 to 178, nine other beds had an aggregate measured thickness of 21 feet 2 inches, which is believed to be supplementary to the 45½ feet of coal found in sec. 10.

Goff and Lion Canyon coal group.—Coal beds of the Goff and Lion Canyon groups were measured at locations 180 to 251 and 259 to 276. (See pls. 19, 24, and 27.) On the basis of thickness and stratigraphic position a tentative correlation of the beds has been made as shown on Plate 24. Even in the field it was impossible to correlate the beds with certainty, owing to their abundance and to the fact that they are continuously exposed for only short distances. As shown on Plate 24 in this area, there are about 16 coal beds in the Goff coal group and 30 in the Lion Canyon coal group, though in all probability this number does not represent all the coal present.

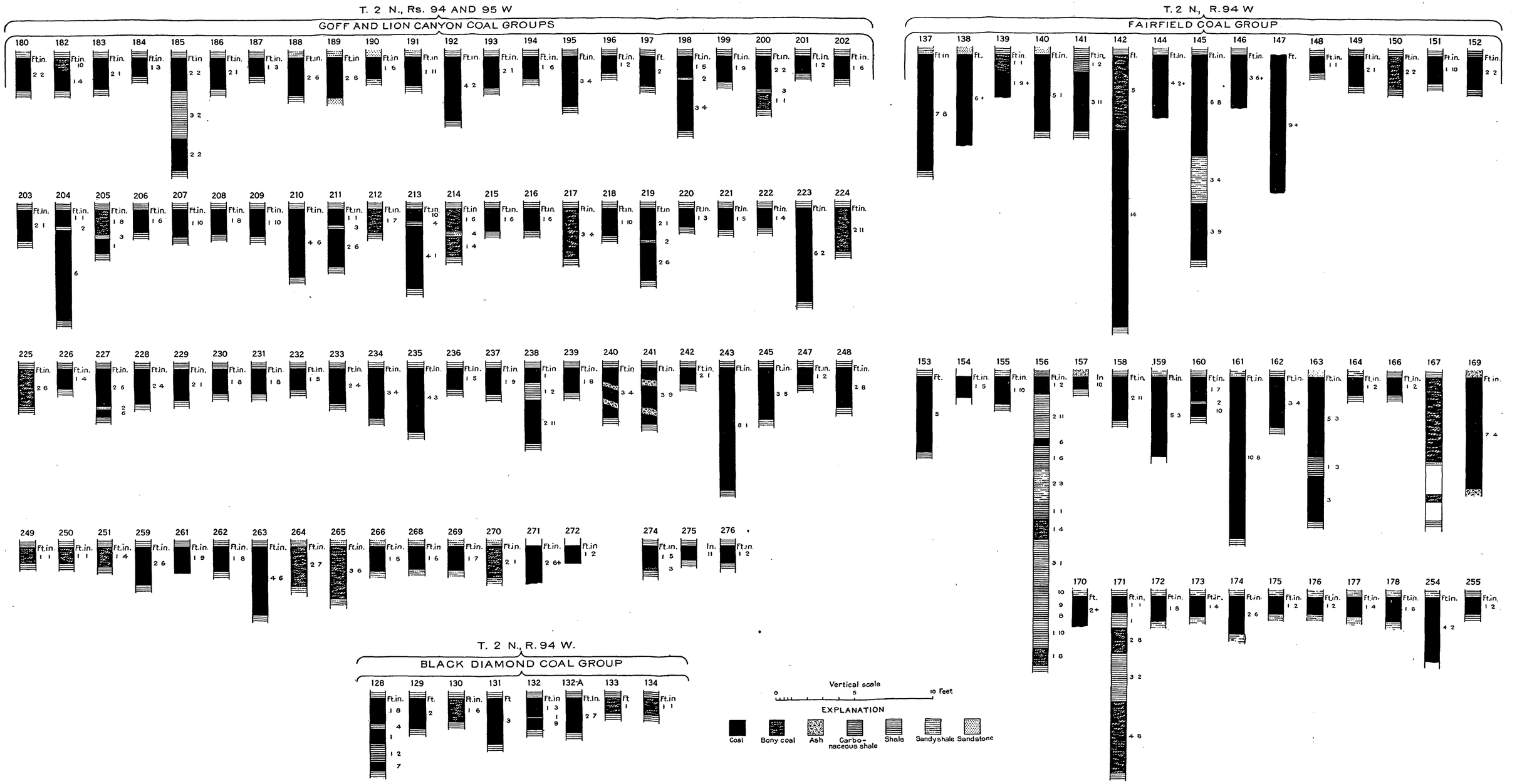
Northwest of the great bend in the formation in the east-central part of T. 2 N., R. 94 W., very little coal is exposed, owing to the character of the surface, and extensive burning of the outcrop of the coal beds of the Goff and Lion Canyon groups is indicated by the abundance of ashes, brick-red sandstone, and baked shale that marks much of the outcrop of the upper part of the Williams Fork formation.

SUGGESTIONS FOR DEVELOPMENT

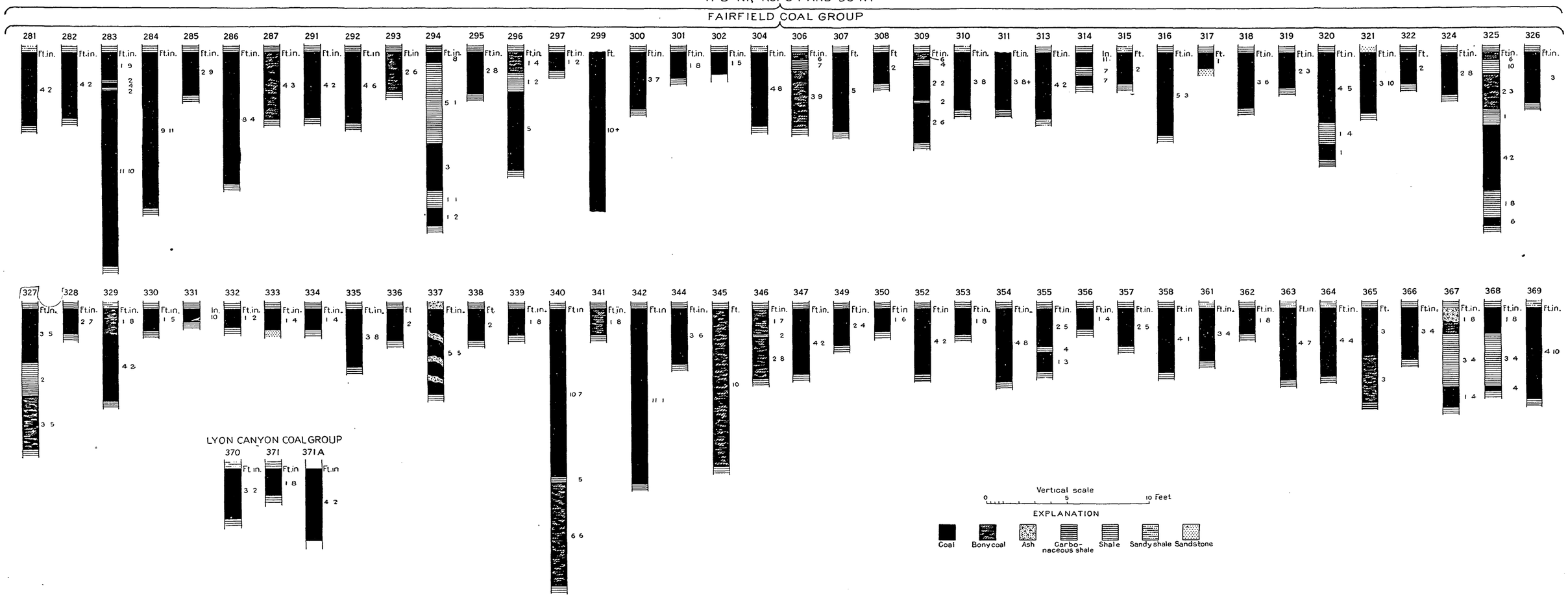
The coal beds that are present in this part of the quadrangle as a rule dip steeply and could be developed in different ways. The beds that occur immediately above and below the Trout Creek sandstone in sec. 36, T. 2 N., R. 94 W., could be reached either by tunneling toward the north or northwest from some point in the bottom of the deep gulch in the SE. ¼ of the section or by tunneling toward the southeast from some point in the valley of Sulphur Creek. The coal could also be reached by sinking either a vertical or an inclined shaft from some point in the valley of Sulphur Creek. The coal beds of the Goff and Lion Canyon groups could be opened by tunneling either from the valley of Sulphur Creek or from the valley of Strawberry Creek. The coal of the entire Williams Fork formation in the northern part of the townships could be reached by inclined shafts sunk in a northeasterly direction from some convenient point, as, for example, the valley of Strawberry Creek.

QUANTITY

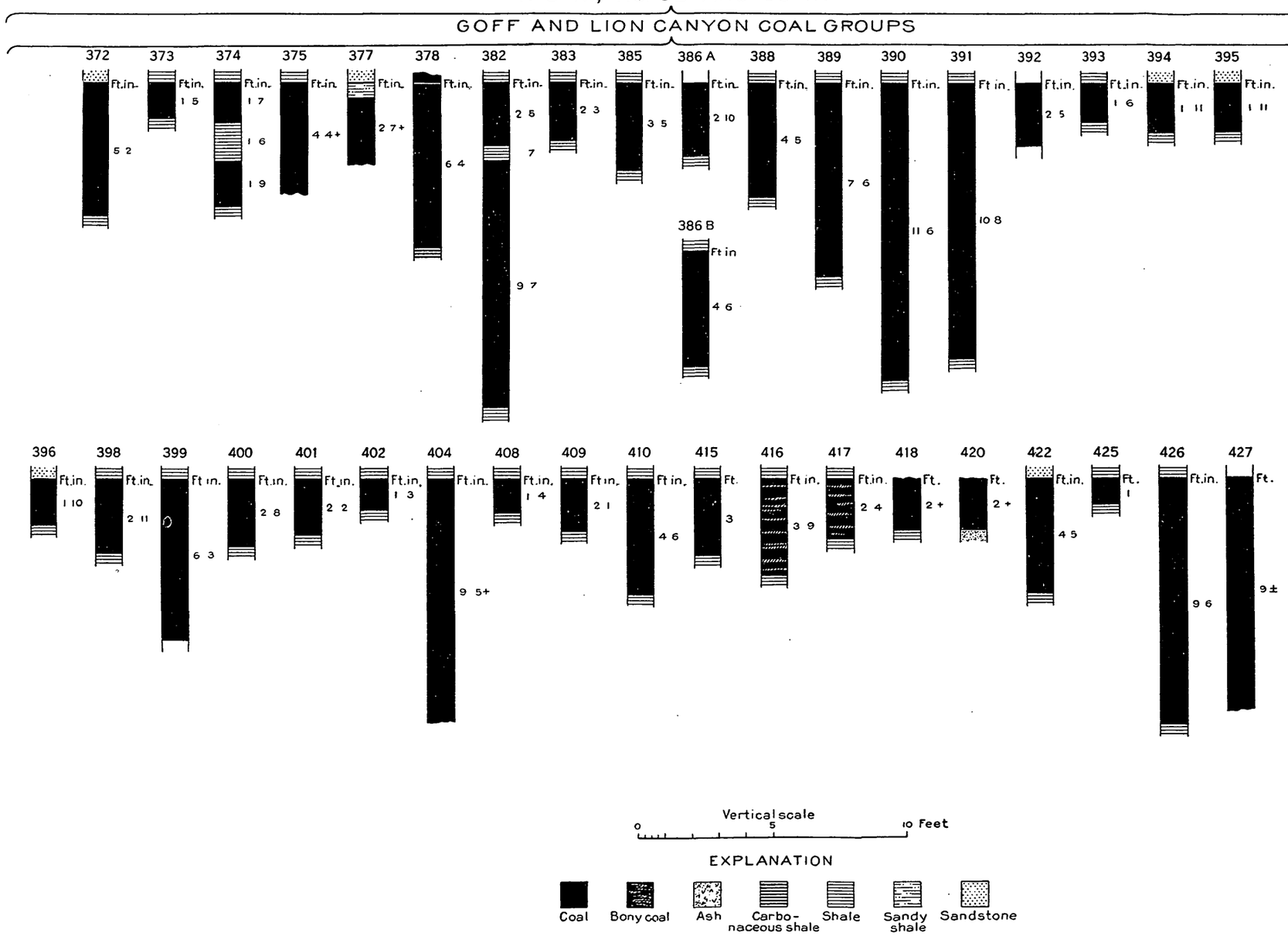
The tonnage of coal in this area was computed by assuming 16 feet for the total thickness of coal in the Black Diamond group, 67 feet

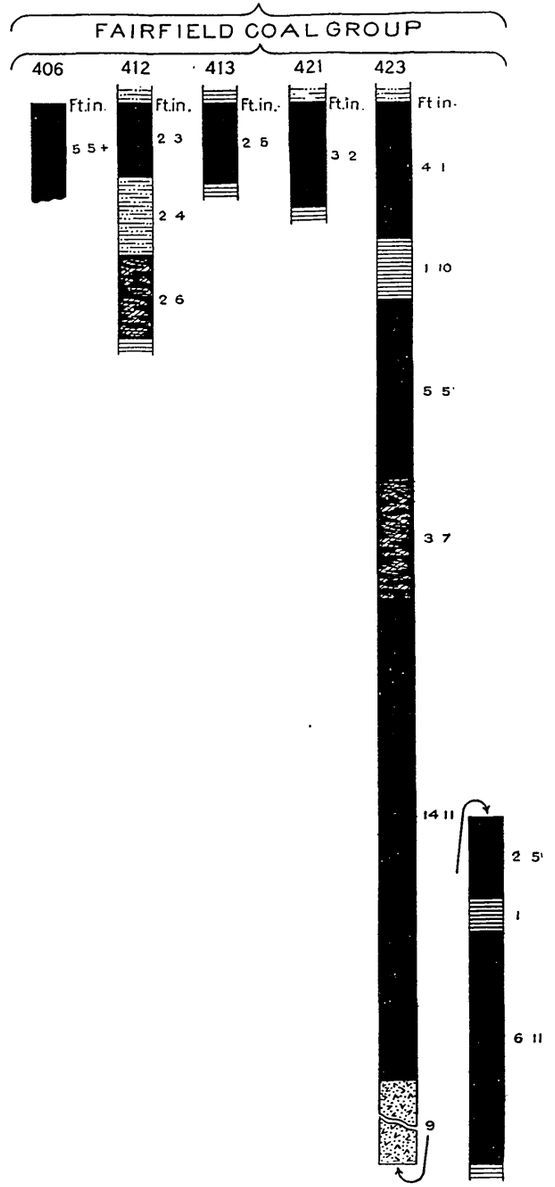


SECTIONS OF COAL BEDS MEASURED IN T. 2 N., RS. 94 AND 95 W., COLORADO



SECTIONS OF COAL BEDS MEASURED IN T. 3 N., RS. 94 AND 95 W., COLORADO



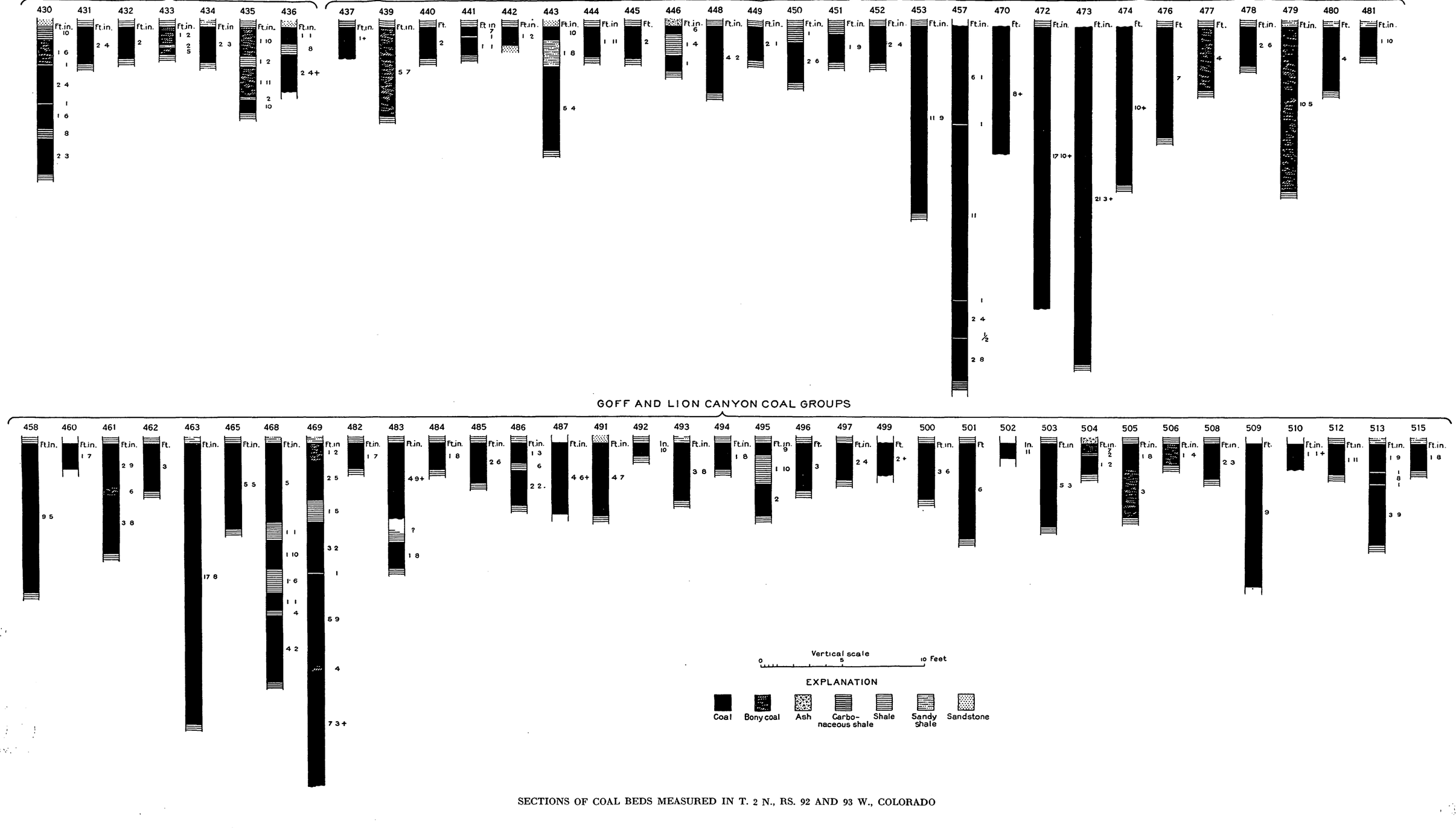


SECTIONS OF COAL BEDS MEASURED IN T. 3 N., RS. 92 AND 93 W., COLORADO

BLACK DIAMOND COAL GROUP

FAIRFIELD COAL GROUP

GOFF AND LION CANYON COAL GROUPS



SECTIONS OF COAL BEDS MEASURED IN T. 2 N., RS. 92 AND 93 W., COLORADO

for the Fairfield group, and 44 feet for the Lion Canyon group. The quantity of coal in these groups, within 3,000 feet of the surface, is estimated at about 315,000,000 tons in the Black Diamond group, 1,340,000,000 tons in the Fairfield group, and 630,000,000 tons in the Goff and Lion Canyon groups. The approximate total for the area is 2,285,000,000 tons.

T. 3 N., RS. 94 AND 95 W.

GEOLOGY

The most conspicuous physiographic feature in T. 3 N., Rs. 94 and 95 W., is the narrow divide that separates the drainage basins of White and Yampa Rivers and extends southeastward across the townships. (See pl. 19.) Along this divide rise a number of rather conspicuous peaks, the more prominent of which are Magnetic Mountain, Coal Butte, and Devils Hole Mountain. From the main divide narrow spurs project to the northeast and southwest between deep valleys.

The sandstone and sandy shale that crop out in these townships all belong to the Mesaverde group. The Trout Creek sandstone member of the Iles formation can be recognized and its top was mapped throughout this area. As in the township to the south, the sandstone is almost horizontal near the axis of the Danforth Hills anticline, but the dip rapidly increases southwestward, so that the sandstone in a short distance passes beneath the surface. North of the anticlinal axis there is a rather uniform structural slope toward the north, as shown by the structure contours on Plate 19, and the gently dipping sandstone can be recognized along the valleys of the tributaries of Wilson Creek. Below the Trout Creek sandstone the beds as a rule are not well exposed.

The Danforth Hills anticline, whose apex coincides with the central part of the area of lower Mesaverde rocks exposed in T. 3 N., R. 94 W., is the principal structural feature of the northwestern part of the quadrangle. The general configuration of the anticline and its relation to the other structural features of the quadrangle are illustrated by the structure contours on Plate 19.

COAL

GENERAL FEATURES

The tracing and correlation of coal beds in these townships was attended with difficulty, owing to the extent to which the beds have been burned at the outcrop and also to the large amount of débris that mantles the surface. It was practically impossible to trace any individual bed for a considerable distance along the outcrop.

The correlations of the coal beds measured, as indicated by Plate 24, are therefore suggestive rather than definite and are based almost entirely on the general stratigraphic relationships of the beds and not on actual tracing.

Lower coal group.—No coal beds that belong to the lower coal group were found in these townships, and apparently erosion has not exposed the zone in which these beds occur. The extent of this group in the northwestern part of the Meeker quadrangle is consequently indeterminable.

Black Diamond coal group.—The Black Diamond group of coal beds seems to be of little value in this part of the quadrangle. The zone that contains this group of beds farther south is fairly well exposed, but little coal was seen in it during the course of the field work. At location 279, in the SW. ¼ NW. ¼ sec. 35, T. 3 N., R. 94 W., two beds of poor coal 15 and 14 inches thick, separated by 8 feet of gray shale, occur about 150 feet below the Trout Creek sandstone, and at location 280, in sec. 33, two beds of coal, 20 and 22 inches thick, are exposed.

Fairfield coal group.—Probably all the coal beds exposed in the north half of T. 3 N., R. 94 W., belong to the Fairfield group, and locations 281 to 369 (see pl. 19) are believed to have been made on coals that belong to this group. Sections of the coal beds measured at these locations are shown graphically on Plate 28. In secs. 31 and 32, T. 3 N., R. 94 W., several hundred feet of brick-red sandstone and baked shale above the Trout Creek sandstone indicates that practically all the beds of the Fairfield group that were seen farther south have been burned at the surface. One of these outcrop burns, at location 298, in sec. 31, is believed to mark the outcrop of a thick bed of coal. Locations 288, 289, 290, 305, 312, and 343 were made on the outcrops of coal beds of undetermined thickness, and locations 303, 323, 348, 351, 359, and 360 mark burned outcrops of coal beds.

SUGGESTIONS FOR DEVELOPMENT

The coal beds present on the southwest flank of the Danforth Hills anticline could be opened by entries driven in nearly parallel to the strike of the beds from the valleys of tributaries of Strawberry Creek, and coal beds north of the divide could be similarly opened from the valley of Wilson Creek and from Morgan and Collom Gulches.

QUANTITY

The quantity of coal in these townships is estimated to be 1,540,000,000 tons. This estimate includes only the known available and workable coal beds and therefore only the coals of the Fairfield group.

T. 3 N., RS. 92 AND 93 W.

GEOLOGY

The upper part of the Iles formation is exposed along the east flank of the Danforth Hills anticline in the western part of T. 3 N., R. 93 W., and dips eastward beneath the Williams Fork, the surface formation over the greater part of the shallow Elkhorn synclinal basin, which is the dominant structural feature of the northeastern part of the Meeker quadrangle. (See pl. 19.)

The prominent sandstone ledge in the Williams Fork formation that crops out along Good Spring Creek furnishes a key to the structure in the southeast corner of the township. This sandstone ledge is thought to lie about 1,200 feet above the Trout Creek sandstone. It possibly corresponds to the Twentymile sandstone member of the Williams Fork formation farther northeast in Colorado. At the point where Elkhorn Creek empties into Good Spring Creek, a fraction of a mile beyond the north border of the quadrangle, the top of the sandstone lies about 75 feet above the bottom of the valley. Here it strikes nearly north and dips 6° E.; it passes beneath the valley a few hundred feet east of the junction of the two streams. This same sandstone crops out on both sides of Good Spring Creek almost as far south as the James mine, at location 378, in the NW. ¼ sec. 14, T. 3 N., R. 93 W., and in the vicinity of location 377 it dips 4° to 5° E. It is therefore believed that the steeper dip evident at the James mine is somewhat local in its nature and possibly is not a true dip but a result of slumping. This sandstone could not be traced farther south with certainty. Near the northeast corner of sec. 12 the beds dip 10° S. 85° E. About a mile east of this point, in the valley of Milk Creek, the beds strike north and dip 6° W., which indicates that a synclinal axis passes a short distance east of the northeast corner of sec. 12.

GENERAL FEATURES

The coal beds in the parts of T. 3 N., Rs. 92 and 93 W., within the Meeker quadrangle are for the greater part poorly exposed, partly owing to the mantle of débris and vegetation on the slopes but more largely owing to the extent to which the coal has burned along the outcrops, especially along the sides of the deeper valleys, where the best exposures would otherwise occur—for example, along the valleys of Good Spring and James Creeks.

Black Diamond coal group.—Only the upper part of the rocks associated with the Black Diamond coal group are exposed in T. 3 N., R. 93 W., and no coal beds were found in them. It is therefore doubtful whether the Black Diamond group is of value in this part of the Meeker quadrangle.

Fairfield coal group.—The extensive burns that mark the slopes above the outcrop of the Trout Creek sandstone are the chief indication of the local presence of valuable and numerous coal beds in the Fairfield group, although a few exposures of coals that belong to this group were found in T. 3 N., R. 93 W. Some of these coal beds were measured at locations 406, 412, 413, 421, and 423, and others of undetermined thickness were seen at locations 405, 407, 411, and 414. The Mount Streeter (Joseph Collum) mine, in the NE. ¼ sec. 2, T. 3 N., R. 93 W., just north of the Meeker quadrangle, is opened on a coal at or just above the top of the Fairfield group. Laboratory sample No. 14545 was taken from the face of a side drift in this mine about 400 feet from the opening and 40 feet south of the main drift. As exposed on the hillside near the opening the entire bed was measured as follows:

Section of the coal bed in the Mount Streeter (Joseph Collum) mine, in the SW. ¼ NW. ¼ sec. 2, T. 3 N., R. 93 W., Colorado

	Ft.	in.
Top, brown and gray shale.		
Coal, good	6	9½
Parting, shale, brown, sandy.		
Coal, good	13	3½
Bottom, shale, brown.		

At the point where the samples were taken the bed appears to dip 3½° S. 29° W.

Coal beds above the Fairfield coal group.—The Lion Canyon sandstone member loses its identity in this area, and it is not possible to distinguish the coals of the Goff and Lion Canyon coal groups. The barren rocks above the Fairfield group also appear to carry a few coal beds in the vicinity. Sections of these coals are given on Plate 29, and their tentative correlations are given on Plate 24. These correlations are, however, merely suggestive, for the relative position of these beds above the Trout Creek sandstone is not positively known. The Trout Creek sandstone is not exposed in this area, and it is therefore impossible to measure the interval between it and these coals. In addition to the locations made on measured coal beds, locations 376, 384, 397, 419, and 424 were made on the burned outcrops of coal beds, and locations 379, 403, 427, 428, and 429 indicate the position of outcropping coal beds of undetermined thickness. Location 378 was made at the James mine, in the NW. ¼ sec. 14, T. 3 N., R. 93 W., from which laboratory sample No. 12704 was taken. At the point of sampling 6 feet 4 inches of coal was measured between a coal roof and dark-brown carbonaceous shale floor. The coal is hard, has a vitreous luster, and on the weathered face is cut by numerous parallel seams, some of which run almost at right angles to the bedding. These seams are commonly coated with a white substance, probably gypsum.

SUGGESTIONS FOR DEVELOPMENT

The coals of this area can be mined from openings along the valleys of Wilson, Taylor, Good Spring, James, and Elkhorn Creeks, either by entries driven essentially parallel to the strike of the beds, with just enough rise to give good drainage and haulage grade, or by horizontal crosscuts.

QUANTITY OF COAL

Practically all of the part of the Meeker quadrangle within T. 3 N., Rs. 92 and 93 W., is underlain by coal-bearing rocks, and the estimation of its coal reserves was based on the calculation that the total thicknesses of coal beneath different tracts, including all the coal groups, were equivalent to 62 feet of coal under 32.1 square miles. On this basis the total quantity of coal in this area is estimated to be about 2,300,000,000 tons.

T. 2 N., RS. 92 AND 93 W.

GEOLOGY

The surface rocks of T. 2 N., R. 93 W., and of the part of T. 2 N., R. 92 W., within the Meeker quadrangle belong to the Mesaverde group, and, as shown on Plate 19, the distribution of these rocks is directly controlled by the Sulphur Creek syncline, which extends east and west across the central part of T. 2 N., R. 93 W. The Trout Creek sandstone was traced almost continuously across the southern part of this area, but the Lion Canyon sandstone was recognized only in outcrops near the synclinal axis in the N. ½ sec. 19, T. 2 N., R. 93 W., and in the SE. ¼ sec. 16. As shown by the structure contours of Plate 19, the Elkhorn syncline, which extends southward across T. 3 N., R. 93 W., continues into T. 2 N. and produces a structural saddle between the Danforth Hills anticline and the Yellowjacket uplift, in the Coal Creek district, in T. 2 N., R. 92 W., east of Transfer.

COAL

GENERAL FEATURES

Extensive burning of coal beds has taken place in T. 2 N., Rs. 92 and 93 W., as in other parts of the Meeker quadrangle, and this burning, together with the abundant rock débris that mantles many slopes, made it impossible to trace individual coal beds over any great distance. Plate 24 shows the best estimate that can be made as to the correlation of the coal beds located and measured, and Plate 30 shows graphically the thickness of the more valuable beds measured.

Lower coal group.—The lower coal group is of no commercial value in the east-central part of the Meeker quadrangle. About a

mile east of Curtis Creek 16 feet of black shale that contains 1 foot of coal crops out 75 feet above the "rim rock." An old prospect, probably on the same bed, was also found near the south line of sec. 34, T. 2 N., R. 93 W., just west of the road leading up Aichers Draw. The section at this prospect is as follows:

Section measured in Aichers Draw near the south line of sec. 34, T. 2 N., R. 93 W., Colorado

	Ft.	in.
Shale, brown.		
Coal, with some black, carbonaceous shale		8
Coal, poor	1	9
Shale, brown	1	1
Interval	5	
Shale, brown		2
Coal, very poor and dirty	1	5
Shale, black		4
Coal, fair quality		8
Shale, black		6
Coal, dirty	1	3
Bottom, shale, brown.		
Total coal	5	9

Black Diamond coal group.—The Black Diamond group of coal beds is rather valuable in the western part of T. 2 N., R. 93 W., but is believed to become less valuable toward the east, though the less favorable conditions for obtaining good exposures of the group near the east line of the quadrangle render its value in that vicinity uncertain. Coal beds measured at locations 430 to 436 belong to the Black Diamond group (see pl. 24), and the thickness of these beds is shown graphically on Plate 30. Location 430 was made at the Miller mine, on the west side of Curtis Creek, in the SE. ¼ SW. ¼ sec. 29. In 1911 this mine consisted of an entry that ran into the hill about 80 feet S. 80° W. and then opened to the surface. The width of the entry increased from about 5 feet at the mouth to 30 feet at the extreme end, where coal has been mined out along the dip. The coal bed strikes N. 80° W. and dips 24° N. 10° E.

Some thin coal beds that belong to the Black Diamond group were also seen in the high bluff east of the Wesson mine. At this point the beds are inclined about 70°. About 250 feet stratigraphically below the Trout Creek sandstone a 14-inch bed of coal was seen with brown shale above and below. Two other beds, separated by 36 inches of gray shale, lie 25 feet below this bed. The upper of the two beds measured 25 inches and the lower 22 inches. About 50 feet below these two beds ashes and burned shale indicated the position of another coal bed.

Fairfield coal group.—Burning of the coal beds of the Fairfield group has been very general in T. 2 N., R. 93 W., and the value of the coals of the group is correspondingly in doubt. Exposures along

Coal Creek in T. 2 N., R. 92 W., near the Wesson mine, at locations 448 to 457 (see pls. 24 and 30), indicate the local presence of at least 8 coal beds that belong to the Fairfield group. Coal beds of this group crop out at locations 437 to 457 and 470 to 481, and the best estimate that could be made of the stratigraphic position of these beds is given in Plate 24. The thicknesses that were measured at these locations are shown graphically on Plate 30. At locations 455, 459, and 475 outcrop measurements were not obtainable, nor were reliable thicknesses determinable at abandoned prospects at locations 456 and 471. Location 454 was made on a 20-foot bed of black carbonaceous shale; location 438 on a burned coal outcrop; and location 447 marks a point beneath which practically the entire zone of outcrop of the Fairfield group has been reddened by burning of coal beds.

Locations 450 and 451 were made at the old Bloomfield mine, in the NE. ¼ SW. ¼ sec. 30, T. 2 N., R. 92 W., and location 457 marks the location of the Wesson mine. A thickness of 18 feet of pure coal was measured in the bed operated at this mine, and Mr. Wesson reported that an additional 4 feet of coal formed the mine roof.

Location 469, in the SW. ¼ sec. 10, T. 2 N., R. 93 W., marks the location of the Cornrike mine. This mine in 1911 consisted of an entry bearing N. 55° E. that penetrated the hill on the east side of Spring Creek Valley. The opening, which was about 8 feet wide and 8 feet high, followed the strike of the coal closely and was about 30 feet long. It then widened out into a room about 16 feet wide, 45 feet long, and 9 feet high. A sample was taken from the face about 35 feet in from the mouth of the entry. At that point 7 feet 6 inches of coal was measured without reaching either roof or floor. The details of the analysis are shown in the table (p. 219) under laboratory No. 12695. The coal was without partings greater than three-eighths of an inch, so that no part of the bed had to be excluded from the sample. The most complete section across the bed was taken at the mouth of the entry. At that point the following measurement was made:

Section measured at the Cornrike mine, in the SW. ¼ sec. 10, T. 2 N., R. 93 W., Colorado

	Ft.	in.
Top, shale, gray, sandy.		
Coal, with some brown shale	1	2
Coal, clean	2	5
Shale, brown and lenticular	1	5
Coal, clean	3	2
Shale, brown		1
Coal, clean	5	9
Coal, with some carbonaceous shale		4
Coal, clean	7	3+

The bottom of the bed was concealed by débris, but the above section shows that the bed is at least 21 feet 7 inches thick. The bed at the mine strikes N. 63° E. and dips 20° S. The stratigraphic position of this bed suggests its correlation with the Mount Streeter bed, as measured in sec. 2, T. 3 N., R. 93 W., and the similar thicknesses of coal at the two mines support this suggestion. Locations 464, 466, and 467 are thought to be in the Cornrike mine bed, but the coal was not exposed sufficiently for measurements to be obtained.

Coal beds above the Fairfield coal group.—Locations 458 to 459 and 482 to 515 were made on the outcrops of coal beds that probably belong to the Goff and Lion Canyon coal groups, and the thicknesses of the several beds measured are shown graphically on Plate 30. Their probable stratigraphic position is also indicated by Plate 24. No measurements of thickness were obtainable at locations 459, 490, 498, and 511. Locations 488, 489, 507, and 514 mark the burned outcrops of coal beds.

SUGGESTIONS FOR DEVELOPMENT

The coal beds of the part of these townships north of the divide can best be opened by entries or tunnels driven from the valleys of tributaries of Good Spring Creek; south of the divide Curtis and Coal Creeks and Aichers Draw afford the best approach to the coal.

QUANTITY

The quantity of coal in these townships, assuming 9 feet for the total thickness of coal in the Black Diamond group, 67 feet for the Fairfield group, and 15 feet for the combined Goff and Lion Canyon groups is, respectively, 370,000,000 tons, 2,665,000,000 tons, and 125,000,000 tons, or a total for the township of 3,160,000,000 tons.

TPS. 1 N. AND 1 S., RS. 92 AND 93 W.

T. 1 N., R. 93 W., and the parts of T. 1 N., R. 92 W., and T. 1 S., Rs. 92 and 93 W., included in the Meeker quadrangle are, so far as known, devoid of commercially valuable coal, although the lower and Black Diamond coal groups and the basal part of the Fairfield group are exposed in a narrow strip along the north line of T. 1 N., Rs. 92 and 93 W., and coal beds have been prospected in the northern part of sec. 3, T. 1 N., R. 93 W. South of the Mancos-Mesaverde contact (see pl. 19) the coal-bearing rocks have been removed by erosion from above the Meeker dome.