DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 757

GEOLOGY AND COAL RESOURCES OF THE AXIAL AND MONUMENT BUTTE QUADRANGLES MOFFAT COUNTY, COLORADO

BY

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

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GEOLOGY AND COAL RESOURCES OF THE AXIAL AND MONUMENT BUTTE QUADRANGLES, MOFFAT COUNTY, COLORADO

By E. T. Hancock

INTRODUCTION

LOCATION AND ACCESSIBILITY

The Axial and Monument Butte quadrangles, as shown by Figure 1, are in Moffat County, northwestern Colorado, and lie east of the Uinta Range and north of the White River Plateau. The quadrangles have an aggregate area of about 450 square miles and include parts of two great coal-bearing areas, the Green River Basin on the north and the Uinta Basin on the south. The Green River Basin contains a vast quantity of coal, which is being mined in a large way in the vicinity of Rock Springs and Kemmerer, Wyo. The Uinta Basin includes such centers of coal production as Crested Butte, Newcastle, and Cameo, Colo., and Thompson, Sunnyside, and Castlegate, Utah.

There are two post offices in the Axial quadrangle—Axial, in the southeastern part, and Juniper Springs (locally known as Juniper Hot Springs), in the northwestern part. In the Monument Butte quadrangle the only post office is Hamilton, near the center. The quadrangles are crossed by the main stage road connecting Meeker with Craig by way of Axial and Hamilton. The center of the territory embraced in the quadrangles is about 59 miles north and 10 miles east from Rifle, the nearest station on the Denver & Rio Grande Western Railroad, and is about 72 miles south of the main line of the Union Pacific Railroad. The northeast corner of the Monument Butte quadrangle is about 2¾ miles southeast of Craig, the present western terminus of the Denver & Salt Lake Railroad ("Moffat road"). The impending completion of the Moffat tunnel and the proposed extension of the Moffat road from Craig to Salt Lake City will doubtless lead to extensive exploitation of the great reserves of subbituminous coal and bituminous coal of low rank[1] contained in these quadrangles.

[1] The word rank, as now used by the United States Geological Survey, is intended to apply to those differences in coal which are the results of metamorphism, or the gradual change in the material from the original plant débris to anthracite.

EARLIER GEOLOGIC INVESTIGATIONS

The earliest complete maps of Colorado were made by the King and Hayden surveys and were published in the form of two large atlases. The Axial and Monument Butte quadrangles lie in the re-

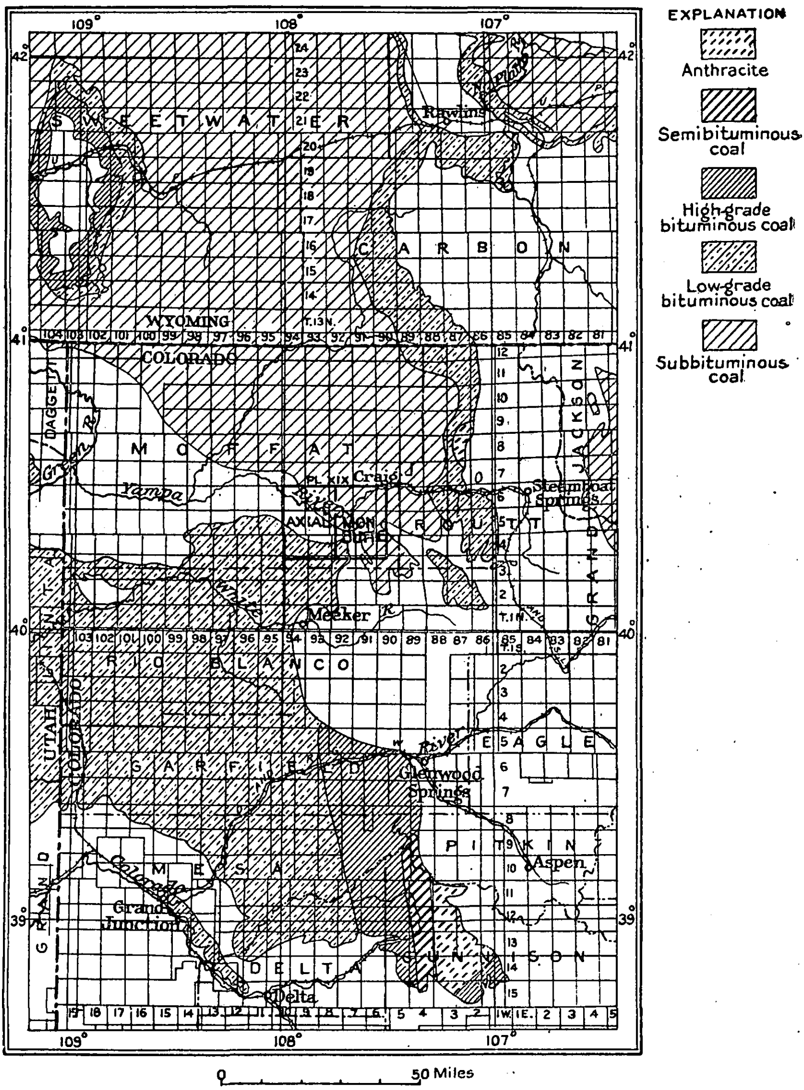

FIGURE 1.—Map showing the relation of the Axial and Monument Butte quadrangles to the two great coal-bearing areas of Green River Basin and Uinta Basin

gion mapped by the Hayden Survey in the summer of 1876. This region was again surveyed in the summers of 1906 and 1907 by a party under the general supervision of Hoyt S. Gale, in a reconnaissance study of the coal resources. In the summer of 1909 a portion of the Monument Butte quadrangle, including T. 6 N., R. 91

W., and that part of T. 5 N., Rs. 90 and 91 W., which lies north of Williams Fork, was studied in detail, but without the aid of an accurate topographic map, by a party under the supervision of John Allen Davis. The only additional work done by the writer in this part of the field was that of mapping the geologic boundaries and of tying in to the topographic base a number of points located during the detailed mapping, so as to make the geologic work fit the new topographic map.

GENERAL PLAN OF FIELD WORK

The field examination of the Axial and Monument Butte quadrangles that furnished the basis for this report was made by the writer, assisted by Carl B. Anderson, in the summers of 1912 and 1913; it was carried on under the general supervision of M. R. Campbell, to whom the writer is indebted for valuable suggestions. The investigations included a study of the age, character, thickness, and attitude of the strata and a determination of the quality and quantity of the coal. To accomplish this purpose it was necessary to make numerous collections of fossils and to study the beds and measure stratigraphic sections at many localities. It was also necessary to trace out and map certain key sandstones, to ascertain the altitude of these key beds at numerous points in order to determine the structure, to trace out and measure the coal beds, and to measure stratigraphic sections, carefully tying the coal beds to the key sandstones. In order to determine the quality of the coal, samples of unweathered coal were obtained wherever it was possible to do so.

A topographic survey of the quadrangles was being made at the same time, and in order that the observations of the geologist might be accurately tied to the topographic map, the geologic party worked in cooperation with the topographic party. Each location made by the geologist on the outcrop of a coal bed or prominent ledge of sandstone was accurately located both horizontally and vertically by the topographers.

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CHAPTER I.—GEOGRAPHY

SURFACE FEATURES

The surface features of the Axial and Monument Butte quadrangles are the result of the long-continued erosion of rocks that differ considerably in their resistance to the disintegrating action of the atmosphere and the scouring of the streams and have been more or less deformed or folded and tilted by movements within the crust of the earth.

The most conspicuous land form in these quadrangles is the more or less continuous escarpment surrounding the broad, relatively low tract commonly known as Axial Basin. The sandstones described on pages 15–20, which make up the escarpment, at one time formed a complete arch over what is now Axial Basin, but erosion has gradually worn them away from the crest of the arch, and now what is left of the haunches of the arch forms the prominent escarpment surrounding the basin. As soon as the sandstones were removed from the crest of the arch the agencies of erosion acted more effectively upon the underlying shale and produced the lowland now called Axial Basin.

Yampa River, the principal stream of the area, flows westward across the northern part of the quadrangles. After passing through intrenched meanders on the north side of the Axial Basin anticline, cut without apparent regard for the structure or relative hardness of the rocks, the river crosses the northwest end of Axial Basin and enters a deep canyon between Juniper and Little Juniper mountains. The origin and significance of the river course and of the striking parallelism of the smaller streams is discussed by the writer in another paper.[2]

CLIMATE

As the surface of the quadrangles ranges in altitude from 6,000 to 8,800 feet above sea level, the climate, except in midsummer, is rather cool, and as the precipitation is not great the region is better adapted to grazing than to the raising of farm crops. January is distinctly the coldest month and July the warmest. Some of the data on temperature, precipitation, etc., collected at Meeker, Colo., from 1906 to 1916, are summarized in the following table:

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[2] Hancock, E. T., The history of a portion of Yampa River, Colo., and its possible bearing on that of Green River: U. S. Geol. Survey Prof. Paper 90, pp. 183–189, 1915.

Climatic data collected at Meeker, Colo., 1906–1916

Year	January temperature (°F.)		July temperature (°F.)		Last killing frost in spring	First killing frost in autumn	Precipitation from rain and melted snow (inches)
	Minimum	Mean	Maximum	Mean			
1906	−20	18.1	90	63.4	June 21	Aug. 27	20.35
1907	−8	29.2	88	63.0	June 25	Sept. 9	17.93
1908	−21	19.2	87	63.6	June 23	Aug. 31	16.30
1909	−17	29.0	89	64.3	June 11	Sept. 22	16.60
1910	−21	20.0	90	63.9	June 19	Aug. 25	14.36
1911	−20	28.7	87	61.2	June 12	Sept. 7	15.11
1912	−27	21.2	88	62.0	June 20	Sept. 6	16.62
1913	−43	14.5	90	63.0	May 22	Sept. 17	11.44
1914	−24	21.4	85	63.8	June 9	Sept. 13	16.98
1915	−27	19.2	88	62.4	June 24	Sept. 9	12.67
1916	−25	21.0	89	64.2	June 23	Sept. 12	20.62

This table brings out the rather remarkable fact that the mean temperature for July, the hottest month, in eleven years varied only 3.1°. The mean temperature for January had a much greater variation, ranging from 14.5° to 29.2°. The annual precipitation ranged from 20.35 inches in 1906 to 11.44 inches in 1913 and averaged 16.27 inches.

Chapter II.—GEOLOGIC FORMATIONS

The strata that crop out in the Axial and Monument Butte quadrangles comprise only a small part of the great series of sedimentary beds that was laid down at a time when this portion of the continent was submerged. The presence in the rocks of the remains of plants and animals in general comparable to those that abound in bodies of water or on the land at the present time is evidence of the conditions under which the materials composing the rocks were originally deposited. That these conditions in all probability ranged from deep sea to shallow water and swamps and from salt to brackish and fresh water is shown by the presence in the strata of marine, brackish-water, and fresh-water invertebrates and also of plants. The sedimentary beds were originally deposited in nearly horizontal positions. As a result of the various forces that have been active in the earth's crust, however, they have been bent into folds and in many places broken, so that it is now necessary to study their attitude and position in order to explain the relation of one set of beds to another. A summary of the principal formations is given below.

Cretaceous and Tertiary formations of the Axial and Monument Butte quadrangles

Geologic age	Formation	Character	Topographic features	Thickness (feet)	Economic value
Tertiary (Miocene?).	Browns Park formation.	The great mass of the formation consists of sandstone of a chalky white color. The sandstone is soft and friable, consisting of small round quartz grains partly consolidated by calcareous cement. Basal beds are in places reddish or yellowish brown and contain considerable conglomerate.	The beds ordinarily lie horizontally upon the older upturned beds and in places form high cliffs, covered by a sparse growth of cedar and piñon.	Not determined.	
Marked unconformity					
Upper Cretaceous.	"Laramie" formation.	Massive sandstones interbedded with sandy shale containing an occasional thin bed of carbonaceous shale.	The two massive sandstones near the base of the formation are important cliff makers.	Not determined.	
	Lewis shale.	Consists essentially of soft dark-gray to drab clay shale but contains many layers of thin-bedded sandstone and spherical masses of limestone or calcareous rocks.	The outcrop of the shale portion of the formation is commonly marked by a broad valley between the ridges formed by the sandstones in the upper part of the Williams Fork formation and that at the base of the "Laramie" formation.	1,600	Valuable agricultural lands occur at many places in the broad valleys.

Cretaceous and Tertiary formations of the Axial and Monument Butte quadrangles—Continued

Geologic age	Formation		Character	Topographic features	Thickness (feet)	Economic value
Upper Cretaceous.	Mesaverde group.	Williams Fork formation.	Consists of alternating beds of sandstone, sandy shale, and coal through almost its entire thickness. Formation rests on the Trout Creek sandstone member of the Iles formation.	Characterized by hogback ridges and rugged hilly country. Steeply dipping beds erode, leaving narrow jagged ridges. Gently dipping massive sandstones form minor scarps along the sides of the valleys.	1,600	Contains many valuable coal beds.
		Iles formation.	Consists of alternating beds of sandstone and sandy shale, including some relatively unimportant coal beds near the base and also near the top. The formation is capped by the Trout Creek sandstone member.	Forms hogback ridges and rugged hilly country. Steeply dipping beds erode, leaving narrow jagged ridges. Gently dipping massive sandstones form small escarpments along the sides of the valleys. Massive sandstones at the base form a prominent escarpment surrounding Axial Basin.	1,350	Contains some relatively unimportant coal beds near the base and near the top.
	Mancos shale.		Consists essentially of soft dark-gray to drab clay shale. A zone several hundred feet thick at the base consists of bluish and dark-grayish slaty shale, dark-gray shale, and calcareous sandstone. The upper 800 feet is characterized by zones of thin-bedded sandstone. The most conspicuous belt of thin-bedded sandstone (the Morapos sandstone member) occurs about 800 feet below the top of the formation and is 15 to 30 feet thick.	Commonly forms broad valleys and parks, such as Agency Park and Axial Basin. The sandstone in the lower part commonly forms ridges parallel with those formed by the underlying Dakota sandstone. The thin-bedded sandstone in the upper part of the formation in many places forms cliffs below the main Mesaverde escarpment.	5,000	The broad valleys and parks formed in the shale generally contain valuable agricultural lands. The formation is oil-bearing in the Rangely district.
	Dakota sandstone.		Consists of slightly banded greenish-gray quartzitic sandstone containing pebbles at the base. Above, these beds change rapidly to a highly quartzitic sandstone.	Does not yield any prominent topographic features in the Axial and Monument Butte quadrangles, being chiefly concealed by the overlying Browns Park formation.	250	

Careful study of the lithology and fossil contents of the rocks of the Axial and Monument Butte quadrangles shows them to range in age from Pennsylvanian to late Tertiary. The rocks older than the Dakota sandstone are exposed at only one locality and are not included in the above table. Practically all the formations have received names derived from localities outside of this region and have previously been described in other reports.

PRE-DAKOTA ROCKS

Rocks older than the Dakota sandstone come to the surface only in the western part of T. 6 N., R. 94 W. Their stratigraphic succession is so much obscured by the cover of Browns Park beds and alluvium that they are not differentiated on the geologic map (Pl. XIX). The section is probably comparable to that exposed on Vermilion Creek, in T. 10 N., R. 101 W. sixth principal meridian, Colo., recently measured by Sears,[3] in part as follows:

Partial section of beds measured on Vermilion Creek in T. 10 N., R. 101 W.

	Feet
Cretaceous (?):	
Morrison formation (variegated clay shale and lenses of conglomeratic sandstone)	495
Jurassic:	
Twin Creek limestone (thin-bedded gray limestone and gray shale)	125
Nugget sandstone (cross-bedded white and gray sandstone and red sandy shale)	950
Triassic (?):	
Ankareh (?) shale (red and gray sandy shale; sandstone and grit)	208
Triassic:	
Thaynes (?) formation and Woodside shale (gray and drab shale; thin beds of limestone and sandstone)	762
Permian and Pennsylvanian:	
Park City formation (white and gray limestone, chert, sandstone, and shale)	115
Pennsylvanian:	
Weber quartzite (white and buff quartzitic sandstone)	900
Older Pennsylvanian rocks (limestone, shale, sandstone, and thin coal beds)	525
Top of Mississippian.	

The oldest rocks seen in T. 6 N., R. 94 W., are exposed in the canyon of Yampa River, which cuts the northeastern flank of the Juniper Mountain uplift. These are alternating beds of quartzitic sandstone and metamorphosed limestone, as shown in the following section, measured along the river from the highest to the lowest beds exposed.

Section along Yampa River canyon between Little Juniper and Juniper mountains, beginning with the younger beds at the east end of the canyon

	Ft.	in.
Limestone, hard, crystalline, in beds from 3 to 8 inches thick; strike N. 10° E., dip 15° S. 80° E.	24	
Quartzite, light yellowish, in rather thick beds	45	
Limestone, hard, crystalline	27	6

[3] Sears, J. D., Geology and oil and gas prospects of part of Moffat County, Colo., and southern Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 751, pp. 269–319, 1924.

	Ft.	in.
Sandstone, yellowish brown, rather friable, with considerable cross-bedding, in places quartzitic	46	
Limestone, hard, crystalline	8	6
Quartzite	8	
Concealed	20	
Limestone, hard, crystalline	13	
Quartzite, yellowish brown	10	
Limestone, hard, crystalline	5	
Concealed, probably soft sandstone and limestone, interbedded	35	
Quartzite, characterized by large nodules of chert	18	
Limestone	3	
Sandstone, yellowish brown, somewhat quartzitic	10	
Limestone, hard, crystalline	20	
Sandstone, yellowish brown, in places quartzitic	3	6
Concealed	15	
Limestone, hard, massive, fine grained, containing long, fibrous coral of *Favosites* type	5	
Limestone	25	
Limestone; considerable iron oxide stain near base	60	
Limestone, thin bedded, colored red by iron oxide; strike N. 7° E., dip 50° S. 83° E	56	
Limestone, massive, more or less crystalline	168	
Limestone, rather thin bedded	66	
Limestone, rather thin bedded, crystalline	235	
	926	6

The following species of invertebrate fossils were collected by the writer from beds rather uniformly distributed throughout the section:

Bellerophon crassus.
Bellerophon sp.
Composita subtilita.
Chaetetes milleporaceus.
Crinoidal fragments.
Derbya n. sp.
Endothyra sp.
Echinocrinus sp.
Edmondia gibbosa.
Fusulina sp.
Fenestella sp.
Meekella n. sp.
Marginifera splendens?
Productus cora.
Productus semireticulatus.
Postula nebraskensis.
Postula punctata.
Stenopora sp.
Spirifer boonensis?
Spirifer cameratus.
Spirifer rockymontanus.
Squamularia perplexa.
Textularia? sp.
Zaphrentis sp.

These fossils were identified by G. H. Girty, who says:

> The faunas are of the Mississippi Valley type, and they appear to represent early Pennsylvanian time. Compared with the faunas of the San Juan region, their relationship is with the Hermosa rather than with the Rico (Permian?) fauna. The faunas of the Weber quartzite of the Wasatch Mountain section are little known, but those of the lower Weber are more nearly comparable to the collections from the Axial quadrangle than those of the upper Weber.

Reeside,[4] who visited this locality in 1923, believes that the rocks exposed in Yampa River canyon include the Park City formation and the Weber quartzite as well as the older Pennsylvanian beds.

Eastward from Little Juniper Mountain the pre-Dakota rocks are almost completely concealed. A few outcrops near Juniper Hot Springs show white cross-bedded sandstone and greenish and reddish shale and sandstone, believed to be parts of the Nugget sandstone and the Morrison formation.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

DAKOTA SANDSTONE

Lying immediately above the beds just described as occurring at Juniper Hot Springs are beds having a total thickness of about 250 feet, which, from their relation to the overlying abundantly fossiliferous shale, are in the stratigraphic position of the Dakota sandstone. The evidence furnished by the section exposed indicates an apparent conformity between the Dakota sandstone and the underlying beds. As the Dakota sandstone is regarded as the basal formation of the Upper Cretaceous, however, its apparent conformity upon the Morrison may not be real. The lowest beds of the Dakota sandstone are exposed near the top of the hill a few hundred feet southwest of Juniper Hot Springs. At that point the Dakota consists essentially of quartzitic sandstone, in places very conglomeratic. The beds immediately overlying are not well exposed. Farther east, however, there is an outcrop of light-colored vitreous quartzite near the top of the hill immediately south of the main spring. This being the highest exposure of the metamorphosed sandstone, the top of the Dakota sandstone was mapped about midway between it and a belt of shale presently to be described.

No fossils were found in the Dakota sandstone in the Axial quadrangle. Owing to the remarkable uniformity in the character of the sandstone and its continuity of exposures over extensive areas it has been accepted as a key bed for the correlation of widely distributed sections of the Mesozoic both above and below it.

MANCOS SHALE

The Mancos shale occupies a large area in the Axial and Monument Butte quadrangles. The formation conformably overlies the Dakota sandstone and underlies the Mesaverde group. The name Mancos shale was first used in the description of the Telluride quadrangle,

[4] Reeside, J. B., jr., personal communication.

of southwestern Colorado, where it was applied to the body of shale that lies above the Dakota sandstone and beneath the Mesaverde formation and which is characteristically developed in Mancos Valley, especially about the town of Mancos.

No opportunity was afforded for measuring the thickness of the Mancos in the Axial and Monument Butte quadrangles, but according to Gale[5] that portion of the shale above the sandstone which yields Benton fossils maintains a very constant thickness in all parts of the coal fields where measurements were made of approximately 5,000 feet, or about a mile. The results of computations made by the writer and based on average dips and horizontal outcrop indicate a similar thickness.

The lower beds of the formation are exposed only along Yampa River for a distance of about 1,200 feet east of the Dakota-Mancos contact. At the base the formation consists of at least 75 feet of bluish and dark-grayish shale, which weathers out into more or less rectangular masses. The rocks exposed for some distance farther east and higher in the formation than those just described consist largely of dark-gray shale and calcareous sandstone. The following fossils were collected at this locality and are said by T. W. Stanton to belong to the Benton fauna, in the lower part of the Mancos shale:

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

On the south side of Yampa River in sec. 16, T. 6 N., R. 94 W., these dark calcareous and fossiliferous shale beds usually appear moist on the fracture planes and emit the odor of petroleum to a marked degree.

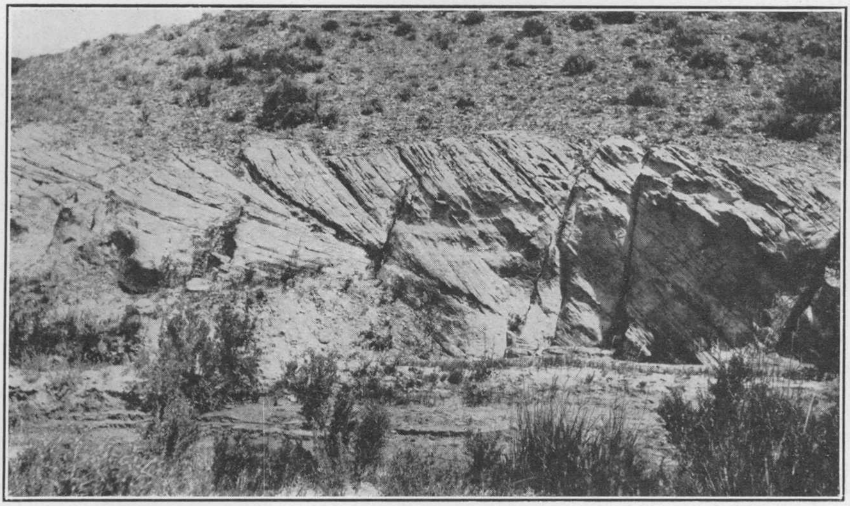
The main mass of the formation consists of a homogeneous clay shale including a few sandy layers. Throughout most of the shale these sandy layers are not thick enough to affect the surface features, but the upper 800 feet of the formation is characterized by groups of thin-bedded sandstone that form pronounced benches on the hill slopes. The presence of two such groups is recognized in the surface forms on the north side of Axial Basin about 2 miles west of the east boundary line of the Axial quadrangle. In the Monument Butte quadrangle what is probably the lower one of these groups forms a continuous line of cliffs from a point near the southeast corner of T. 5 N., R. 92 W., down into the valley of Morapos Creek and thence southwestward to a point about three-quarters of a mile

[5] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, p. 61, 1910.

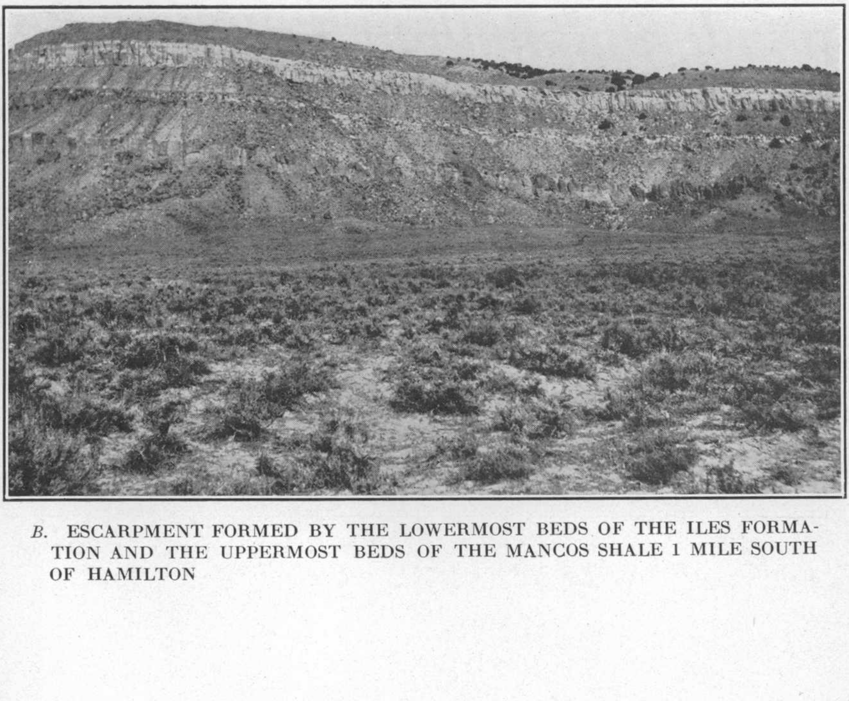
southwest of Monument Butte. Owing to the presence of a fault there is at this point an offset in the formation, and it is next recognized as forming the high cliff immediately south of Monument Butte. It forms a continuous cliff from the butte southeastward to the south line of the Monument Butte quadrangle. Owing to its numerous outcrops in the vicinity of Morapos Creek the name Morapos sandstone member has been chosen for this pronounced zone of thin-bedded sandstones, 15 to 30 feet thick, which lies 800 feet below the top of the Mancos shale. The uppermost beds of the Mancos shale usually form a considerable part of the steep slope on both sides of Axial Basin, because these beds are protected by the overlying sandstone that forms the principal escarpment near the base of the Iles formation and is here designated the "rim rock." The upper part of the "rim rock" in places consists of very white sandstone that weathers out into rounded forms, but the lower part weathers out into huge rectangular blocks of yellowish-brown color. About 75 feet below the "rim rock" there commonly occurs another bed of sandstone from 15 to 25 feet in thickness which resembles the "rim rock" in color and mode of weathering. The base of this sandstone was regarded as the contact between the Mancos shale and the Iles formation.

About 100 feet below the contact occurs another sandstone of an entirely different character. It is very soft and in places shows only as lumplike masses in the talus slope. It is greenish gray, has a sugary texture, is without bedding planes, and in places yields an abundance of invertebrate fossils. Plate I, *B*, is a view of the characteristic escarpment, in which is shown the "rim rock" at the top, the contact ledge in the middle, and the greenish-gray sugary ledge at the base. The following invertebrate fossils, identified by T. W. Stanton, were obtained by the writer from the fossil-bearing sandstone and associated beds comprising about 400 feet of the upper part of the Mancos shale:

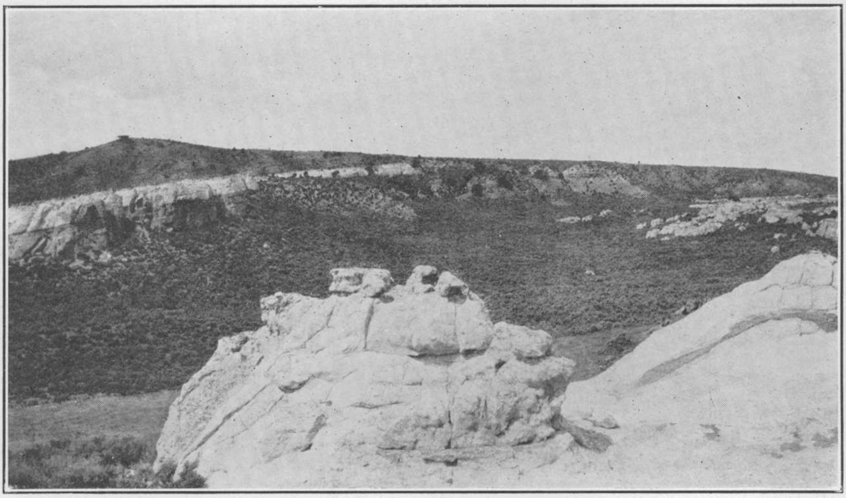
Anatina sp.
Arca? sp.
Avicula nebrascana Evans and Shumard.
Anisomyon patelliformis Meek and Hayden.
Avicula linguiformis Evans and Shumard.
Baculites compressus Say.
Baculites ovatus Say.
Burrows probably made by some pelecypod.
Callista sp.
Cardium speciosum Meek and Hayden.
Corbulamella gregaria Meek and Hayden.
Gervillia sp.
Goniomya americana Meek and Hayden.
Inoceramus sagensis Owen?



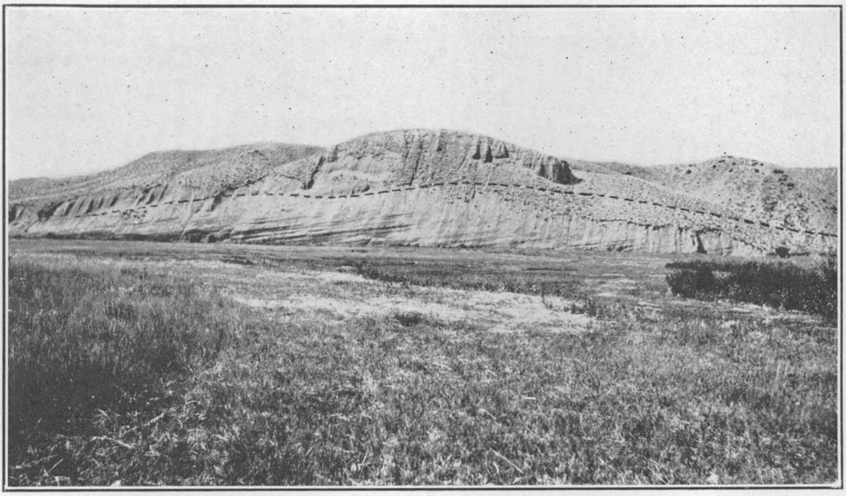
A. NUGGET (?) SANDSTONE ONE-FOURTH MILE WEST OF JUNIPER HOT SPRINGS



B. ESCARPMENT FORMED BY THE LOWERMOST BEDS OF THE ILES FORMATION AND THE UPPERMOST BEDS OF THE MANCOS SHALE 1 MILE SOUTH OF HAMILTON



A. WHITE SANDSTONE AT THE TOP OF THE WILLIAMS FORK FORMATION IN THE BELL ROCK DOME, T. 6 N., R. 92 W.



B. GENTLY DIPPING MANCOS SHALE, OVERLAIN BY HORIZONTAL BEDS OF THE BROWNS PARK FORMATION, SEC. 22, T. 6 N., R. 94 W.

Inoceramus barabini Morton.
Inoceramus oblongus Meek?
Lingula sp.
Liopistha undata Meek and Hayden.
Lucina sp.
Mytilus subarcuatus Meek and Hayden.
Ostrea sp., smooth form.
Ostrea sp., corrugated form.
Sphaeriola sp.
Syncyclonema rigida Hall and Meek.
Tellina sp.

MESAVERDE GROUP

The Mesaverde group, like the Mancos shale, occupies a large part of the Axial and Monument Butte quadrangles. It overlies the Mancos shale conformably and forms an almost continuous escarpment surrounding Axial Basin, the great depression eroded out of the underlying shale. The name Mesaverde group was applied by W. H. Holmes to the mass of sandstone and shale forming the Mesa Verde (Spanish for green table-land), the plateau covered with evergreens a few miles southwest of Mancos, Colo.

In the detailed mapping of the Mesaverde rocks in northwestern Colorado two rather massive beds of sandstone were recognized over wide areas. The lower one of these beds was named by Fenneman and Gale[6] the Trout Creek sandstone, on account of its excellent exposure near Trout Creek, on the northeast side of Twentymile Park. The upper bed was also first mapped and described by Fenneman and Gale and was named the Twentymile sandstone, from its typical development in and around Twentymile Park. This sandstone was not recognized in the Axial and Monument Butte quadrangles south of Axial Basin. In mapping the coal fields of northwestern Colorado and northeastern Utah Gale[7] recognized a prominent white sandstone at the base of the principal group of coal beds on both sides of Axial Basin and designated it the "white rock." The detailed work of Davis, described later on in this report, and also that of the writer leaves very little doubt as to the identity of the "white rock" with the Trout Creek sandstone of the Yampa coal field. The base of the principal group of coal beds is one of the most distinctly marked horizons in the Mesaverde, both by the presence of the coal beds above and by the common occurrence of the so-called "white rock." As a result Gale, in his mapping, separated the Mesaverde into the "upper part of the Mesaverde formation" and

[6] Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: U. S. Geol. Survey Bull. 297, 1906.

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

the "lower part of the Mesaverde formation," including the "white rock" in the upper part. The Mesaverde was so separated and mapped from Vernal, Utah, to Craig, Colo., and as far south as Newcastle. On account of the almost universal recognition of the "white rock," the abundance of coal above it, and the fact that it marks a horizon which can be recognized over a wide territory, it has now been decided to subdivide the Mesaverde rocks into two formations and to retain the name Mesaverde in a group sense. The name Iles formation is here introduced for the lower formation of the Mesaverde group, because that portion of the Mesaverde forms nearly all of Iles Mountain, a conspicuous topographic feature north of Axial Basin, and the name Williams Fork formation is applied to the upper formation, which is exposed in the Williams Fork Mountain and also along Williams Fork near its junction with Yampa River. The "white rock" or Trout Creek sandstone is a conspicuous feature, and its top is here made the division line between the Iles and Williams Fork formations, because in many places where the base of the member was not well exposed the top of the sandstone could be readily recognized and therefore lent itself more readily to detailed mapping.

There is a fundamental difference between the Mancos shale and the rocks of the Mesaverde group, and this difference is of considerable economic importance. The shale is in the main part consolidated mud, whereas the sandstones of the Mesaverde group are composed of grains of sand more or less firmly cemented together. As a result of this difference in composition such agencies as frost, wind, rain, and running water have acted more vigorously on the shale than on the sandstones. The sandstones thus give rise to more rugged land forms, whereas the shale areas are characterized by long, gentle slopes. The portions of these quadrangles where the rocks of the Mesaverde group occur at the surface are not so readily tilled as the Mancos areas, but they are better adapted to grazing, because the soil supports a more vigorous growth of grass for feed, as well as small trees and shrubs for shade. Furthermore, a greater volume of water issues from the sandstones along the steep-sided valleys than from the great mass of shale, where the surface is much more even. The economic importance of the difference in composition is most strikingly exemplified in the detailed consideration of the coal that is given on succeeding pages, where it is shown that the coal beds are confined entirely to the rocks of the Mesaverde group, and that the valuable beds occur in the lower part of the Williams Fork formation, which overlies the Trout Creek sandstone.

ILES FORMATION

CHARACTER AND DISTRIBUTION

The Iles formation makes up nearly all of Iles Mountain and crops out in a narrow belt between the large area of Mancos shale in Axial Basin and the region occupied by the Williams Fork formation. On the south side of the basin the belt is narrow because the dips are steep; on the north side the belt is much wider because of the gentler dips. This formation consists of an alternation of thick beds of sandstone and sandy shale, together with a few thin coal beds near the base and near the top.

The group of coal beds occurring 150 to 350 feet below the Trout Creek sandstone in the vicinity of Meeker was named by Gale the Black Diamond coal group, from the Black Diamond mine, which is working one of the beds. This group of coal beds seems to be of very little economic importance in the Axial and Monument Butte quadrangles. The line marking the base of the Iles formation is drawn at the base of a thin bed of sandstone about 75 feet below the "rim rock" as described on page 12. The "rim rock" and the massive sandstone immediately above it form a very resistant zone compared with the overlying soft shale, and as a result they form a bold escarpment on both sides of Axial Basin. The boundary line between the Iles formation and the Williams Fork formation is drawn at the top of the Trout Creek sandstone member of the Iles formation, described on page 14.

The following section measured on the east side of Milk Creek shows the character of the Iles formation:

Section of Iles formation on east side of Milk Creek at opening into south side of Axial Basin

	Ft.	in.
Sandstone, white (Trout Creek); estimated	75	
Concealed; probably sandy shale and shaly sandstone	135	
Shale; gray, sandy		
Coal		8
Shale, brown		1
Coal	1	11
Shale, black, carbonaceous		2
Coal streaked with selenite	1	9
Shale, brown	3	
Sandstone, shaly	17	
Coal, impure		6
Shale	1	
Coal	1	
Shale, sandy	11	
Shale, brown	1	
Coal, impure		9
Shale, brown	2	9
Shale, brown, sandy	15	

	Ft.	in.
Sandstone, iron stained, rectangular jointed	3	
Shale, brown	1	6
Coal		6
Shale, brown	3	
Coal	1	
Shale, brown	1	5
Sandstone, yellowish brown, jointed	8	
Largely concealed, containing considerable shale	72	
Sandstone, soft, thin bedded	84	
Sandstone, yellow, soft, massive	20	
Sandstone, soft, shaly	22	
Sandstone, yellowish brown	15	
Concealed; probably shaly sandstone	34	
Sandstone, yellow, soft	17	
Sandstone, soft, shaly	49	
Sandstone, yellowish brown, conspicuously jointed	9	
Sandstone, containing considerable brown shale	19	
Sandstone, thin bedded	9	
Shale, sandy	18	
Sandstone, shaly	8	
Sandstone, white, jointed	7	
Concealed; probably soft shaly sandstone	40	
Sandstone, white, massive	20	
Sandstone, shaly	5	
Sandstone stained with iron oxide	3	
Sandstone, shaly	3	
Sandstone, brown	3	
Sandstone, soft, shaly	35	
Sandstone, brown	4	
Concealed	13	
Sandstone, brown	5	
Sandstone, thin bedded	15	
Sandstone, yellowish brown, massive	20	
Sandstone, shaly	10	
Shale, brown	1	3
Coal, splintery	1	3
Shale, brown, sandy	4	
Coal	1	2
Shale, gray, sandy	3	
Coal	1	
Shale, brown	1	2
Sandstone, yellow, thin bedded	30	
Sandstone, shaly	20	
Sandstone, yellow, thin bedded	13	
Concealed	52	
Shale, black, carbonaceous	1	
Shale, sandy	3	
Sandstone	16	
Concealed; probably thin-bedded sandstone	35	
Sandstone, white	24	
Sandstone, yellowish brown, thick bedded, jointing fairly conspicuous	43	
Sandstone, mainly thin bedded	23	

	Ft.	in.
Shale, brown to black, carbonaceous	11	
Sandstone, soft	20	
Coal	1	7
Shale, brown, sandy	10	
Coal	2	7
Shale, brown, partly concealed	9	
Shale, black, carbonaceous, containing thin streaks of coal	1	9
Concealed; probably shaly sandstone	9	
Sandstone, brown	4	
Shale, brown and gray	5	6
Shale, black, carbonaceous, containing small lenses of coal		7
Shale, brown	3	
Sandstone, shaly	5	
Sandstone, brown, thick bedded	63	
Talus slope at foot of massive sandstone	33	
	1,296	10

The thickness of the Iles formation, according to measurements made near Milk Creek and in the gulch east of Red Cone, in the southwest corner of T. 5 N., R. 94 W., is about 1,350 feet.

FOSSILS

The following invertebrate fossils, mostly marine, were collected from a zone about 400 feet thick at the base of the Iles formation in the Meeker, Axial, and Monument Butte quadrangles and identified by T. W. Stanton:

Marine species:
- Cardium speciosum Meek and Hayden.
- Donax? sp.
- Inoceramus pertenuis Meek and Hayden.
- Inoceramus sp. fragments.
- Mactra sp.
- Shark teeth.
- Tellina sp.

Brackish-water species, very abundant in one or more thin beds near the base:
- Ostrea subtrigonalis Evans and Shumard.
- Anomia sp.

The following invertebrates were collected from the upper 250 feet of the Iles formation and identified by Mr. Stanton:

Marine species:
- Cardium speciosum Meek and Hayden.
- Haminea sp.
- Inoceramus sp.
- Inoceramus barabini Morton.
- Mactra sp.
- Tellina sp.

Brackish-water species, abundant in thin beds:
- Ostrea subtrigonalis Evans and Shumard.

A few fossil plants collected from the Iles formation were identified by F. H. Knowlton as *Halymenites major* Lesquereux (abundant throughout the lower part of the formation) and *Ficus populoides*? Knowlton.

WILLIAMS FORK FORMATION

CHARACTER AND DISTRIBUTION

The Williams Fork formation is well exposed along Williams Fork near its junction with Yampa River and also in the Williams Fork Mountains. It occupies a considerable part of the Axial and Monument Butte quadrangles, cropping out in a continuous belt that extends from about the middle of the north side of the Axial quadrangle southeastward and eastward across both quadrangles. On the opposite side of Axial Basin the Williams Fork formation occupies the north flank of the Danforth Hills. In the southeastern part of the Monument Butte quadrangle the same beds occupy an area entirely surrounded by the outcrops of the Iles formation. The base of the Williams Fork formation, being also the base of a valuable group of coal beds, has been accurately located throughout these quadrangles. It is placed at the top of the Trout Creek sandstone member described above. The Williams Fork formation consists of an alternation of sandstone, sandy shale, carbonaceous shale, and coal beds. The sandstone is by far the most conspicuous owing to its greater resistance to erosion. The individual beds of sandstone are neither so pronounced nor so persistent as those in the Iles formation, and although the whole Mesaverde group produces rugged surface features they are more truly characteristic of the Iles than of the Williams Fork.

About 900 to 1,050 feet above the Trout Creek sandstone member is another sandstone member which is sufficiently well defined and persistent to be used as a horizon marker. It was first recognized near the top of the high peak in sec. 36, T. 6 N., R. 93 W., whence it was traced east and then northwest and finally into the valley of Yampa River, where it was found to be continuous with the Twentymile sandstone of Fenneman and Gale,[8] named from its typical development in and around Twentymile Park. The sandstone was later traced as far west as Yampa River, during a detailed coal investigation under the direction of John A. Davis, in the summer of 1909. West of sec. 36, T. 6 N., R. 93 W., the Twentymile sandstone is not so well defined. Its approximate position was merely inferred on the basis of structural contours and surface contours. There is also a bed of fairly persistent white sandstone near the top of the

[8] Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: U. S. Geol. Survey Bull. 297, p. 27, 1906.

Williams Fork formation, but in places there are as many as three prominent white sandstones in this part of the formation, as, for example, along the hillside west of Yampa River near the south end of Big Bottom. These sandstones are also well exhibited around the border of the area of Williams Fork formation near the northwest corner of the Monument Butte quadrangle. (See Pl. II, *A*.)

In the Axial quadrangle the coal beds are uniformly distributed throughout the Williams Fork formation from its base to a level within about 200 feet of its top. Farther east, however, the coal beds immediately below the Twentymile sandstone are thinner and less numerous.

The group of coal beds extending from 1,000 to 1,300 feet above the Trout Creek sandstone at Meeker, Colo., was called by Gale the Fairfield coal group, from the well-known Fairfield mine, and the corresponding beds in the Axial and Monument Butte quadrangles will be referred to as the Fairfield coal group, for the purpose of indicating correlation.

As distinguished from the Iles formation the Williams Fork formation is characterized by thick zones of brick-red sandstone and baked shale produced by the burning of large beds of coal. The steep slopes along Yampa River are in many places made up from top to bottom of material of this kind.

FOSSILS

Several species of fossil invertebrates and plants were obtained from beds about 1,100 feet thick immediately above the Trout Creek sandstone in the Meeker, Axial, and Monument Butte quadrangles. Some of the beds contain only marine invertebrates, others are characterized by brackish-water forms, and a few contain only fresh-water types showing an alternation of marine, estuarine, and swamp conditions. The invertebrates were identified by T. W. Stanton and the plants by F. H. Knowlton.

Invertebrates:
- Marine species:
  - Cardium speciosum Meek and Hayden.
  - Inoceramus sp.
  - Inoceramus barabini Morton.
  - Liopistha undata Meek and Hayden.
  - Lingula sp.
  - Lunatia sp.
  - Mactra sp.
  - Tellina sp.
- Brackish-water species:
  - Anomia sp.
  - Corbicula cytheriformis Meek and Hayden.
  - Corbula undifera Meek.
  - Modiola sp.

Invertebrates—Continued.

Brackish-water species—Continued.

Ostrea glabra Meek and Hayden.

Ostrea subtrigonalis Evans and Shumard.

Fresh-water species:

Campeloma? sp.

Sphaerium sp.

Tulotoma thompsoni White.

Unio sp.

Viviparus? sp.

Plants:

Ficus sp.

Ficus speciosissima? Ward.

Ficus trinervis? Knowlton.

Ficus wardii? Knowlton.

Magnolia tenuinervis Lesquereux=M. inquirenda Knowlton.

Myrica torreyi Lesquereux.

Narrow Salix-like leaves.

Salix? sp.

Sequoia reichenbachi (Geinitz) Heer.

Viburnum sp.

The species *Ostrea glabra* occurs abundantly in the white sandstones at the top of the formation.

THICKNESS

There is very little opportunity to measure the thickness of the Williams Fork formation in the Axial and Monument Butte quadrangles, but its approximate thickness was determined from structure sections B–B′, C–C′, and D–D′, Plate XIX, to be 1,600 feet.

LEWIS SHALE

CHARACTER AND DISTRIBUTION

The Lewis shale crops out in the northern part of the Axial and Monument Butte quadrangles. It appears to rest conformably upon the uppermost beds of the Williams Fork formation and is conformably overlain by the "Laramie" formation.

The formation consists essentially of soft shale of a dark-gray color and closely resembles the Mancos shale. Interbedded with the shale are a few thin beds of sandstone, which readily separate into thin slabs along the bedding planes. These beds attain a sufficient thickness in places to indicate their presence topographically by low ridges. For example, one such bed was traced almost continuously from sec. 8, T. 6 N., R. 93 W., as far southeast as a point a mile north of Round Bottom. Concretions in the form of large spherical masses of limestone or calcareous rock are also common to certain portions of the formation.

FOSSILS

The following species of marine invertebrates were obtained from the lower half of the formation. The first three came from a thin-bedded sandstone about 400 feet above the base, and the last eight from beds about 200 feet higher. The species were identified by T. W. Stanton, who states that they are probably of upper Montana age but are not especially characteristic of the Lewis.

Anomia sp.
Callista? sp.
Crenella sp.
Leda sp.
Legumen sp.
Lunatia sp.
Modiola sp.
Nucula sp.
Syncyclonema sp.
Tellina sp.
Tellina? sp.

The following species were obtained from beds extending from 360 feet to 450 feet below the top of the formation:

Actaeon attenuatus Meek and Hayden.
Anomia sp.
Avicula sp.
Cardium speciosum Meek and Hayden.
Dentalium sp.
Lunatia sp.
Mactra sp.
Modiola sp.
Ostrea glabra.
Protocardia? sp.
Pyrifusus sp.?
Tellina scitula Meek and Hayden.

The following species were obtained from beds about 200 feet higher in the formation:

Anomia sp.
Cardium speciosum Meek and Hayden.
Crenella sp.
Entalis? sp.
Gervillia recta Meek and Hayden.
Leda sp.
Legumen sp.
Lunatia sp.
Mactra sp.
Modiola sp.
Tellina scitula Meek and Hayden.

"LARAMIE" FORMATION

CHARACTER AND DISTRIBUTION

Conformably overlying the Lewis shale are massive sandstones interbedded with sandy shale and an occasional thin bed of carbonaceous shale which occupy a small area in the northeast corner of the Axial quadrangle. These beds have been mapped in neighboring areas as the basal 250 feet of the "Laramie" formation, and they are so treated in this report, for convenience of mapping, although the fauna they contain allies them more closely with the Lewis. There are two prominent beds of sandstone. Only about 30 feet of the lower bed is exposed in the Axial quadrangle, but half a mile north of Craig a sandstone that seems to bear the same relation to the underlying shale forms a vertical cliff about 100 feet high and is the most conspicuous sandstone in the region. In the Axial quadrangle the sandstone is coarse grained, has a yellowish to light-gray color, and occurs in rather thin beds that weather into round forms. About 200 feet higher up is another prominent sandstone of similar color, which weathers into rectangular masses. About 100 feet above the lower massive sandstone in the vicinity of Craig is a rather thick coal bed, but the coal is lenticular and does not appear to be very thick in the Axial quadrangle. At the Kimberly mine, a short distance east of Craig, the coal is 7 feet 8 inches thick.

FOSSILS

The following invertebrates were obtained from the lower massive sandstones at the base of the "Laramie":

Anomia micronema Meek.
Cardium speciosum Meek and Hayden.
Ostrea glabra Meek and Hayden.
Scaphites? sp.
Several small undetermined pelecypods and gastropods.
Sphenodiscus lenticularis (Owen)?
Tellina scitula Meek and Hayden.

All these except the *Anomia* and the *Ostrea*, according to Stanton, are marine species and belong to the fauna of the Lewis shale. The two ammonoids (*Sphenodiscus lenticularis* (Owen)? and *Scaphites?* sp.) indicate that the lower sandstone is older than true Laramie and suggest Fox Hills age. *Anomia micronema* Meek and *Ostrea subtrigonalis* Evans and Shumard are usually found in brackish-water beds and range from the Mesaverde to the Lance, inclusive.

The following species of invertebrates were obtained from beds about 200 feet above the lower massive sandstone. With the exception of *Ostrea glabra*, they belong, according to Stanton, to the marine fauna of the Montana group and are therefore older than the true Laramie.

Avicula fibrosa Meek and Hayden.
Avicula linguiformis Evans and Shumard.
Cardium speciosum Meek and Hayden.
Mactra? sp.
Ostrea glabra Meek and Hayden.
Tellina scitula Meek and Hayden.
Tellina? sp.
Baculites sp.

The fossils listed below were obtained from a thin-bedded sandstone about 50 feet above the upper one of the two massive sandstones referred to above and therefore about 250 feet above the lowermost sandstone. According to Mr. Stanton these are also marine species and belong to the fauna of the Montana group.

Cardium speciosum Meek and Hayden.
Cinulia sp.
Entalis sp.
Leda sp.
Lunatia sp.
Nucula sp.
Protocardia sp.
Tellina scitula Meek and Hayden.

The positions in the formation of the fossils listed above show that marine conditions prevailed long after the sediments changed from fine clay to coarse sand, and the presence of a thick coal bed between the two sandstones indicates that for a time the sea became shallow enough to permit the growth and accumulation of vegetable matter.

TERTIARY SYSTEM

MIOCENE (?) SERIES

BROWNS PARK FORMATION

CHARACTER AND CORRELATION

Although in the region to the north the "Laramie" formation is overlain by beds of late Cretaceous and possibly early Tertiary age, succeeded by the still later Wasatch and Green River formations, none of these formations are present in the Axial and Monument Butte quadrangles, where a still younger formation overlaps all the Paleozoic and Mesozoic formations with marked unconformity. In the Craig quadrangle, immediately to the north, these beds rest unconformably on the early Tertiary coal-bearing formation and the younger Wasatch beds. They correspond to the rocks described by Powell and others as the Browns Park "group" and later described by C. A. White [9] in their eastern extension from Browns Park to Fortification Butte (now better known as Cedar Mountain).

According to Powell [10] they are much younger than the Green River and Bridger formations, for in speaking of the Browns Park "group" he says: "Its unconformity with the Upper Green River, Lower Green River, and Bridger beds is well exhibited in the Dry

[9] White, C. A., On the geology and physiography of a portion of northwestern Colorado and adjacent parts of Utah and Wyoming: U. S. Geol. Survey Ninth Ann. Rept., p. 691, 1889.

[10] Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto, p. 168, 1876.

Mountains in many fine exposures." C. A. White regarded these beds as geologically equivalent to the Uinta or latest Eocene formation exposed south of the Uinta Mountains, but his reasons for this correlation are not clear. They appear to be much younger.

In a recent paper [11] the author points out some of the physiographic relations of the Browns Park formation.

The altitude of the Browns Park formation at Cedar Mountain compared with its altitude in the river bank in sec. 22, T. 6 N., R. 94 W., indicates a total thickness of at least 1,500 feet. Powell [12] gives the thickness of the Browns Park beds as 1,800 feet, and White [13] gives it as 1,200 to 1,800 feet. It is not at all improbable that further study will show a much greater thickness for these beds than those indicated, for the reason that remnants of sandstone and conglomerate, whose relation to the Browns Park formation is unknown, were observed at much higher altitudes. For example, sandstone capped by a very coarse conglomerate is exposed about 6 miles southeast of Pagoda and about 100 feet below the top of the great sheet of basalt that forms the "Flat tops," at an altitude of about 10,000 feet. (See Pl. III, *B*.) The conglomerate is made up entirely of well-rounded pebbles and boulders of basalt, some of which are as much as 18 inches in diameter.

The basal beds of this formation, where best exposed in the Axial quadrangle, consist of soft, more or less unconsolidated reddish and yellowish-brown sand. These beds usually contain a large amount of conglomerate, the pebbles of which consist of schist, gneiss, coarse and fine grained granite, white and reddish quartzite, and white and reddish vein quartz. At least 50 feet of such material overlies horizontally the gently dipping Mancos shale in the bank of the river in the southwest corner of sec. 22, T. 6 N., R. 94 W. The relations are well shown in Plate II, *B*. These basal beds grade upward rapidly into the soft white sandstone that makes up much the greater part of the formation. The sandstone is everywhere of a chalky white color and consists of soft friable material made up largely of rounded quartz grains, more or less consolidated by calcareous cement, and a few layers and irregular masses of hard, somewhat quartzitic sandstone that is much darker.

FOSSILS

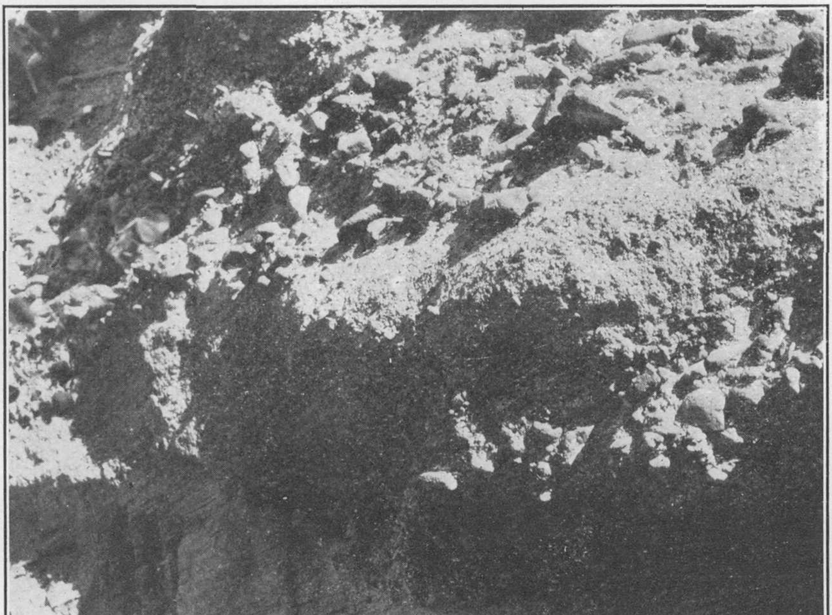
Although diligent search was made at several horizons in the Browns Park formation for the remains of animal and vegetable

[11] Hancock, E. T., The history of a portion of Yampa River, Colo., and its possible bearing on that of Green River: U. S. Geol. Survey Prof. Paper 90, pp. 183–189, 1915.

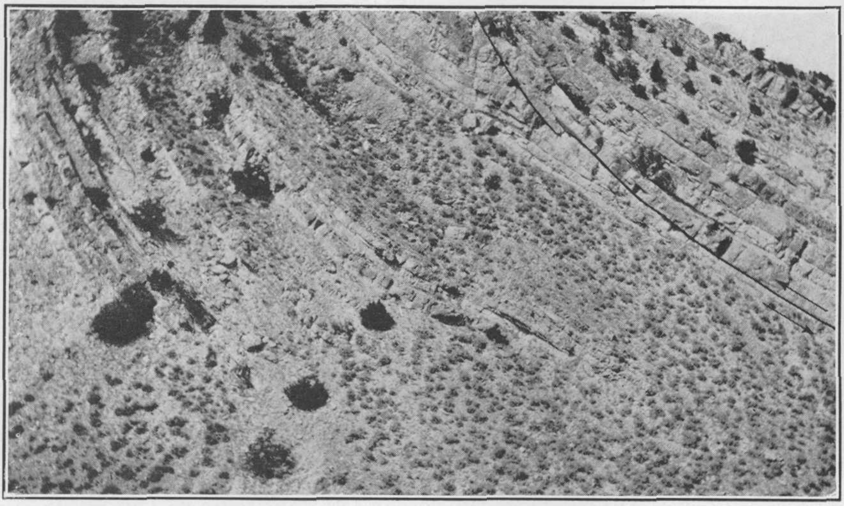
[12] Powell, J. W., op. cit., p. 40.

[13] White, C. A., On the geology and physiography of a portion of the northwestern Colorado and adjacent parts of Utah and Wyoming: U. S. Geol. Survey Ninth Ann. Rept., p. 686, 1889.

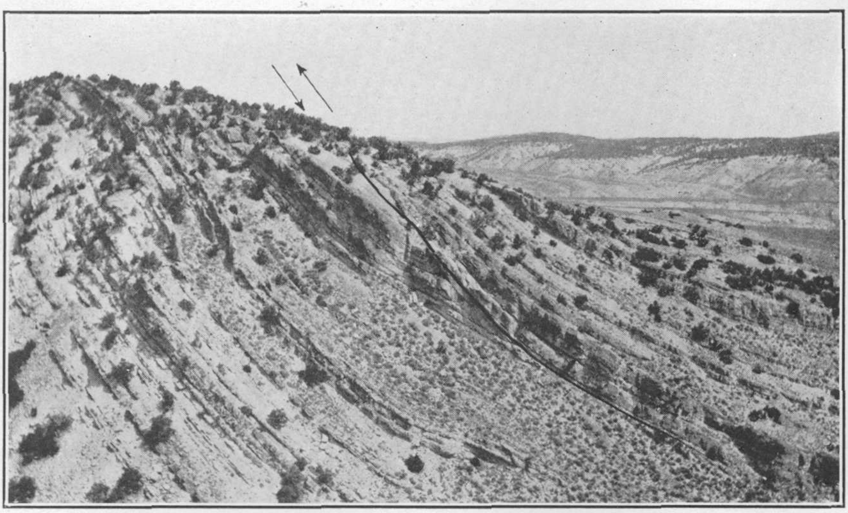
A. MEANDERS ALONG WILLIAMS FORK NEAR THE EAST EDGE OF THE MONUMENT BUTTE QUADRANGLE



B. SANDSTONE AND COARSE CONGLOMERATE 100 FEET BELOW THE "FLAT TOPS," ABOUT 6 MILES SOUTH OF PAGODA



A. NORTH SIDE OF YAMPA RIVER CANYON AT JUNIPER MOUNTAIN, SHOWING A THRUST FAULT IN CARBONIFEROUS BEDS AT LOW ANGLE WITH THE BEDDING PLANES



B. NORTH SIDE OF YAMPA RIVER CANYON AT JUNIPER MOUNTAIN, SHOWING A THRUST FAULT IN CARBONIFEROUS BEDS life, nothing was found except some tubular forms of a white substance from one-eighth to three-eighths of an inch in diameter and from an inch to several inches in length. They lie at all angles with the bedding planes. Some of the forms exhibit a cellular structure resembling that of bone, although it is more probable that they are fossilized stems or roots.[14]

QUATERNARY SYSTEM

Certain materials of Quaternary age that occur in the Axial and Monument Butte quadrangles are believed to represent different stages in the topographic development of the region. These materials consist of glacial deposits, terrace gravel, and alluvium.

PLEISTOCENE SERIES

GLACIAL DEPOSITS

Scattered over the surface of these quadrangles are thin deposits that may have resulted from glacial action, but no regional investigation has been made with a view of determining their origin. In many places the surface is partly covered by gravel, the pebbles of which range from a small fraction of an inch to 10 inches in diameter. The pebbles observed in these deposits were in places found to be made up of granite, syenite, red and white quartzite, chert, vein quartz, and basalt. In many places the gravel is accompanied by more or less rounded and irregular-shaped masses of basalt, some of them as much as 5 feet in diameter. Pebbles were observed having one or more facets with well-defined interfacial angles, but no striae were seen. Some of the basalt, from all appearances, merely represents the remains of broken down basaltic flows, particularly where the basaltic material caps the higher elevations. In places, however, the basalt occurs as more or less rounded boulders associated with the pebbles of other rocks and occupies the bottom of a valley, without any connection with the higher areas. Such occurrences were noted especially along Morapos Creek about 1½ miles southwest of the Hamilton ranch, near the northwest corner of T. 4 N., R. 91 W., and a short distance south of east of Monument Butte. C. A. White in his description of "scattered drift" over the region between the Uinta and Park ranges expresses the opinion that the drift originated from one or the other of these two ranges. He says:

---

[14] Vertebrate fossils discovered by Earl Douglass in the Browns Park formation in 1923 have been studied by A. O. Peterson, who states, in a personal communication, that he has recognized among them an advanced form referred to the genus *Phlaocyon*. This genus has been found in the Oligocene, but he thinks that the Browns Park species is probably of lower Miocene age.—T. W. Stanton.

The character of the rocks composing the axial portions of the Uinta and Park Range uplifts, respectively, is so different that it is quite easy to refer any collection of pebbles that may be found in the vicinity of both ranges to the one from which they were really derived, and also to recognize any mixture of pebbles as such that have been derived from both ranges.

He concludes his discussion by stating the probable limit of distribution of the drift from each range and closes by saying:

So far as my observation has extended there appears to be no reason why we may not regard the distribution of this drift of the Park Range and Uinta Mountains as contemporaneous with that of the great northern glacial drift.[15]

RECENT DEPOSITS

TERRACE GRAVEL

At certain places on Yampa River beds of gravel were observed at different altitudes above the present level of the stream. The most notable deposit is in the low hills bordering Big Bottom. At that locality the chief gravel bed appears to be from 30 to 50 feet above the bottom of the valley, although a bed of gravel was found near the center of sec. 29, resting in horizontal position upon the massive sandstone near the base of the Lewis shale, at about 150 feet above the valley. It is not at all improbable that these beds record different stages in the development of the present river channel.

ALLUVIUM

Alluvium occurs along the valleys of Yampa River and Williams Fork. Where the river cuts through the hard formations, the valleys are usually narrow, but where it crosses the Mancos shale or Lewis shale the valleys are wide and extensive flood plains have been developed. For example, where Yampa River traverses the broad belt of Mancos shale east of Juniper Hot Springs and also where it crosses the Lewis shale at Big Bottom it has built up a flood plain over a mile wide, but in many places along its meandering course through the Mesaverde deposits the valley is very little wider than the river. In a similar manner Williams Fork, where it established its course in the soft Mancos shale, has developed a flood plain that furnishes considerable valuable ranch land, whereas its valley through the Mesaverde is as a rule a narrow canyon. Plate III, *A*, shows the course of Williams Fork over its flood plain near the east edge of the Monument Butte quadrangle. The view shows how the stream has straightened its course by abandoning certain portions of its channel. The shape of such cut-offs long ago suggested

[15] White, C. A., U. S. Geol. and Geog. Survey Terr. Tenth Ann. Rept., p. 56, 1878.

the term "oxbow." In the foreground of the picture are two such cut-offs. The smaller one of the two was separated from the larger while the latter was a portion of the main channel, and the larger one was in turn cut off from the present channel at a somewhat later date.

IGNEOUS ROCKS

The only igneous rocks observed in the Axial and Monument Butte quadrangles are sheets of basalt capping many of the higher hills. They occur throughout the southeastern part of the Monument Butte quadrangle, as shown on the geologic map. Where the igneous rock is present the top of the hill is almost without exception covered by an abundance of irregular-shaped masses of basalt. Narrow, fingerlike projections from the main mass are seen in many of the side gullies, as for example, along the hillside east of Waddle Creek about a mile northwest of the Hart ranch. Part of the basalt is massive, and part of it is distinctly vesicular—that is, it exhibits numerous cavities formed by the escape of gases while the lava was cooling. In places almost the entire mass is vesicular.

Very little is known regarding the exact age of the basalt flows. They appear, however, to represent in part the northern extension of the great outflow of basalt which occurs so extensively throughout the White River Plateau, but they may have been erupted at intervals from the first flow, now represented by the Flat tops, down to very recent times. Some of the basalt must have originated before the glacial drift of that region was laid down, because pebbles of the basalt occur in the drift. The relation of the basalt to the Browns Park formation is apparently shown at Cedar Mountain, about 7 miles northwest of the northeast corner of the Monument Butte quadrangle. There the mountain, the main mass of which consists of the Browns Park formation, is capped by basalt. Overlying the basalt at one point is a bed of sandstone resembling in every way the sandstone below the basalt. This overlying sandstone was found on examination to contain numerous waterworn masses of the basalt, and the openings in the upper part of the vesicular basalt were filled with sand, indicating that the sandstone was deposited subsequent to the formation of the basalt and that the basalt of Cedar Mountain is contemporaneous with the Browns Park beds. The evidence for the subsequent deposition of the overlying sandstone is of importance for the reason that the basalt has heretofore been considered of more recent origin than the Browns Park formation.

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Chapter III.—STRUCTURAL GEOLOGY

Very few of the sedimentary rocks of the earth's crust are at present in exactly the same position in which they were originally deposited. Some have undergone very little deformation. Others have been tilted at high angles or even completely overturned. Under the stress of deformation the rocks may break, and the mass on either side of the fracture plane moves in obedience to the existing forces. Whether the beds merely bend or whether they yield by fracturing the attitude that they finally assume is known as structure. Upfolds are called anticlines or, if approximately equal in length and width, domes; downfolds are called synclines.

METHOD OF REPRESENTING STRUCTURE

Structure may be represented by structure sections or by structure contours. When a sufficient number of structure sections have been prepared they furnish an excellent basis for drawing structure contours. It is evident, therefore, that the more complete the field data the more accurate will be the representation of the structure.

Wherever a formation appeared to be in place and sufficient exposures made it possible to obtain accurate readings of strike and dip they were recorded in the field. Certain persistent sandstones were mapped by determining the altitude of numerous points on them in the valleys and on the ridges. The exact altitude of these points was determined by the topographer as the surface was sketched. Three determinations on the same bed—two on adjacent ridges and the third in the bottom of the intervening valley—furnish very accurate data for ascertaining the true strike and dip. The distance between the top of the Mancos shale and the top of the Trout Creek sandstone was determined at five places by measurement. Owing to the low angle of dip and the consequent great horizontal distance between the bottom and top of the outcrop belt measured, it was possible, especially on the north side of Axial Basin, to construct sections with a high degree of accuracy showing the structure for a considerable distance back from the outcrop. From these structure sections it was possible to determine the distance between the Trout Creek sandstone and the Twentymile sandstone and between the Trout Creek sandstone and the base of the Lewis shale, in the Axial quadrangle. These measurements determined under such favorable conditions were assumed to remain fairly constant throughout the Monument Butte quadrangle. On the south side of Axial Basin the structure sections were based partly upon recorded dips and partly upon two or more altitudes on the same sandstone or coal bed. The structure sections across the north limb of the Hart syncline, described under "Folds," were based entirely upon recorded dips. Those across the south limb were based upon recorded dips, upon several altitudes of the same coal beds, and upon the measured thickness of the Iles formation. The plotting of the structure along the east end of the syncline is the most hypothetical, recorded dips being the only data available.

In this field the structure contours are drawn on the top of the Trout Creek sandstone. Inasmuch as the top of the sandstone is seen only where it crops out along the hillsides its altitude at other points must be calculated from observed dips and especially from carefully prepared structure sections. These structure contours present a complete picture of the warped surface of the Trout

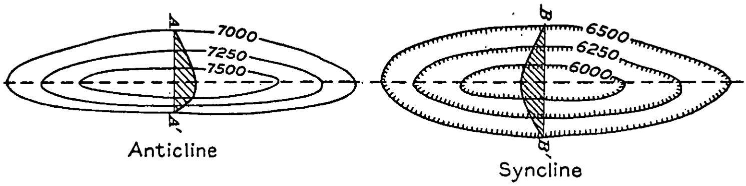


FIGURE 2.—Anticline and syncline represented by structure contours, and cross sections of each along lines marked

Creek sandstone, and as the beds both above and below this key rock are practically parallel with it they furnish a picture of the deformed surfaces of all the rocks of the region. In the first diagram shown in Figure 2 the contours close around a central area, and toward the axis each succeeding contour is 250 feet higher than the one lying on the outside. This means that the surface of the sandstone is arched, and as the contours are more closely spaced on one side than on the other the slope of the surface on that side is much steeper, as shown in the cross section along line A–A′. In the second diagram shown in Figure 2 the contour lines represent a fold in which the highest points are on the outside rim and the lowest point in the center. This is a trough or synclinal fold, and as the contours are about evenly spaced the slope of the sandstone toward the middle is about the same on both sides and the fold is symmetrical, as shown in the cross section along line B–B′.

On the map (Pl. XIX) there are two sets of contours. One set is structural and represents the deformed upper surface of the Trout Creek sandstone; the other set represents the surface of the land.

As both sets represent altitude above mean sea level the difference at any point within the outcrop of the Trout Creek sandstone between the altitude of the structure contour and the altitude of the surface contour is the depth of the sandstone below the surface. In places the structure contours are drawn outside of the area of the Trout Creek sandstone. In such places the sandstone is eroded, and its former position has been calculated from the rocks appearing at the surface. The difference in altitude between the structure contour and the surface contour shows the amount of rock below the top of the Trout Creek sandstone that has been removed by erosion.

FOLDS

Axial Basin anticline.—The dominant structural feature of these quadrangles is the great arch known as the Axial Basin anticline, a southeastward extension of the larger Uinta Mountain arch. The axis of this anticline extends from the Juniper Mountain dome, near the northwest corner of the Axial quadrangle, southeastward to the south side of the Monument Butte quadrangle. The valley known as Axial Basin, from which it is named, lies along its crest. About 2 miles west of Monument Butte the main anticline divides, forming two entirely separate anticlines. The broader one of the two continues southeastward and merges with a very extensive uplift, one of the principal topographic features of which is commonly known as Sleepy Cat Mountain; the other trends a little north of east and terminates at the Round Bottom syncline. The Axial Basin anticline is an unsymmetrical fold—that is, the dips on the south side of the axis are much steeper than those on the north side. It is therefore probable that the crest of the fold lies much nearer the south than the north side of Axial Basin. The prevailing dip of the Iles formation south of Axial Basin is from 20° to 35° as far east as Milk Creek. Thence southeastward the dip increases to about 60° near the south line of the Monument Butte quadrangle. Along the north side of the basin the beds are inclined much less steeply. The prevailing dips there are from 7° to 10°, or from 640 to 900 feet to the mile.

Juniper Mountain dome.—Upon the Axial Basin anticline, partly within the Axial quadrangle at the northwest corner, there is an independent dome referred to in some of the older reports as the Yampa upthrust. The prominent topographic feature resulting from this independent dome is commonly known as Juniper Mountain, and hence the dome itself will be referred to by that name. Like the Cross or Junction Mountain uplift, which bears a similar relation to the anticline farther west, it seems to have resulted either from the intensified application of the forces as a result of which the Axial Basin anticline was formed, or from some inherent weakness in the rocks that caused them to yield more readily to those forces. It is by far the most pronounced uplift in either of the two quadrangles, though so far as area is concerned, it is relatively insignificant. The body of the mountain is composed of hard red quartzite and sandstone, similar in all respects to the typical quartzite and sandstone that form the main core of the Uinta Range.

Round Bottom syncline.—From the great arch of the Axial Basin anticline the beds dip northeastward at the rate of about 750 feet to the mile into a shallow trough that is here named the Round Bottom syncline, from Round Bottom, on Yampa River about 5½ miles below the mouth of Williams Fork. This trough, which is deepest near the northwest corner of T. 6 N., R. 92 W., rises gradually southeastward as far as Fuhr Gulch. Thence the axis rises more steeply, bringing the Trout Creek sandstone to the surface near the top of Iles Mountain, a few miles west of the Hamilton ranch. The beds along the northeast limb of the syncline dip much more steeply than those along the southwest limb. For example, the uppermost beds of the Williams Fork formation along the southwest flank of the Bell Rock dome are inclined southwestward toward the axis of the Round Bottom syncline at angles of 7° to 13°. Similar beds in Bell Rock Gulch are inclined westward as steeply as 27°, and the Trout Creek sandstone exhibits a like dip 1½ miles west of Hamilton. The highest part of the synclinal trough is immediately southwest of the Hamilton dome, or, in other words, in the line of the axis of the northeast branch of the Axial anticline. From that point southward the limbs of the Round Bottom syncline separate rapidly, and the synclinal structure is believed to terminate at the Monument Butte fault.

Hart syncline.—The abrupt change in the attitude of the Mancos beds and those of the Iles formation from a strike of N. 70° W. and a dip to the northeast, south of the Monument Butte fault, to a strike of N. 45° E. and dip to the southeast, north of the fault, indicates the point of a structural trough, which, on account of its relation to Hart Gulch, has been termed the Hart syncline. As in the Round Bottom syncline, one limb of this fold dips much more steeply than the other. It is almost the universal rule in this area that steeper dips are exhibited by the north or northeast limbs of the synclines, and the Hart syncline is no exception to the rule. The beds constituting the southwest limb have a rather uniform dip of about 8°. North of Moody Gulch the beds dip 18°–21° SE.; at the Hart mine, near the mouth of Hart Gulch, the dip is 27°; and still farther southeast, at the east line of the quadrangle, the dip is as high as 40°. The axis of the syncline in its western part pitches steeply toward the east. About a mile southwest of the Hart ranch, however, it reaches its lowest position, and from that point it gradually rises toward the southeast. Among the steeper dips north of the synclinal axis are those along the southeast flank of the Hamilton dome, which, like the Bell Rock dome, is situated upon the axis of an anticline that almost parallels the Round Bottom syncline on the east.

Williams Fork anticline.—An anticline whose axis coincides with the course of Williams Fork for several miles will be referred to as the Williams Fork anticline. It pitches gently northwestward from the Hamilton dome to the structural saddle in sec. 14, T. 6 N., R. 92 W., immediately southeast of the Bell Rock dome, at the rate of about 450 feet to the mile. From that point northwestward the axis rises to the crest of the Bell Rock dome. On the northeast limb of this fold the dips are low, generally not exceeding 10°, but the beds in the vicinity of Bell Rock Gulch, like those southeast of the Big Bend in Yampa River, are inclined west and southwest at comparatively steep angles. For example, the dip of the Trout Creek sandstone about 1½ miles west of the Hamilton ranch is 13° W. Toward the northwest the dip rapidly increases to 28°. Along the west slope of the high ridge in secs. 25, 35, and 36, T. 6 N., R. 92 W., the recorded dips range from 16° to 33°, and the massive sandstone at the top of the Williams Fork formation in the Bell Rock dome dips southwest at an angle of about 13°.

Bell Rock dome.—The Williams Fork anticline plunges northwestward, but in the northern part of T. 6 N., R. 92 W., it rises again to form the elliptical Bell Rock dome. The center of the fold has been eroded to the series of white sandstones capped by coal beds at the top of the Williams Fork formation. The strikes and dips of these sandstones and coal beds show the dome structure clearly, the angle of dip ranging from 13° on the west to 5° on the east side. This dome takes its name from an isolated mass of sandstone on the west side of Bell Rock Gulch, which has been carved by erosion into a form somewhat resembling a bell.

Hamilton dome.—Upon the Williams Fork anticline, in line with the northeast branch of the Axial anticline, is a more or less perfect dome that has been referred to as the Hamilton or Moffat dome. It is near the center of the Mancos shale area about 2 miles south of the Hamilton ranch. The strikes and dips determined at different points on the ledge of thin-bedded sandstone in the Mancos shale about 800 feet below the base of the Iles formation show clearly the presence of a dome. Here, as in all other similar uplifts in this area, the steeper dips lie south or southwest of the axis.

Big Bottom syncline.—The rocks dip northeastward from the crest of the Williams Fork anticline at the rate of about 800 feet to the mile. They dip into the face of the Williams Fork Mountains and form the back slope of this range as they descend into an open structural trough called the Big Bottom syncline. North of the Williams Fork Mountains the trend of the syncline is nearly due west, but as the fold crosses Yampa River it turns nearly due north on the east side of the Bell Rock dome. The dip toward the axis of the syncline is nearly the same on both sides, ranging generally from 7° to 15°.

Breeze anticline.—The axis of the Breeze anticline extends from the northeast corner of T. 6 N., R. 91 W., in a southeasterly direction, passing a short distance south of Breeze Mountain. This anticline is more prominent in the Daton Peak quadrangle, on the east. In the Monument Butte quadrangle it has the form of a gentle arch that is more or less in line with the fault occurring in the northern part of T. 6 N., R. 91 W. (p. 35). In the eastern part of this township the dips north and south of the anticlinal axis range from 5° to 7°. South of the Walker mine, in T. 6 N., R. 90 W., the rocks dip about 4° W., but farther east, in the vicinity of Breeze Mountain, the beds north of the anticlinal axis dip as much as 20° N.

Beaver Creek anticline.—Between the steep north limb of the Hart syncline on the eastern margin of the Monument Butte quadrangle and the northward-dipping coal-bearing formation in the Williams Fork Mountains is an extensive area of Mancos shale denoting the presence of a broad anticline, the extreme northwestern point of which extends into this quadrangle. From a study of the rocks up the valley of Williams Fork, it is known to be an anticline of considerable magnitude and to coincide in a general way with that valley. In accordance with the terminology of Plate 1 of Bulletin 24 of the Colorado Geological Survey, this fold is called the Beaver Creek anticline.

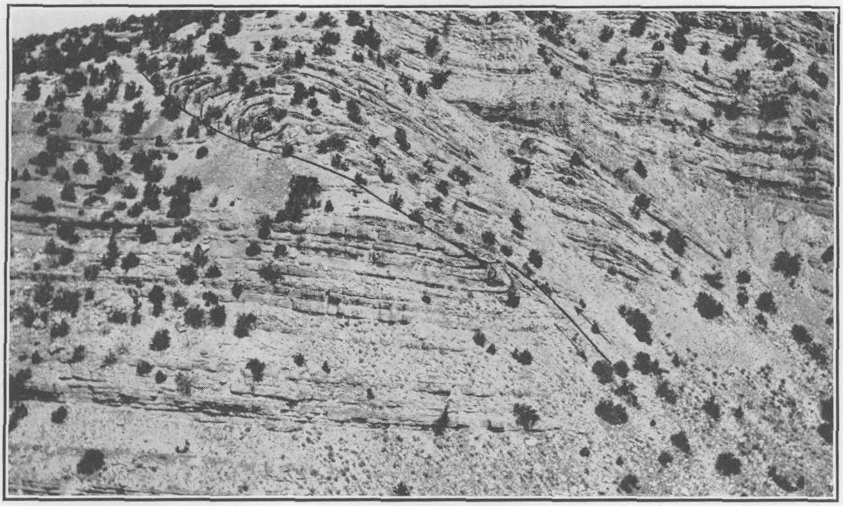
Badger Creek syncline.—The Beaver Creek anticline in general trends northwestward and if prolonged would cross the Williams Fork anticline near Hamilton. It dies down, however, on approaching the Williams Fork anticline, and the two are separated by a slight synclinal fold, which crosses Badger Creek near its mouth and is named the Badger Creek syncline. The synclinal structure of this fold is well shown by the basal sandstones of the Iles formation, which dip eastward and pass below Williams Fork about 1½ miles east of the Hamilton ranch. These same beds rise from water level a few hundred feet northeast of the Hamilton mine. Southwest of the synclinal axis the beds rise gently toward the crest of the Hamilton dome, and on the opposite side they rise toward the axis of the Beaver Creek anticline. This syncline is just deep enough to bring the coal-bearing rocks down below the river level and thus make a connection between the coal field north of Williams Fork and the Hart syncline south of that stream. The combination of this minor syncline with the Hart syncline results in a widening of the Hart syncline in its central portion.

Collom syncline.—On the southwest side of the Axial Basin anticline the rocks dip steeply southwest into a well-defined syncline, which lies from 2 to 3 miles within the coal field of the Danforth Hills and parallel with the edge of the upland which marks that field. It crosses Collom Gulch and passes near the Collom ranches and is therefore called the Collom syncline. Like most other synclinal folds of the Axial and Monument Butte quadrangles this syncline has much steeper dips on the north side of the axis than on the south side. The dips north of the axis as far east as Milk Creek range from 20° to 30°. Thence eastward they rapidly increase to about 60° near the south line of the Monument Butte quadrangle. South of the axis the beds dip north at a very low angle, ranging from 5° to 7°. The Collom syncline has been modified to some extent by cross folds. The location of one cross syncline at Morgan Gulch and another at Milk Creek is brought out in the geologic map by the structure contours, and also by certain portions of the escarpment of Mesaverde rocks projecting into the Axial Basin. The combination of the Morgan Gulch transverse depression with the Collom syncline, the axes of which are approximately at right angles, results in a structural basin that occupies a considerable part of T. 4 N., R. 94 W.

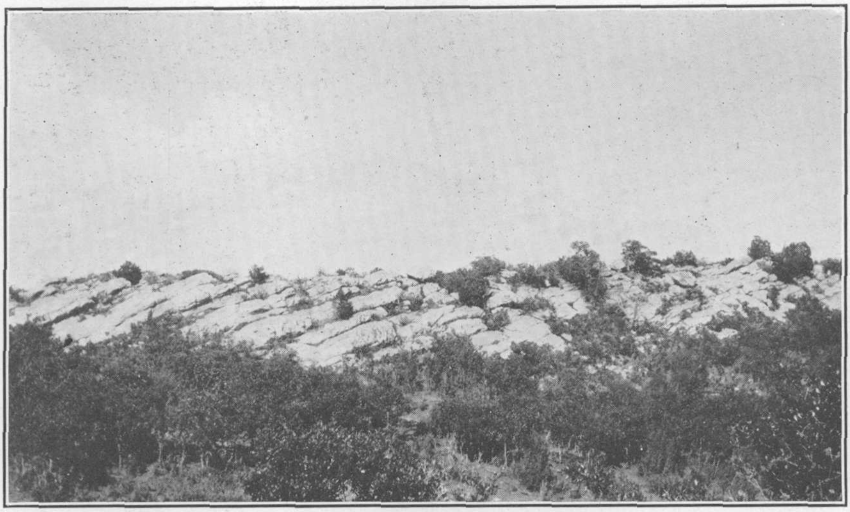
Elkhorn syncline.—The prominent point of the upland east of Milk Creek marks the point of a rather prominent syncline that extends from the southwestern part of the Monument Butte quadrangle in a direction a little west of south across the Danforth Hills, near the east side of the Meeker quadrangle. The axis of that portion of the syncline included in the Monument Butte quadrangle pitches steeply toward the south. In the Meeker quadrangle the synclinal axis lies for some distance along the course of Elkhorn Creek, and for that reason the name Elkhorn is applied to the fold.

FAULTS

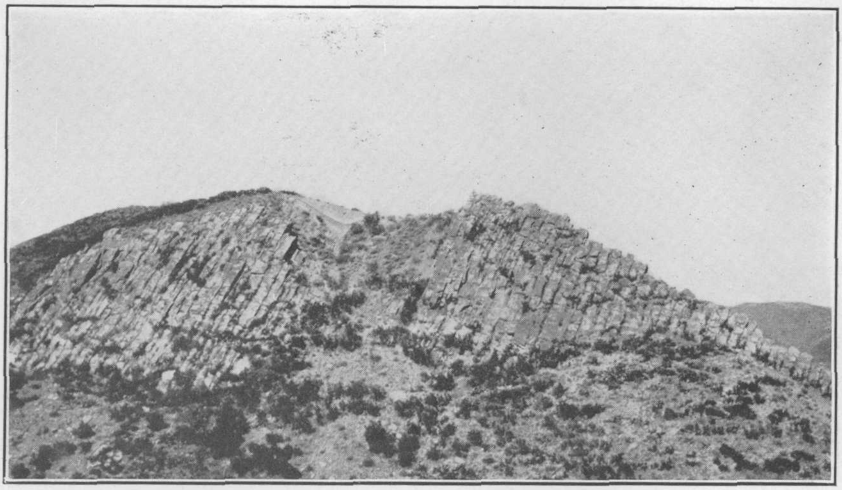
In general, the rocks of the Axial and Monument Butte quadrangles have not been stressed sufficiently to cause them to break. A few normal faults have been observed within these quadrangles, however, and several thrust faults are present in the north wall of the canyon where Yampa River cuts through Juniper Mountain. (See Pls. IV and V, *A*.) The mode of development of a normal fault is illustrated in Figure 3. A represents conditions before the



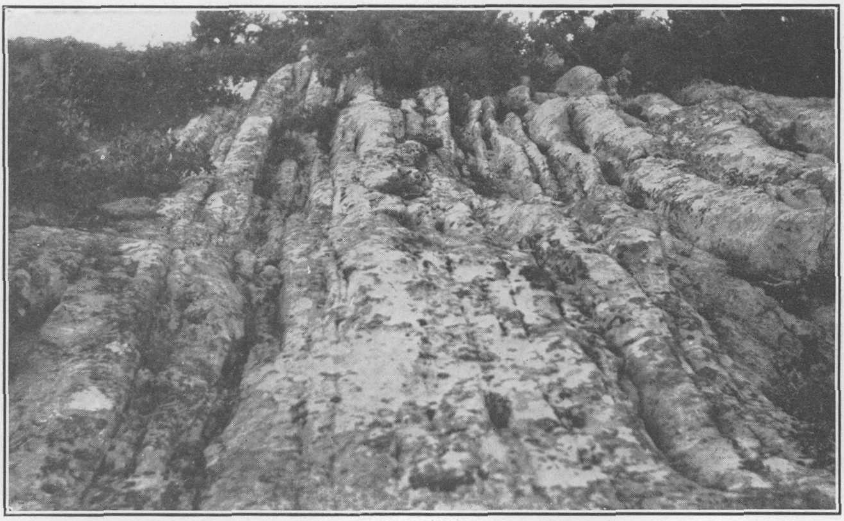
A. NORTH SIDE OF YAMPA RIVER CANYON AT JUNIPER MOUNTAIN, SHOWING OVERTHRUST FAULT IN CARBONIFEROUS BEDS



B. HIGHLY JOINTED MASSIVE WHITE SANDSTONE OF THE WILLIAMS FORK FORMATION IN THE NW. ¼ SEC. 22, T. 2 N., R. 94 W.



A. HIGHLY JOINTED SANDSTONE IMMEDIATELY ABOVE THE TROUT CREEK SANDSTONE MEMBER OF THE ILES FORMATION EAST OF THE GILBERT WESSON MINE, SEC. 30, T. 2 N., R. 92 W.



B. HIGHLY JOINTED MASSIVE WHITE SANDSTONE OF THE ILES FORMATION, T. 4 N., R. 91 W.

fault occurs. When the rocks are under tension, they will part along joint planes, as shown in B, and one side (g'–h) will settle down by sliding along the joint fracture (c–d) until it comes to rest (from e to h). The horizontal space formerly occupied (g–f) will be elongated to g'–f'. Several faults of this type have been discovered in the Monument Butte quadrangle. They may have been formed at the same time that the folds were produced, but it is probable that they originated at a later date.

The mode of development of thrust faults is illustrated by Figure 4. A represents the rocks before faulting or folding occurred, being subjected to horizontal compression, as indicated by the arrows. Under these compressive forces the rocks will begin to bend, and if the force is greater from one side than from the other there is produced what is commonly called an overturned fold, shown in B. If the compression is continued the folded rocks will break along an inclined plane (c–d), and one portion will be thrust over the other along this fracture (c'–d', fig. 4, C).

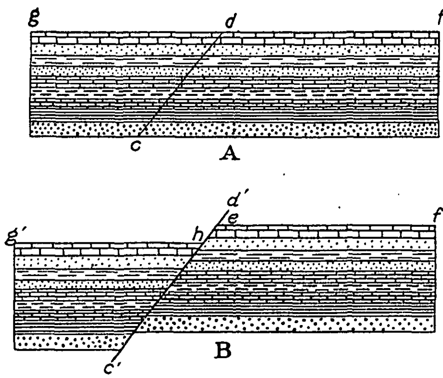


FIGURE 3.—Normal fault

The entire structure as shown in the figure is seldom observed in nature, because while the rocks are being folded and faulted they are being worn down by erosion and finally they are reduced to the present surface, as shown in Figure 4, D.

One of the normal faults observed in this area was found north of a small anticline or elongated dome whose major axis extends through secs. 13, 14, 15, 16, and 8, T. 6 N., R. 91 W. The detailed work in this township was done by a party under the supervision of John Allen Davis, who says:

> The steepest dips, which range from 18° to 20°, are on the south side of the dome. On the north side they vary from 5° to 10°. A fault having a maximum throw of perhaps 200 feet was found a short distance north of the crest of the anticline and traced several miles in an east-west direction approximately parallel to the major axis. Near the highest point of the dome the downthrow of the fault is on the south side, but a short distance in either direction the downthrow is on the other side of the fault.
>
> The amount of displacement is about 200 feet.

A small eastward-trending fault was mapped through the center of sec. 17, T. 6 N., R. 90 W., by J. B. Eby. The downthrow, which amounts to 80 to 100 feet, is on the north side and cuts off the ledge of massive white sandstone that crops out in the ridge to the south.

The Monument Butte fault extends a few degrees north of east from a point near the center of sec. 26, T. 4 N., R. 92 W., for a distance of 5 miles. The fault coincides with the second gully south of Monument Butte, where it has a throw of about 800 feet; east of Deer Creek it is believed to coincide more or less closely with Moody Gulch. The displacement seems to have occurred mainly along the axis of the Hart syncline. The amount of displacement along the fault may have diminished to practically nothing at the Trout Creek sandstone, or the movement may have been taken up, in part, by slipping of the soft sandy shale beds in the Mesaverde group. West of Monument Butte the movement seems to have been rapidly taken up by bending in the soft beds of the Mancos shale.

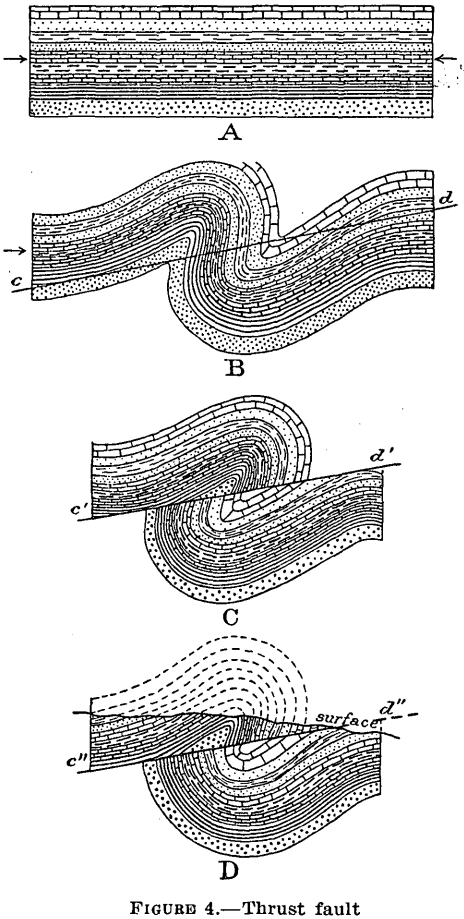


FIGURE 4.—Thrust fault

Two normal faults separated by a downthrown block are visible in the Trout Creek sandstone rim near the south quarter corner of sec. 33, T. 4 N., R. 92 W., and may possibly connect with the Monument Butte fault. A large normal fault, with downthrow toward the south, lies about 1½ miles north of the Monument Butte fault and nearly parallel to it, extending from the east quarter corner of sec. 19, T. 4 N., R. 92 W., to a point southeast of the Hamilton dome, and smaller normal faults are present north of the Bell Rock dome and along the road north of the Walker mine in sec. 17, T. 6 N., R. 90 W.

In each of the thrust faults observed in the Yampa gorge near Juniper Mountain the beds on the east side of the fault plane are thrust up over those on the west side, as shown in Plate IV, *A* and *B*, and Plate V. Plate IV, *B*, shows the easternmost of the three faults. At one point the beds on the downthrust side of the fault are closely contorted and forced back upon themselves, owing to the overthrust-ing of the beds from the east. Plate IV, *A*, shows a fault farther west cutting lower beds. The beds on the upthrust side of the fault plane can be traced continuously from the top of the canyon wall down to the river. On the downthrust side of the fault about 30 feet of the strata end abruptly at the fault plane. In the faults shown in Plate IV the direction of the fault plane is so near that of the bedding that the amount of vertical displacement is small in comparison with the amount of movement along the fault plane. Plate V, *A*, shows another fault a short distance west of the highest point in Little Juniper Mountain. Here the fault plane occurs at an angle of about 30° with the bedding. In this fault, as in that shown in Plate IV, *B*, the beds on the left or downthrust side of the fault plane are closely contorted and forced upward and to the left, while those on the right or upthrust side are bent downward and to the right, strongly indicating that the movement took place as indicated by the arrows. Owing to the impossibility of correlating the beds on the west with those on the east side of the fault plane, the total vertical and horizontal displacement could not be determined.

JOINTS

Stresses applied to rocks that are more or less homogeneous and under considerable load, if evenly distributed, are likely to be relieved by very slight movement along an almost infinite number of parallel joint planes. Jointing is conspicuous in many localities within and near the Axial and Monument Butte quadrangles, and intense development of parallel joints seems to have occurred where a sandstone has been tilted at a high angle, especially where the strike gradually changes, or, in other words, where the outcrop makes a sweeping curve. Plate VI shows exposures of sandstone at two different localities where these conditions exist. In each locality the sandstone is dipping toward the observer, very steeply in *A* but at a low angle in *B*. Plate V, *B*, shows a highly jointed sandstone in which the strike abruptly changes about 90°. Wherever the sandstones have been cut by a system of parallel joints the associated coal beds have probably been affected in a similar manner, and this condition will doubtless have a strong influence on the methods to be employed in keeping the mine safe while the coal is being mined.

Chapter IV.—COAL

DISTRIBUTION

As the coal beds occur in the Mesaverde group, they will be found only where the beds of that group crop out or lie below the surface. The largest area of coal-bearing rocks is in the northern part of the quadrangles, extending from the east margin as far west as the line between Rs. 93 and 94 W. The next largest coal-bearing area is in the southwestern part, extending as far east as Thornburgh Mountain. The third and smallest area is the Hart Basin, in the southeast corner of the Monument Butte quadrangle. About 295 square miles of the Axial and Monument Butte quadrangles is underlain by the Mesaverde group, but the Williams Fork formation—the abundantly coal-bearing portion of the group—is confined to a much smaller area.

DEPTH

The author's interpretation of the structure indicates that most of the coal lies fairly near the surface. The approximate depth to the top of the Trout Creek sandstone member of the Iles formation, or, in other words, the base of the principal group of coal beds (Fairfield) is shown by the structure contours. They indicate that along the axis of the Collom syncline south of Axial Basin the base of the principal group of coal beds may be reached in the bottom of the gulches at depths ranging from 900 to 1,200 feet. In Hart Gulch, which is transverse to the axis of the Hart syncline, the Trout Creek sandstone probably does not lie much in excess of 1,000 feet below the surface. On the north side of Axial Basin the Trout Creek sandstone is believed to have the greatest depth along the axes of the Round Bottom and Big Bottom synclines, but even here it is, in all probability, not much more than 3,000 feet below the surface.

ACCESSIBILITY

The natural routes for the construction of railroads through the Yampa coal field are the valleys of Yampa River and its main tributary, Williams Fork. It is safe to assume that most of the coal mined in the Axial and Monument Butte quadrangles in the next 50 years will be taken out over railroad lines in these valleys, and all statements here made regarding the best points of approach and the best methods of mining are based on that assumption. The northeast corner of the Monument Butte quadrangle is about 2¾ miles southeast of Craig, the present western terminus of the Denver & Salt Lake Railroad. The Saratoga & Encampment Railway has been completed from Walcott, on the Union Pacific, to Encampment, Wyo., only about 14 miles north of the Colorado line. The Colorado, Wyoming & Eastern Railway has been completed 111 miles southwestward from Laramie, Wyo., on the Union Pacific, to Coalmont, Colo., and is reported to have made surveys in the direction of the Yampa coal field. The Union Pacific Railroad is also reported to have made three surveys from Wamsutter, on the main line, south to Craig. It seems probable, therefore, that there will eventually be railway connection between the main lines of the Union Pacific and the Denver & Salt Lake railroads by the construction of one of the branch lines mentioned. This will enable the coals of northwestern Colorado to enter into active competition with those from Rock Springs and Hanna, Wyo. Preliminary surveys have also been made for the extension of the Denver & Salt Lake Railroad west from Craig to Provo, Utah, following a line from half a mile to 2½ miles north of the Axial and Monument Butte quadrangles. The extension of this line to Salt Lake City and on to the Pacific coast should enable the Colorado coals to compete more readily with other western coals. It seems probable, however, that the principal future demand for the coal of this field will originate east of the mountains, and the completion of the Moffat tunnel, now under construction, will remove one great obstacle to the profitable exploitation of the coals of the Yampa field.

Within the Axial and Monument Butte quadrangles the valleys of Yampa River and Williams Fork and of their tributaries afford unusually favorable opportunities for the construction of branch lines of the Denver & Salt Lake Railroad. Between the 107° 30′ meridian, which farther south forms the east line of the Monument Butte quadrangle, and the mouth of Williams Fork, a branch of the railroad built along Yampa River would have a grade of 0.16 per cent. Between the point where Williams Fork enters the Monument Butte quadrangle and its mouth there would be a grade of about 0.4 per cent. It follows, therefore, that all the coal along Yampa River between the main line of the railroad and Williams Fork, as well as that along Williams Fork, could be hauled out to the main line over a branch line whose grade need not exceed 0.16 per cent. The empty cars could easily be hauled up the 0.4 per cent grade from Yampa River up Williams Fork. The moving of the loaded cars on the down trip would require practically no motive power as far as the mouth of Williams Fork and very little from that point out to the main line of the Denver & Salt Lake Railroad. The thick coal beds in the Hart syncline south of Hamilton could be reached either by a spur extending up Morapos and Deer creeks or by one extending south from Williams Fork up Waddle Creek. From the Hamilton ranch to the junction of Morapos and Deer creeks the valley rises with a grade of 0.75 per cent. The gradient of Deer Creek is much steeper, rising at about a 2 per cent grade. From Williams Fork south to the Hart mine the valley of Waddle Creek also rises at about a 2 per cent grade.

Yampa River, from the mouth of Williams Fork to that of Milk Creek, falls at the rate of about 5 feet to the mile. Throughout this distance its meanders have been established in rocks either including the Fairfield group of coal beds or in other beds closely associated with that group. Between the mouth of Milk Creek and the base of the Fairfield coal group near the Shafer mine, on the south side of Axial Basin, the valley of Milk Creek rises with about a 0.7 per cent grade.

If it is desirable to develop the coals farthest west—for example, near the Mount Streeter mine, on Good Spring Creek, or on Jubb Creek or Morgan Gulch—railroad spurs built from Yampa River along Milk and Good Spring or Milk and Jubb creeks would have, respectively, grades of 1.0 and 1.2 per cent.

The Fairfield group of coal beds along Morgan Gulch could be reached by the same route and by like grades, but if the Morgan Gulch coal was to be carried westward it could also be reached by means of a spur from Yampa River up Morgan Gulch, the average grade of which would not exceed 1 per cent.

It seems probable that the coal beds in Horse Gulch and Sand Spring Gulch, north of Yampa River, could be reached by a short spur extending south from the proposed route of the main line of the Denver & Salt Lake Railroad at the head of Sand Spring Gulch. The average grade of this spur would not be much in excess of 1 per cent.

To summarize, it appears that practically all the routes above mentioned are feasible. On the few that involve grades as high as 2 per cent the principal haulage would be down the grade. By means of these branch lines, most of which would not require grades exceeding 1 per cent, the bulk of the coal of the Axial and Monument Butte quadrangles could be brought to the main line, and thence to market either to the east or the west. The occurrence of the coal and the most favorable points of access to it are set forth in the detailed description of townships.

METHODS EMPLOYED IN MAPPING THE COAL BEDS

In this field it was necessary to modify the method ordinarily employed by parties of the United States Geological Survey engaged in mapping coal-bearing areas, owing to the difficulty in tracing individual coal beds of these quadrangles and also owing to the extent to which these coals have burned along their outcrops—as, for example, on the north side of the great meanders of Yampa River, where 700 to 800 feet of brick-red sandstone and baked shale are laid bare along the steep slopes, with scarcely a foot of coal showing, although the rocks here exposed comprise a portion of the great coal-bearing zone immediately above the Trout Creek sandstone. Fortunately, there are in this area certain sandstones that bear a definite relation to the different groups of coal beds, and these were used as key sandstones in the mapping. The two most conspicuous key sandstones, the Trout Creek and Twentymile, are fully described in connection with the Mesaverde group in the chapter dealing with stratigraphy. The Trout Creek sandstone underlies the Fairfield or principal group of coal beds. On the south side of Axial Basin this sandstone was traced almost continuously from the southeast corner of sec. 4, T. 3 N., R. 92 W., to the northwest corner of T. 4 N., R. 94 W., and thence south along the steep slope on the east side of Maudlin Gulch. On the north side of the basin the same sandstone was traced almost continuously from a point near the northeast corner of T. 6 N., R. 94 W., in a southeasterly direction over the ridges and down into the gulches as far east as the east line of the Monument Butte quadrangle. The Trout Creek sandstone was again recognized at the base of the principal group of coal beds along the south side of the Hart syncline. The Twentymile sandstone was traced almost continuously from a point near the southeast corner of T. 6 N., R. 93 W., eastward to the junction of Williams Fork and Yampa River and was located at many points from Yampa River eastward.

The best exposures of coal occur in the gulches, and in the course of the mapping the beds were measured and their stratigraphic relations determined as accurately as possible under the circumstances. Wherever possible the measurement of the entire group of beds was tied to one of the key sandstones, with the results shown in Plate XVIII. The detailed sections of the individual coal beds, as well as of numerous coal beds that were not tied to the key sandstones, are shown in the plates of coal sections for the several townships.

QUALITY OF THE COAL

SAMPLING AND ANALYZING

The ordinary means of estimating the value of a coal is to study its chemical composition as shown by analysis and to determine its heating or fuel value by laboratory tests made especially for that purpose.

Many tests of the relative values of coals were made in 1904,[16] and many analyses of coals have been published since that date. The subject of the chemical analysis of coal is, however, altogether too technical in its nature to be set forth in this report.

Analyses are of two kinds, proximate and ultimate. In the proximate analysis the chemist determines the percentage of moisture, volatile matter, fixed carbon, sulphur, and ash. In the ultimate analysis he determines the proportion of carbon, hydrogen, oxygen, nitrogen, sulphur, and ash. In the commercial valuation of coals a proximate analysis and a calorimeter determination are usually sufficient. The percentages of moisture, volatile matter, fixed carbon, and ash, together with the calorific value, are of chief importance to the engineer, coal dealer, or power-plant superintendent.

The calorific power or heating value is the total amount of heat developed by the complete combustion of a certain amount of fuel; this is expressed in the analyses as the number of heat units generated by 1 pound of coal. In the metric system of measurements the heat unit is the calorie; in the English system it is the British thermal unit. The calorie is the amount of heat required to raise the temperature of 1 gram of water 1° C. when the water is at the temperature of maximum density, 3.9° C. (39.1° F.). This unit, generally called the French calorie or gram-calorie, is not used for coal analyses. The pound-calorie, used in the following tables, is the heat required to raise 1 pound of water 1° C.; the British thermal unit is the amount required to raise 1 pound of water 1° F. The pound-calorie, therefore, bears the same ratio to the British thermal unit that the degree Centigrade bears to the degree Fahrenheit—1.8:1. By recent practice the temperature of the water is assumed to be 62° or 63° F. instead of the temperature of maximum density.

ANALYSES

The table given below includes analyses of samples from most of the mines of the Meeker, Axial, and Monument Butte quadrangles and, for comparison, average analyses of several samples of coals from surrounding fields.

[16] Preliminary report of the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: U. S. Geol. Survey Bull. 261, 172 pp., 1905. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: U. S. Geol. Survey Prof. Paper 48, in 3 parts, 1492 pp., 13 pls., 1906. Holmes, J. A., Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: U. S. Geol. Survey Bull. 290, 240 pp., 1906. Lord, N. W., Experimental work conducted in the chemical laboratory of the United States Geological Survey fuel-testing plant at St. Louis, Mo., Jan. 1, 1905, to July 31, 1906: U. S. Geol. Survey Bull. 323, 49 pp., 1907.

Each analysis is given in four forms designated A, B, C, and D. A is the analysis of the sample "as received," B the analysis of the "air-dried" sample, C the analysis of the moisture-free" or "dry" coal, and D that of "moisture and ash free" coal. The coal received at the laboratory is air dried and then analyzed, and the analyses in forms A, C, and D are calculated from the analysis of the air-dried coal; C and D represent theoretical conditions not existing in nature.

Analyses of coal samples from the Axial and Monument Butte quadrangles and neighboring coal fields

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

Axial and Monument Butte quadrangles

Mine	Formation	Location				No. on map	Laboratory 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
Mount Streeter No. 10 mine (Joseph Collom).	Williams Fork.	NE.	2	3	93	598	14543	2.1	A	11.9	[a]40.6	45.3	2.2	0.32	----	----	----	----	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	----	----	----	----	7,325	13,180
									D	----	47.3	52.7	----	.37	----	----	----	----	7,510	13,520
Do	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	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
Do. (composite of samples 93309 and 93310).	do	----	----	----	----	----	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
Hart mine	do	----	----	4	[b]90	187	17782	1.8	A	11.9	36.8	45.6	5.72	.55	5.83	64.36	1.40	22.14	6,240	11,230
									B	10.2	37.5	46.5	5.83	.56	5.73	65.56	1.43	20.89	6,355	11,440
									C	----	41.7	51.8	6.49	.62	5.12	73.03	1.59	13.15	7,080	12,750
									D	----	44.6	55.4	----	.66	5.48	78.10	1.70	14.06	7,575	13,630
Roby mine	do	----	----	4	[b]91	220	17840	2.2	A	14.2	36.3	45.3	4.18	.59	5.82	63.54	1.22	24.65	6,100	10,980
									B	12.2	37.1	46.4	4.28	.60	5.70	64.98	1.25	23.19	6,235	11,230
									C	----	42.2	52.9	4.87	.69	4.94	74.06	1.42	14.02	7,105	12,790
									D	----	44.4	55.6	----	.73	5.19	77.85	1.49	14.74	7,470	13,450
Shafer mine	do	NE.	31	4	92	249	14909	4.6	A	13.5	38.5	44.1	3.89	.59	5.80	63.11	1.23	25.38	6,125	11,020
									B	9.3	40.4	46.2	4.08	.62	5.54	66.15	1.29	22.32	6,420	11,550
									C	----	44.5	51.0	4.50	.68	4.97	72.97	1.42	15.46	7,080	12,750
									D	----	46.6	53.4	----	.71	5.20	76.41	1.49	16.19	7,415	13,350

Ed. Collom mine	do	SW.	13	4	94	26	14529	2.0	A	14.8	[a] 38.7	42.7	3.82	.66	5.87	61.49	1.17	26.99	5,990	10,780
									B	13.1	39.5	43.5	3.90	.67	5.77	62.74	1.19	25.73	6,110	11,000
									C	------	45.4	50.1	4.49	.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
Badger Creek or Hamilton mine.	Iles	------	24	5	[b] 91	391	9136	9.7	A	12.5	[a] 29.6	48.1	9.79	.84	5.56	60.40	1.26	22.15	5,920	10,650
									B	3.1	32.9	53.2	10.84	.93	4.96	66.89	1.40	14.98	6,555	11,800
									C	------	33.9	54.9	11.19	.96	4.76	69.01	1.44	12.64	6,760	12,170
									D	------	38.2	61.8	------	1.08	5.36	77.71	1.62	14.23	7,615	13,700
Haubrich mine	Williams Fork.	SW.	29	6	91	465	9137	13.8	A	17.7	[a] 30.4	48.1	3.78	.51	5.94	59.61	1.51	28.65	5,740	10,340
									B	4.6	35.2	55.8	4.38	.59	5.12	69.18	1.75	18.98	6,660	11,990
									C	------	36.9	58.5	4.60	.62	4.83	72.50	1.84	15.61	6,980	12,570
									D	------	38.7	61.3	------	.65	5.06	75.99	1.93	16.37	7,315	13,170
Ratcliff mine	do	SE.	31	6	91	444	9138	10.2	A	13.5	[a] 35.4	47.9	3.18	.34	5.82	62.94	1.20	26.52	6,115	11,010
									B	3.7	39.5	53.3	3.54	.38	5.22	70.09	1.34	19.43	6,810	12,260
									C	------	41.0	55.3	3.68	.39	4.99	72.73	1.39	16.82	7,070	12,720
									D	------	42.6	57.4	------	.40	5.18	75.51	1.44	17.47	7,340	13,210
Walker mine	do	SE.	17	6	90	442	22725	4.8	A	16.8	36.4	41.9	4.9	.81	------	------	------	------	5,855	10,540
									B	12.6	38.2	44.1	5.1	.85	------	------	------	------	6,150	11,070
									C	------	43.8	50.4	5.8	.97	------	------	------	------	7,040	12,670
									D	------	46.5	53.5	------	1.03	------	------	------	------	7,475	13,460
Do	do	SE.	17	6	90	------	92668	5.2	A	15.3	31.8	48.9	4.0	.7	5.9	61.3	1.6	26.5	5,935	10,680
									B	10.6	33.5	51.7	4.2	.7	5.6	64.7	1.7	23.1	6,255	11,260
									C	------	37.5	57.8	4.7	.8	4.9	72.3	1.9	15.4	7,000	12,600
									D	------	39.4	60.6	------	.9	5.2	75.9	2.0	16.0	7,350	13,230
Joe Knez mine	do	SE.	20	6	90	------	92667	6.1	A	16.2	31.8	47.8	4.2	.5	------	------	------	------	5,790	10,420
									B	10.8	33.8	50.9	4.5	.6	------	------	------	------	6,165	11,100
									C	------	37.9	57.1	5.0	.6	------	------	------	------	6,910	12,440
									D	------	39.9	60.1	------	.6	------	------	------	------	7,280	13,100
Miller mine	do	SE.	17	6	90	------	92666	7.0	A	16.6	30.8	48.1	4.5	.7	------	------	------	------	5,820	10,480
									B	10.3	33.1	51.7	4.9	.8	------	------	------	------	6,260	11,270
									C	------	36.9	57.7	5.4	.9	------	------	------	------	6,980	12,560
									D	------	39.0	61.0	------	.9	------	------	------	------	7,380	13,280
Battle Era mine (formerly mine of David Morgan).	do	NW.	14	4	94	47	14528	1.3	A	14.7	[a] 36.6	42.6	6.12	.89	5.54	59.06	1.33	27.06	5,635	10,140
									B	13.6	37.1	43.1	6.20	.90	5.47	59.84	1.35	26.24	5,710	10,270
									C	------	42.9	49.9	7.17	1.04	4.58	69.21	1.56	16.44	6,500	11,880
									D	------	46.3	53.7	------	1.12	4.93	74.55	1.68	17.72	7,110	12,800
Moore mine	do	------	16	5	[b] 90	300	9134	10.0	A	12.4	34.1	48.0	5.47	.50	5.54	62.34	1.32	24.83	6,170	11,110
									B	2.7	37.9	53.3	6.08	.55	4.92	69.27	1.47	17.71	6,855	12,340
									C	------	38.9	54.8	6.25	.57	4.76	71.19	1.51	15.72	7,045	12,690
									D	------	41.5	58.5	------	.61	5.07	75.94	1.61	16.77	7,515	13,530

[a] By modified method. [b] Unsurveyed.

Analyses of coal samples from the Axial and Monument Butte quadrangles and neighboring coal fields—Continued

Axial and Monument Butte quadrangles—Continued

Mine	Formation	Location				No. on map	Laboratory 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
Wise mine	Williams Fork.		6	5	[b] 91	316	9135	10.7	A	13.3	33.5	45.8	7.40	0.51	5.66	60.27	1.05	25.11	5,835	10,510
									B	2.9	37.5	51.3	8.29	.57	5.01	67.49	1.18	17.46	6,535	11,760
									C		38.6	52.9	8.53	.59	4.83	69.50	1.21	15.34	6,730	12,110
									D		42.2	57.8		.65	5.28	75.98	1.32	16.77	7,355	13,240
Producers No. 1 mine	Iles	SE.	9	6	91	490	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	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
Do. (composite of samples Nos. 93306 and 93307).	do						92308	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	do	SE.	9	6	91	513	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	do	SE.	9	6	91	487	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

Neighboring coal fields

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 Coa 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
Black Diamond mine	Iles		15	1	94		12776	2.5	A	10.8	37.2	44.0	7.98	.49	5.52	63.98	1.32	20.71	6,230	11,220
									B	8.5	38.2	45.1	8.18	.50	5.37	65.62	1.35	18.98	6,390	11,510
									C		41.8	49.3	8.95	.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
Meeker Coal Co.'s mine	do	NW.	22	1	94		12426	6.6	A	12.7	35.9	45.6	5.83	.44	5.69	64.92	1.25	21.87	6,330	11,390
									B	6.5	38.5	48.8	6.24	.47	5.31	69.51	1.34	17.13	6,775	12,200
									C		41.1	52.2	6.68	.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
Casper Webber mine, Dunkley Canyon, Dunkley, Colo. (grab sample).			2	4	87		30862	3.3	A	13.2	35.8	44.9	6.41	.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	9,560
									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
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	7,275	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	.63	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

Analyses of coal samples from the Axial and Monument Butte quadrangles and neighboring coal fields—Continued

Neighboring coal fields—Continued

Mine	Formation	Location				No. on map	Laboratory 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
Hanna, Wyo. (average of 2 analyses).	------	------	------	------	------	------	------	2.2	A	11.5	41.0	40.7	6.80	0.37	5.68	61.84	0.93	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

14543. 400 feet northwest of mine mouth.
17782. 100 feet N. 39° W. of mine mouth.
17840. 75 feet N. 56° W. of mine mouth.
14909. 189 feet northeast of mine mouth.
14529. 75 feet northwest of mine mouth.
14528. 130 feet northeast of mine mouth.
9134. 140 feet northwest of mine mouth.
9135. At end of an entry 250 to 275 feet long.
9136. At end of an entry 150 feet long.
9137. At end of an entry about 70 feet long.
9138. At end of a tunnel 60 feet in the mine.
22725. 580 feet N. 55° W. of mine mouth.
12776. 174 feet northeast of mine mouth.
12426. 500 feet northeast of mine mouth.

CHEMICAL AND PHYSICAL EFFECTS OF WEATHERING

In comparing the analyses of coals the weathered or unweathered character of the coal should as far as possible be taken into account. Samples collected from surface diggings and shallow prospects, or from faces along the walls of the entries, slopes, and rooms of mines, where the coal has been exposed to the air for a long time, commonly have deteriorated to some extent, owing to the oxidation and decomposition of the coal incident to weathering. On long-continued exposure many coals lose all their original physical characteristics and suffer great reduction in calorific value. As the alteration goes on there is a gradual increase in moisture and oxygen and a corresponding decrease in the percentage of carbon. In general the percentages of volatile matter, ash, sulphur, hydrogen, and nitrogen remain fairly constant, although there is commonly a slight increase in the ash content in the weathered belt and a decrease in sulphur. The reddish-brown films that form along newly developed fracture planes in the coal indicate that some of the iron sulphide in the coal has been changed to iron oxide. From these facts it is obvious that analyses will not be of greatest value unless the conditions under which the samples were taken are known.

SIGNIFICANCE OF THE DIFFERENT CONSTITUENTS SHOWN BY THE ANALYSES

Moisture.—The moisture contained in coal may be separated into two parts, loosely retained or mechanically held moisture such as is present in coal as it comes from the mine, and moisture retained by coal that has reached an air-dried condition. The difference between these two amounts is the "air-drying loss." The moisture contained in the air-dried sample is gradually given off as the temperature rises, and if the finely powdered sample is heated for an hour in air at a temperature of 105° C. the free or loosely held water and some of the hydrocarbons are expelled. In the table the percentage of moisture given in analysis A, for the coal "as received," represents the moisture removed from the sample in producing "dry" coal, the composition of which is given in analysis C. According to the modified method lignites and coals high in moisture are heated at a low temperature until all the moisture is drawn out, in order to avoid mechanical losses from material thrown out of the crucible by the rapid escape of steam and volatile matter. This preliminary heating for four to six minutes is followed by the application of the full flame. Moisture not only fails in itself to produce heat, but it tends to diminish the heating value of a coal by displacing its own weight of combustible matter. Furthermore, it absorbs the heat required to raise the temperature along with the temperature of the fuel in which it is included; and finally it absorbs the latent heat of volatilization, by which it is passed off as steam. It is evident, therefore, that the presence of a large amount of moisture in a coal greatly diminishes its heat-producing power.

Volatile matter and fixed carbon.—The volatile matter of coal includes the gaseous combinations of hydrogen and carbon, the oxidation of which in the processes of burning generates heat, and also includes a certain amount of inert gas. Coals that contain a large proportion of volatile matter are said to be soft. They ignite readily and burn with a long, smoky flame.

The term "volatile matter" does not refer to a definite compound that was in the coal before it was heated, for different degrees or rates of heating will give more or less volatile matter.

Ash.—The ash contained in a sample of coal may come from mineral matter intimately mixed with the carbonaceous material of the coal, or it may be derived from thin layers of shale, pyrite nodules, or other impurities in the coal hed. If the ash is derived from the first source it is likely to be fairly uniform in the different parts of the same bed, but if it comes from the second source it is likely to vary greatly from place to place and the percentage of ash will depend on the number and thickness of the partings and on the care with which they are separated from the coal in mining. The chief constituents of coal ash are silica, alumina, iron, and lime. An ash high in silica does not fuse readily, and one containing a high percentage of iron and lime is easily fusible and is apt to clinker badly in a furnace.

Sulphur.—Sulphur is a common impurity in coal which may be present in combination with lime and magnesia as sulphates, in combination with the coal substances as organic sulphur, or in combination with iron as pyrite or marcasite. Sulphur when burned corrodes the metal parts of furnaces, and its presence is objectionable in connection with the use of coal for metallurgical processes, especially those used in producing iron and steel, as it exerts a detrimental effect upon the finished products.

Hydrogen.—Part of the hydrogen is combined with oxygen to form water, and this part is inert so far as heat-producing power is concerned. Probably most of the remainder is combined with carbon, and a considerable proportion of the heat-producing power resulting from the combustion of the coal is due to the oxidation of these hydrocarbons.

Carbon.—Carbon is the chief fuel constituent of coal. Part of it combines with hydrogen to form the volatile hydrocarbons, and another part remains as "fixed carbon."

Nitrogen.—Nitrogen is an inert substance possessing no heat-producing power. It is of interest mainly to the gas and coke manufacturer who recovers part of the nitrogen as ammonia, which is used extensively in the form of ammonium sulphate in the manufacture of fertilizer. It usually averages from 0.5 to 2 per cent in coal.

Oxygen.—It is the practice of fuel chemists to regard all the oxygen in the coal as being combined with hydrogen in the ratio 1:8 to form water. The excess of hydrogen is considered as being combined with carbon and as such is a potent heat producer.

SPONTANEOUS COMBUSTION

The extent to which the coal of this field has burned out at the surface is mentioned on page 41. The large beds of the Fairfield coal group seem to have been more susceptible to spontaneous combustion than the beds of any other group. The combustion is attributed by some to the oxidation of pyrite or marcasite. In certain places it may have been started by lightning during violent electric storms. Calorific determinations have shown, however, that exposure of coal at the surface for a certain length of time produces a decrease in its heating value, apparently due to a slow oxidation of its constituent volatile hydrocarbons. Many low-rank coals, such as those of northwestern Colorado, when finely divided and exposed to the atmosphere often develop heat and burn with a flame in a short time. In this field not enough mining has been done to furnish any 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 the air, which will support combustion to considerable depths. As an illustration of extreme depth of burning may be mentioned the Sunnyside field of Utah, where, according to Clark,[17] the coal has in places 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 this field is strong evidence of the natural combustibility of the coal. It is said that in mining the thicker beds at Newcastle, about 60 miles due south of this field, on the Denver & Rio Grande Western Railroad, it sometimes became necessary to remove all or a part of the coal from the rooms before completion, owing to the tendency of the loose coal to heat and take fire. In fact, the old Wheeler mine at Newcastle was abandoned years ago because the fire could not be controlled, and it is still burning.

[17] Clark, F. R., personal communication.

PHYSICAL PROPERTIES

The coal from this field in its unweathered state has a deep black color and often breaks with a very pronounced conchoidal fracture. In some of the coal incipient parallel joints have developed to such an extent that it "slabs off" readily when struck with a miner's pick. The physical properties of the Mesaverde coals are very different from those of the younger coals included in the so-called "Laramie" and post-"Laramie" formations of neighboring areas. The younger coals are of a distinctly inferior rank and fall within the subbituminous class as defined in recent reports of the United States Geological Survey. The Mesaverde coals of this field are somewhat superior in quality and rank about on the border line between bituminous and subbituminous coal.

Both ranks of coal are thoroughly black when fresh, but the younger coals are tougher and more tenacious, a property which is often referred to inaccurately as hardness by the miners. On exposure to the air the younger coals may develop a platy stucture, but the Mesaverde coal tends to weather out into rectangular blocks by the development of two sets of parallel joints. On exposure to the air, sun, and rain the younger coals usually break down to a very fine powder or dust, which interferes seriously with the use of the coal. The somewhat higher rank Mesaverde coals may be said to withstand to only a moderate degree the action of the weather. Samples that have been in the office in glass jars for five years show but little tendency to break down, and if placed in sheds or bins affording protection from the sun and rain such coal could probably be stored with little difficulty for considerable time. If, on the other hand, it is placed in the open air without protection it develops joints and breaks down in a few months. Obviously a coal whose physical properties require that it be transported in closed cars is somewhat at a disadvantage in competing in the market with coals that may be shipped in open cars.

METHODS USED IN ESTIMATING QUANTITY OF COAL

Coal groups considered.—Owing to the thickness of overburden, the extent of burning along the outcrop, and the consequent difficulty of tracing the individual coal beds, in estimating tonnage the coal beds had to be combined into groups. The different coal groups are fully described in the chapter on stratigraphy. The Black Diamond group of coal beds, which occurs locally from 200 to 400 feet below the Trout Creek sandstone and which is of considerable value near Meeker, Colo., is represented in the vicinity of Axial Basin by a few thin beds of coal of very little economic importance and accordingly was not taken into account in the estimation of tonnage.

The only two coal groups considered are the Fairfield and the Twentymile. The Fairfield group occurs between the Trout Creek and Twentymile sandstones and the Twentymile group above the Twentymile sandstone.

Quantity of coal in each coal group.—The most complete stratigraphic sections measured south of the Axial Basin anticline, particularly in the Meeker quadrangle, show between 60 and 70 feet of coal in the Fairfield group, although the evidences of burning indicate that considerable coal has burned at the surface. As neither the amount of coal nor the depth of burning is definitely known, in order to arrive at a conservative estimate of the tonnage only the quantity of coal actually measured was taken into account. The quantity of coal assumed for the Fairfield group north of Axial Basin is based upon the section measured about a mile southeast of Lay, Colo., in the S. ½ sec. 31, T. 7 N., R. 93 W.; the section measured along Horse Gulch in T. 6 N., R. 93 W.; and the section measured in secs. 30 and 31, T. 6 N., R. 91 W.

The total number of coal beds and their thicknesses and relations are clearly shown in Plate XVIII. At the point where the Lay section was measured there is practically no evidence of burning, a condition which probably accounts for the abundance of coal there. In this section there is a total of 117 feet 8 inches of coal in beds that exceed 14 inches in thickness.

The thickness for the Twentymile coal group was taken as 22 feet, that being the amount of coal measured above the Twentymile sandstone in Horse Gulch. This amount agrees very closely with the total coal included in the section measured by Gale and Fenneman[18] at the mouth of Sage Creek canyon, about 5 miles southeast of Hayden. That section, which is said to be rather typical of the upper group, contains 25 feet 8 inches of coal.

Reduction due to erosion.—Wherever erosion has removed a portion of the formation including one of the groups of coal beds a corresponding reduction was made in the estimate for the amount of coal.

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[18] Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: U. S. Geol. Survey Bull. 297, p. 28, 1906.

Chapter V.—DETAILED DESCRIPTION OF TOWNSHIPS

In the following township descriptions are given local details of stratigraphy, structure, distribution and thickness of coal beds, and other details that bear directly upon the extent and availability of the coal resources of individual areas within the Axial and Monument Butte quadrangles.

T. 6 N., R. 90 W.

TOPOGRAPHY

The western part of T. 6 N., R. 90 W., occupies a portion of the long, gentle slope extending northward from the summit of the Williams Fork Mountains. Although the surface is rendered uneven by numerous small gullies, there are no very conspicuous land forms. It is drained by Flume and Deacon gulches, both of which head near the south line of the township and run north, opening out into the valley of Yampa River, whose alluvial deposits produce some of the richest land in the township.

STRATIGRAPHY

The strata that crop out in this township include only the Williams Fork formation and a few of the lower beds of the Lewis shale near the west line of the township. A detailed description of these formations is given in Chapter II. The surface conforms very closely to the dip of the rocks, and so the beds are not well exposed. For that reason very little coal crops out, although there is every reason to believe that the western part of the township is underlain by as much coal as is exhibited in the columnar section for T. 6 N., R. 91 W., shown on Plate XVIII. One of the most conspicuous stratigraphic features in this part of the township is a prominent sandstone that was traced continuously from a point near the southeast corner of sec. 32 northward as far as location 427. in the southwestern part of sec. 17. The altitudes determined at several points on this sandstone afford valuable information relating to structure.

STRUCTURE

The beds in the western part of this township as a rule dip gently toward the north, but this dip is modified somewhat by the Breeze anticline, whose axis crosses the township in an east-west direction. The prominent sandstone mentioned above dips west in sec. 20 at an angle of about 4°.

COAL

BEDS EXPOSED

The long dip slopes do not favor the outcrop of many coal beds in this township, although it is evident that most of the coal beds contained in the Mesaverde group elsewhere underlie this township also. The prominent sandstone that was traced from location 426 to location 427 immediately underlies a belt of brown to black carbonaceous shale, which in some places grades laterally into coal. For example, at location 428 there occurs immediately above the sandstone about 9 feet of brown and gray shale containing two thin streaks of coal 1½ inches in thickness. The same brown shale bed occurs at location 429. At location 430 there is 2 feet 11 inches of coal overlain and underlain by sandy shale. At location 431 the coal bed measures 3 feet 2 inches, and at location 432 it measures 2 feet 11 inches. No coal was seen above the sandstone north of location 432. The best exposures of coal in the western part of the township occur on the east side of Deacon Gulch. Locations 433, 434, 435, and 436 are believed to be on the same coal bed. At location 433 the bed measures 3 feet 8 inches and is overlain by gray sandy shale and underlain by brown shale. At location 434 it measures 3 feet 1 inch and is overlain and underlain by brown shale. Still farther north, at location 435, the bed contains 3 feet 5 inches of coal, overlain by shaly sandstone and underlain by brown shale. Another coal bed about 25 feet below this one was measured at location 437 and found to contain 2 feet of coal overlain and underlain by brown shale. A 14-inch bed is exposed at location 438, which is about 75 feet above the bed at locations 433, 434, 435, and 436. About 25 feet above the bed at location 438 is another one (439) 5 feet thick, overlain and underlain by brown sandy shale. Locations 440 and 441 are also on the same bed as that measured at location 439. The bed seems to have changed in character, however, in passing from location 439 to 440. (See fig. 5.)

The Walker mine (location 442) is on the west side of the gulch about one-third of a mile northwest of location 440. The bed mined here was sampled at the face of the main drift, about 580 feet N. 55° W. of the mine mouth. The results of the analysis are shown under laboratory No. 22725, on page 45. The analysis of a sample obtained later is given under laboratory No. 92668.

A definite correlation of the bed here mined with any of the beds across the valley is impossible. The Walker coal bed, however, appears to lie in about the same stratigraphic position as the upper bed measured on the east side of the valley.

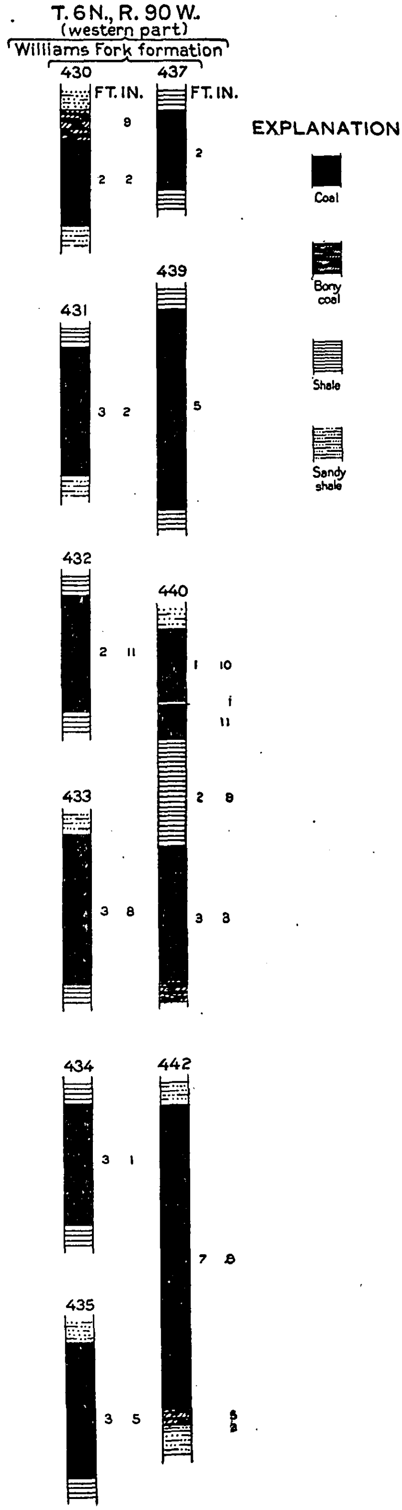


FIGURE 5.—Sections of coal beds in the western part of T. 6 N., R. 90 W.

The upper bed on the east side of the valley was sampled in a small mine called the Miller mine. The analysis of the coal is given under laboratory No. 92666. Half a mile south of the Walker mine the Joe Knez mine was recently opened and the coal sampled. The analysis of the coal from this mine is given under laboratory No. 92667.

QUANTITY OF COAL

The total coal in the Fairfield and Twentymile coal groups in this township was computed mainly upon the basis of the amount of coal measured in a stratigraphic section 1 mile southeast of Lay (see columnar section, Lay, Pl. XVIII) and a section measured on the east side of Yampa River and Williams Fork in secs. 30 and 31, T. 6 N., R. 91 W., and sec. 6, T. 5 N., R. 91 W. It appears probable that there is in this township at least 140 feet of coal above the Trout Creek sandstone. Owing to the lenticular character of the thin beds of coal in the Iles formation no additional estimate is made for the coal in that formation. From the data given it is estimated that there is 1,813,600,000 short tons of coal in the portion of this township included in the Monument Butte quadrangle.

POSITION OF COAL BEDS IN RELATION TO MINING

The main line of the Denver & Salt Lake Railroad is only about three-fourths of a mile north of the northeast corner of the Monument Butte quadrangle, so that the coal in this township is readily accessible to railroad transportation. It is possible to mine only a few of the coal beds of this township by means of drifts and slopes carried in from the surface. By sinking a shaft near the railroad or at some point farther south, however, an enormous tonnage of coal could be taken out.

T. 6 N., R. 91 W.

TOPOGRAPHY

The south half of T. 6 N., R. 91 W., is a part of the gentle slope extending north from the summit of the Williams Fork Mountains. The north half is somewhat elevated as a result of the faulted uplift of the massive sandstones of the Mesaverde group in line with the Breeze anticline. Yampa Valley, the main natural artery of communication through the coal field of which this township is a small part, receives all the drainage. A large portion of it originates on the north slope of the Williams Fork Mountains and flows north in a number of small gullies, finally reaching the flood plain of the Yampa at Big Bottom. Toward the summit of the mountains these gullies conform in slope very closely to the north dip of the upper sandstones of the Williams Fork formation, but on reaching the Lewis shale they are much less steeply inclined. In all probability the coal that will be mined in this township will be transported by rail along Yampa Valley to the main line of the Denver & Salt Lake Railroad, or possibly to other lines that may reach Craig at some future date. The grades involved in the construction of branch lines of railroad south from the proposed route of the Denver & Salt Lake Railroad are described under "Accessibility" in Chapter IV.

STRATIGRAPHY

The strata that crop out in this township are of Upper Cretaceous age and represent an uninterrupted period of sedimentation. The beds are included in the Williams Fork and Lewis formations, details of which as related to the entire coal field are given on pages 18–21.

The Williams Fork formation underlies all except the central part of the township. In certain localities very conspicuous sandstones occur at the top of the formation. On the steep slope west of Yampa River in the NW. ¼ sec. 30 three thick beds of very white sandstone occur at that horizon and present a very striking appearance. The upper one of these beds was traced almost continuously from location 593, on the east side of Yampa River, as far east as location 594, in the SE. ¼ sec. 24. The same group of sandstones was again recognized dipping 15°–18° S. in the west bank of the river near the east line of sec. 17 and as isolated masses on the south slope of the long ridge running east. Owing to the fact that the drainage courses in a great measure conform to the dip of the sandstones, no great thickness of rocks is exposed in most of this township. There is, however, a rather complete section of the Williams Fork formation exposed in the east bank of Williams Fork in sec. 31 of this township and sec. 6 of the township immediately south. The coal beds of this section are represented graphically in columnar section in Plate XVIII. This section and others in neighboring localities warrant the belief that this township is underlain by many thick coal beds.

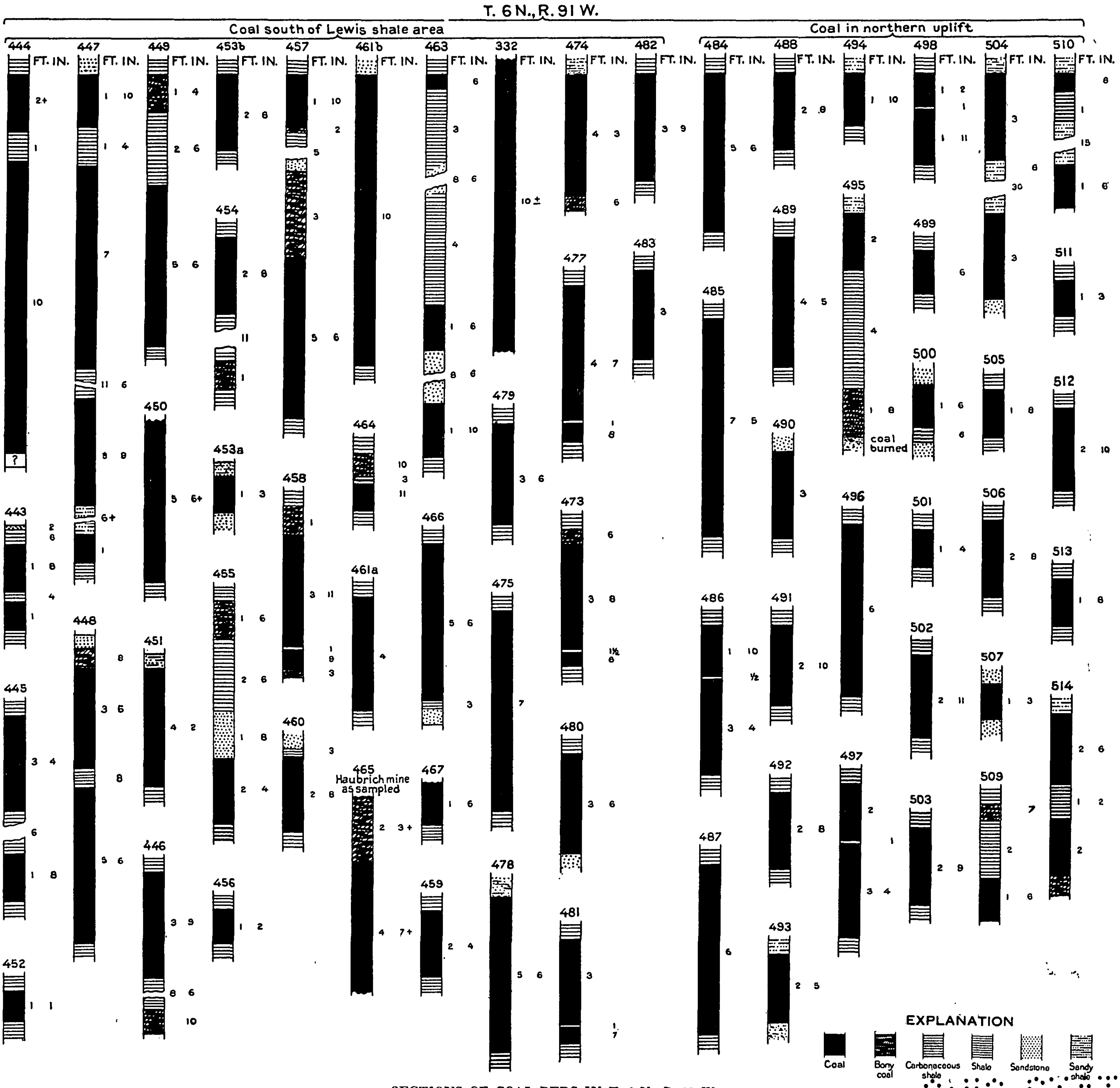
STRUCTURE

The structure of this township is for the most part synclinal, as it is crossed from east to west by the axis of the Big Bottom syncline. In the northern part of the township the beds were uplifted and faulted, as shown by the structure contours on the map. This uplift is in all probability the western extension of the Breeze anticline, whose principal development is east of the Monument Butte quadrangle. The steepest dips are on the south side, where they range from 11° to 15°. On the north side they range from 5° to 10°. South of the axis of the Big Bottom syncline the prevailing dip is 8°–11° N. A fault having a maximum throw of perhaps 200 feet is present a short distance north of the crest of the anticline and can be traced several miles in a direction approximately parallel to the major axis. Near the highest point of the anticline the downthrow of the fault is on its south side, but a short distance away in either direction the downthrow is on the north side of the fault.

COAL

BEDS MEASURED

The entire central portion of the township is occupied by the Lewis shale, which is non coal-bearing in its lower part. It is evident from the accompanying map that the only exposed beds older than the Twentymile sandstone are those in the SW. ¼ sec. 31. The best exposures of coal occur on the steep slopes east of Williams Fork and Yampa River in the southwestern part of the township and also where Yampa River cuts through the anticline and exposes the rocks of the Mesaverde group in the northern part of the township. Twenty-one different beds were uncovered and measured in this township on the steep slope east of Williams Fork and Yampa River in secs. 29, 30, and 31. Their thicknesses and stratigraphic relations are shown in columnar section in Plate XVIII. Six of the beds occur below the Twentymile sandstone, and fifteen of



SECTIONS OF COAL BEDS IN T. 6 N., R. 91 W.

them occur above that member. The stratigraphic sections measured in sec. 31 show the coal beds and associated strata in a zone of the formation approximately 368 feet in thickness immediately above the Twentymile sandstone.

Wherever more than a single measurement was made on the same bed the location numbers appear on the left in the columnar section, and the average thickness, as shown by the different measurements, is shown on the right. The details of each separate measurement are shown on Plate VII. The coal beds are numbered consecutively from 443 to 468 as they appear in that portion of the columnar section embraced in this township. The coal beds as shown in these sections range in thickness from 1 foot 6 inches to about 12 feet. Locations 449, 453a, 453b, and 461a are not shown on Plate XIX.

The lowest bed measured in this township occurs at location 443. The top of the coal bed is 56 feet below the bottom of the one measured at the Hart or old Ratcliff mine, which is designated by location 444.

The Ratcliff bed was sampled about 60 feet in from the mine mouth. At this point the bed is composed of an upper bench 2 feet thick and a lower bench 10 feet thick, separated by 1 foot of shale. The sample was taken from the lower bench, and the results of the analysis are shown under laboratory No. 9138, on page 45.

No additional coal beds were seen on the east bank of Williams Fork below the Twentymile sandstone, but about 50 feet above the sandstone a coal bed was measured at location 445.[18a]

The next higher bed was examined at location 446. This bed, which is about 25 feet above that at location 445, contains 3 feet 9 inches of coal.

About 30 feet higher in the formation is a thick coal bed that was measured at three different places. The details of the different measurements are shown in coal sections numbered 447, 448, and 449. A 10-foot white sandstone that occurs in the interval of 11 feet 6 inches in section 447 is probably the same bed as the white sandstone that lies about 2 feet below the lower coal bed at locations 448 and 449.

A much thinner bed than the one mentioned above was measured at locations 450 and 451. At location 451 the bed contains 4 feet 2 inches of coal overlain by carbonaceous shale and underlain by brown shale. At location 450 the top of the coal is indefinite, but the bed contains at least 5 feet 6 inches of coal underlain by carbonaceous shale.

The next two beds higher in the series are thin—the upper one is about 1 foot 4 inches thick and the lower one about 2 feet 5 inches—

[18a] Two locations numbered 445 are shown on Plate XIX. The southeastern one of these locations is an error, and it should be omitted.

and they are separated by an interval of about 45 feet. Each of these beds was measured at three different places. The measurements made on the lower bed are shown in coal sections 452, 453b, and 454, and those made on the higher one in coal sections 453a, 455, and 456. (See Pl. VII.)

About 40 feet higher in the formation is a much thicker coal bed, which was examined at locations 457 and 458. The details of the measurements are shown in the coal sections having the corresponding numbers. The bed shown in section 458 in all probability represents the lower bench of the coal bed at location 457. (See Pl. VII.) A thin bed about 75 feet higher in the formation was measured at locations 459 and 460.

Location 461 is on a thick bed of coal about 30 feet higher in the formation. At that location, which marks an old prospect, the bed contains 10 feet of good coal overlain by sandstone and underlain by shale. Between that bed and the one at the Haubrich mine are three thin beds. The thickness of the upper bed is shown by coal section 464 and that of the lower one by section 461a, the location of which does not appear on the map. The lower bed is only about 40 feet above the one at the old prospect. The middle bed was measured at two places west of Yampa River, and the measurements are shown in coal sections 463 and 470.

Location 465 marks the Haubrich mine, and locations 466 and 471, on the west bank of Yampa River, are believed to be on the same coal bed. At location 466 the bed contains 5 feet 6 inches of coal, overlain and underlain by shale. At location 471 the overlying and underlying beds are similar and the coal measures 5 feet 5 inches. The mine bed was sampled at a point 70 feet in from the mine mouth, where it consists of an upper bench 2 feet 3 inches thick and a lower bench 4 feet 7 inches thick, separated by a 1-inch shale parting. The portion of the coal bed below the parting was sampled, and the results of the analysis are shown in the table on page 45 under laboratory No. 9137.

Only two other coal beds above the Haubrich mine bed were measured east of Yampa River. The lower bed, which is 1 foot 6 inches thick, was measured at location 467, and the upper one, which contains only 1 foot of coal, at location 468. Locations 469 and 472, on the west bank of Yampa River, are on the same coal bed, which caps one of the massive white sandstones that crop out in that locality. As coal sections 469 and 472 clearly show, the coal bed is composed of two thin benches of coal separated by a bed of brown shale. From its relation to the base of the Lewis shale this may be the same coal bed as the one measured at location 468, east of the river.

Certain beds of coal were seen on the north slope of the Williams Fork Mountains in secs. 32, 33, 34, and 35, but they are so poorly exposed in the gentle dip slopes that an absolute correlation was impossible. By taking into account the elevations of the different exposures along with the dip and strike of the beds it was possible to make a tentative correlation, as shown on the map, but this correlation may be subject to considerable error. The lowest bed in that locality is the one at location 332. It contains at least 4 feet of coal overlain by shale, but the bottom of the bed was not found. It seems probable that locations 459 and 479 are on the same coal bed, although the bed at location 479 contains 3 feet 6 inches of coal, whereas at location 459 it is only 2 feet 4 inches thick. Locations 475, 476, and 478 are probably on the same coal bed. Location 476 merely marks a point on the bed where weathered coal shows on the surface. The actual thickness of the coal, together with the overlying and underlying beds, is shown in coal sections 475 and 478. Locations 474 and 477 are on coal beds a little higher in the formation, but whether or not they are on the same coal bed is uncertain. The similarity in the thickness of the coal and in the underlying beds indicates that the two sections are on the same bed.

The highest bed of coal in this vicinity was seen at locations 473, 480, and 481. The coal sections measured at locations 473 and 481 are very similar, in that each is composed of three separate benches of coal or bone and each is underlain by a massive white sandstone. Coal section 480 in all probability shows only a part of the coal bed. Locations 482 and 483 are on coal beds lower in the formation, but their relations to those farther west are very uncertain. The upper bed (482) contains 3 feet 9 inches of coal overlain and underlain by brown shale. The lower one contains 3 feet of coal overlain and underlain by brown shale.

According to the best correlation of the beds in the northern part of the township it is believed that at least eight separate coal beds are there present. The structure, however, is rather complicated, as the beds are faulted as well as folded, so that the relative stratigraphic positions of some of them are uncertain. The columnar section in Plate XVIII shows the inferred relations and correlations. The different sections of what was taken to be a single bed are shown by location numbers on the left, and the average thickness as shown by the measurements appear on the right. The details of the various coal sections are shown on Plate VII and are numbered consecutively 484 to 514, from the lowest to the highest beds as they appear in the columnar section. The stratigraphic position of the bed measured at location 512 is very uncertain, and hence it was not correlated with any of the eight beds shown in the columnar section.

The lowest bed in the group is that measured at location 484. It contains 5 feet 6 inches of coal, overlain and underlain by shale. The details of the next higher bed are shown in coal sections 485, 486, and 487. From those sections the coal, which is overlain and underlain by shale, averages about 6 feet 3 inches in thickness. The next coal bed is about 75 feet higher in the formation. In passing from location 488 east to location 489 and thence to location 490 the coal thickens from 2 feet 8 inches to 4 feet 5 inches and then thins to 3 feet. About 20 feet higher in the formation is a somewhat thinner coal bed whose average thickness of 2 feet 4 inches is shown by coal sections 491, 492, 493, and 494. The four highest coal beds of the group are more widely separated stratigraphically. They range in thickness from 1 foot 7 inches in the highest bed to 4 feet 10 inches in the lowest. The details of four measurements of the lowest bed are shown by coal sections 495, 496, 513, and 514. The separate measurements on each of the upper three beds are shown in the columnar section in Plate XVIII, and the details of the measurements are given in coal sections 497 to 511, Plate VII. The section measured at location 504 in reality contains two separate coal beds separated by an interval of 30 feet, and is shown on the plate as 504a and 504b.

The coal bed measured at location 512, near the fault on the east bank of Yampa River, for lack of evidence, was not correlated with any one of the eight beds shown in the columnar section. It contains 2 feet 10 inches of coal, overlain and underlain by shale.

QUANTITY OF COAL

The tonnage of coal in this township was computed mainly upon the same basis as that in T. 6 N., R. 90 W. (p. 56). It appears probable that there is at least 140 feet of coal above the Trout Creek sandstone in this township. Owing to the lenticular character of the thin beds of coal in the Iles formation no additional estimate is made for the coal below the Trout Creek sandstone member. The entire portion of this township included in the Monument Butte quadrangle, or about 30.25 square miles, is underlain by the coal-bearing formations, and it is therefore estimated that this area contains 878,700,000 short tons of coal.

RELATION OF STRUCTURE AND DRAINAGE TO MINING

With the possible exception of a few of the beds immediately above the Trout Creek sandstone practically all the coal beds included in the Williams Fork formation in this township are either exposed or could be uncovered with little difficulty on the banks of Yampa River and Williams Fork. Drifts could be driven in on any of the coal beds and extended as far east or west as practicable. In mining on a large scale, however, it might be advisable to sink a shaft near the center of the basin—for example, near the middle of sec. 21. If the conclusions relative to structure are approximately correct, a shaft sunk at that point would reach the Trout Creek sandstone at a depth of about 2,750 feet. The shaft would probably pass through the coal beds as indicated in the columnar section. As the beds dip from nearly all directions toward this point at angles of 4° to 5° the ordinary problems relating to drainage and haulage would be reduced to a minimum. The ease with which such a shaft could be reached by rail from the main line of the Denver & Salt Lake Railroad near Craig is pointed out in Chapter IV.

T. 6 N., R. 92 W.

TOPOGRAPHY

The highest and most conspicuous surface features in T. 6 N., R. 92 W., are on the axis of the Williams Fork anticline. These elevated portions at the Bell Rock dome and in the southeastern part of the township are from 800 to 1,000 feet above the valley of Yampa River and in general about 550 feet above the average altitude of the rest of the township. They are the direct result of the relatively high position of the massive sandstones at the top of the Williams Fork formation.

The entire township is drained by Yampa River and its tributaries. The tributaries, which flow in long gulches, head near the northern part of the township and run south or southwest into the river. These gulches contain running water only during the short periods while snow is melting or after a fall of rain. The drainage in the eastern part of the township reaches Yampa River through Bell Rock Gulch; that from the central part flows into Fuhr Gulch through numerous small side gullies and finally reaches the river near the southwest corner of the township. The run-off from the northwestern part of the township finally reaches Yampa River in sec. 35 of the township on the west.

Yampa River has intrenched its meanders down into the coal-bearing rocks of the Williams Fork formation, entering the township in secs. 31, 34, and 36, and it seems reasonable to assume that a large portion of the coal mined in the township in the future will be taken out by rail along the river valley. A portion of the coal could also be reached by a branch line of railroad extending south from the proposed route of the Denver & Salt Lake Railroad west of Craig. The most feasible routes south from this proposed line and the grades involved are stated in Chapter IV.

STRATIGRAPHY

The beds that crop out in this township are of Upper Cretaceous age and represent an uninterrupted period of sedimentation. Upon the basis of lithology and fossil content they have been separated into the Williams Fork, Lewis, and "Laramie" formations, detailed description of which is given in Chapter II. The rocks of the Williams Fork formation crop out in the southern part of the township and in the Bell Rock dome. The rest of the township is occupied by the Lewis shale and the "Laramie" formation. In the southeastern part of the township practically the entire thickness of the Williams Fork formation is exposed, including all the beds from the top of the Trout Creek sandstone member of the Iles formation to the base of the Lewis shale. In the Bell Rock dome only a few hundred feet of the uppermost beds of the formation are exposed. The top of the Williams Fork formation in the western part of the township is marked by a brown sandstone that weathers into individual masses. The position of this bed is denoted in certain localities by a succession of isolated masses of sandstone from 10 to 50 feet in height. Bell Rock, in sec. 10, is one of these isolated masses shaped more or less like a bell. On the steep slope of Yampa River this sandstone is very white and consists of at least three separate beds, each capped by a bed of coal. The same sandstones and the overlying coal beds were recognized and traced from the west side of sec. 4 around the south side of the Bell Rock dome to a point near the center of sec. 11. The contact between the Williams Fork and Lewis formations was drawn about 75 feet above the highest of these sandstones, because above the sandstones the formation changes rapidly into typical shale. There is a very distinct difference between the rocks of the two formations. The great bulk of the Lewis is shale, a mass of partly consolidated mud, whereas the sandstones that constitute nearly all of the Williams Fork formation are made up of grains of sand held more or less firmly together by a cementing material. Certain portions of the sandstone are more firmly cemented than others, and in consequence these are left as isolated masses, with various shapes, after the softer portions have been worn down and carried away by the action of heat and cold, wind, rain, running water, and other agencies. If the rocks in the southeastern part of the township and those of the Bell Rock dome were of the same nature as the Lewis shale, they too would probably have been reduced to about the same level as the rest of the township.

Even the Lewis formation is not a perfectly homogeneous mass of shale, for interbedded with the soft shale are many thin layers of sandstone. Such sandy zones are well developed in this township. They were carefully traced and mapped, and the dip and strike of the beds were recorded at many places in order to ascertain the form of the folds. One such zone was traced almost entirely across T. 6 N., R. 93 W., and from the southwest corner of sec. 18 southeastward to the SW. ¼ sec. 27 in this township. Another zone was traced northwestward from the SW. ¼ sec. 22. A very prominent ledge of thin-bedded sandstone was traced from the center of the south side of sec. 2 southeastward to the center of the east side of sec. 24 and thence down to Yampa River. The sandstones, sandy shale, and carbonaceous shale of the "Laramie" formation are exposed in the northeast part of the township, as shown on the map.

STRUCTURE

The structure in this township is rather complex. The axis of the major structural features, the Round Bottom syncline and the Williams Fork anticline, cross the township in a northwesterly direction. Farther southeast the axis of the anticline coincides more or less closely with the valley of Williams Fork. The axis of the syncline extends from the east end of Iles Mountain northwestward through Round Bottom and on to the northwestern part of this township. These major folds have been further modified by a broad synclinal fold that forms a saddle in the Williams Fork anticline southeast of the Bell Rock dome.

The dips on the west limb of the anticline range from 20° to 30° in the southeastern part of the township. Those on the southwest flank of the Bell Rock dome range from 7° to 13°, but the east flank is less steep, the dip being 6° to 8°. Where the massive sandstones are exposed on the east side of sec. 24 the dip is about 10°. Southwest of the Round Bottom syncline the dip is uniformly 6°–8° NE.

COAL

The coal that was found in this township occurs entirely in the upper part of the Williams Fork formation. Sections of coal beds measured in this township are given in Plate VIII.

COAL IN SECS. 31 AND 32

Location 515 is on a bed of coal on the east side of Fuhr Gulch about half a mile north of Yampa River. This bed, which is underlain and overlain by brown shale, measures 2 feet 6 inches, but it is broken by a brown shale parting from one-eighth to one-fourth of an inch thick 18 inches from the top. Location 516, on the opposite side of the gulch, is at a point where a coal bed has burned out. This bed is believed to be the same as that at location 515. A higher bed occurs farther up the gulch at location 517.

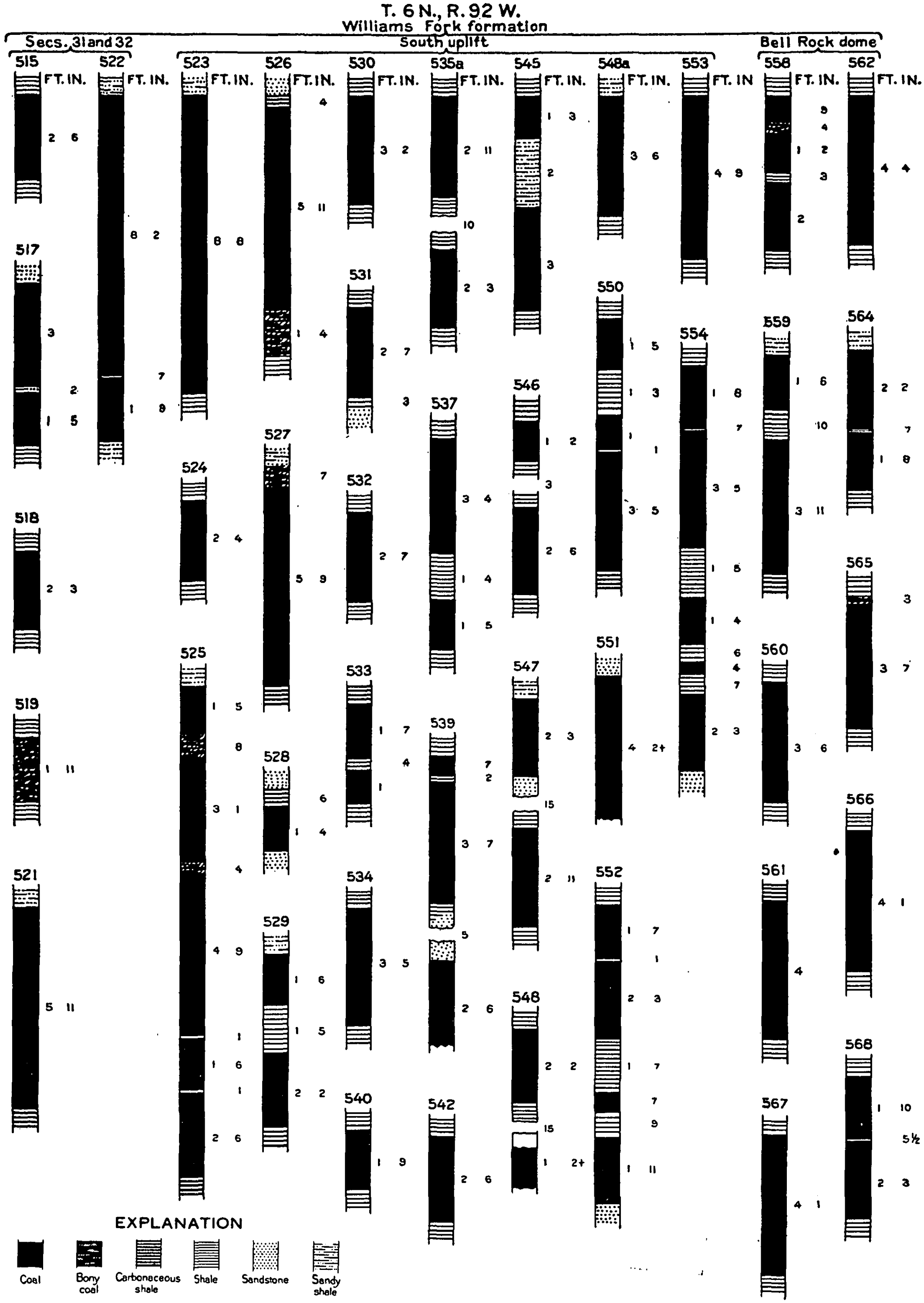
From 50 to 75 feet above this exposure a coal bed was measured at location 518 which contains 2 feet 3 inches of coal overlain and underlain by brown shale. Three beds of coal were measured at locations 519, 520, and 521, in the western part of sec. 32. The lowest of these beds (519) is 1 foot 11 inches thick but contains considerable brown earthy material, which when pulverized yields a brown powder. The coal is overlain and underlain by brown shale. About 50 feet above this coal bed there is a ledge of white sandstone (location 519), immediately above which is a thin bed of coal 10 inches thick. Still higher there is another coal bed (location 521) that contains 5 feet 11 inches of coal overlain by sandy shale and underlain by black, carbonaceous shale. Location 522, near the head of the gulch, marks the position of a mine. The drift runs in N. 10° W. for about 100 feet. The beds appear to strike about S. 10° E. and dip 10° N. 80° E.

COAL IN THE NORTHWEST END OF THE WILLIAMS FORK ANTICLINE

The lowest coal beds that were observed in this township are exposed on the west side of Yampa River near the center of sec. 36. The sections in Plate VIII will give some idea as to the character of the coal beds and their relative thicknesses. About 50 feet above the highest coal bed in the section (location 523) is a very prominent belt of brick-red sandstone and baked shale, indicating that a large bed of coal has burned out at the surface.

Location 529 marks an old mine, the opening of which has been almost filled by caving. Later this mine was cleaned out and the section shown in Plate VIII was measured. This mine is on the same bed as the one at location 526 in the section given above.

Although the slope of the surface is moderately steep and the beds are fairly well exposed immediately west of the point at which the section given above was measured, no more coal beds were seen between the top of this section and the Twentymile sandstone, although some evidences of burning were observed. The next coal beds above this section were measured on the steep slope on the west side of the gulch in the E. ½ sec. 25. The lowest bed is exposed at location 530, about 70 feet above the Twentymile sandstone. It contains 3 feet 2 inches of coal, overlain by sandstone and underlain by brown shale. At 15 feet above this bed is another (531) which measures 2 feet 7 inches in thickness. The coal is overlain by brown shale and underlain by 3 inches of brown shale, which in turn is underlain by the same sandstone that occurs above the coal bed at location 530. Location 532 is on another bed which contains 2 feet 7 inches of coal, overlain and underlain by brown shale. The relation of the other two beds was not noted.



SECTIONS OF COAL BEDS IN T. 6 N., R. 92 W.

The next coal beds higher in the formation occur at locations 533 and 534, near the northeast corner of sec. 35. The lower one of these beds (533) contains two benches of coal separated by 4 inches of brown shale. The upper bench measures 1 foot 7 inches of coal, overlain by black carbonaceous shale; the lower bench contains 1 foot of coal, overlain by brown shale. About 50 feet above this bed there is another (534) which includes 3 feet 5 inches of coal, overlain and underlain by brown shale. These coal beds dip so steeply toward the west that the upper bed (534) passes beneath the bottom of the gulch at location 535. The different belts of dark-red sandstone and baked shale on the north side of the gulch between locations 535 and 536 indicate that several coal beds have burned out at the surface between these points. Location 537, in the SE. 1/4 sec. 26, is on a coal bed that contains two benches of coal separated by 1 foot 4 inches of brown shale. The upper bench measures 3 feet 4 inches of coal, overlain by brown shale, and the lower bench 1 foot 5 inches of coal, underlain by shale. This coal bed lies below a prominent sandstone that dips below the bottom of the gulch at location 538. It is in all probability above the beds exposed at locations 533 and 534 and is one of the beds burned at the surface west of location 535. Location 535a marks a coal bed 15 feet below the top of a rather prominent ledge of sandstone. It contains two benches of coal separated by an interval of 10 feet. The upper bench contains 2 feet 11 inches and the lower bench 2 feet 3 inches of coal.

The next coal beds in ascending order occur at locations 539 and 540, about one-fourth mile farther north.

As this bed is exposed in the bottom of the gulch it was impossible without a great amount of digging, to determine the exact thickness of the lower bench.

A coal bed about 15 feet below that described above was measured at location 540. This bed contains 1 foot 9 inches of coal, overlain and underlain by brown shale. The coal beds at locations 539 and 540 dip below the bottom of the gulch only a few hundred feet west of the point where the sections were measured. Location 541 is on the top of a sandstone ledge that is higher than these beds, and location 542 marks a coal bed 2 feet 6 inches thick which is about 15 feet below the top of the same sandstone.

Another sandstone considerably higher in the formation was traced from location 543, in sec. 23, southwestward to location 544, where its outcrop swings around the hill and dips into the gulch immediately to the west. Two coal beds are exposed below this sandstone at locations 545 and 546. Location 546 in reality marks two beds; the upper one is 1 foot 2 inches thick and the lower one 2 feet

6 inches. They are separated by 3 feet of brown and black carbonaceous shale. Location 545 also marks a double bed; the upper part, containing 1 foot 3 inches of coal, is separated from the lower part, containing 3 feet of coal, by 2 feet of sandy shale. Locations 547, 548, and 548a are believed to be on the same group of coal beds above a bed of sandstone. At location 547 there is 2 feet 3 inches of coal, overlain by gray sandy shale and underlain by shaly sandstone. At 15 feet below this bed is another which contains 2 feet 11 inches of impure coal, overlain and underlain by gray sandy shale. At location 548 the upper one of the two beds is 2 feet 2 inches in thickness. There is the same interval of 15 feet below, but the lower of the two beds measures only 1 foot 2 inches. At location 548a a bed was found that contains 3 feet 6 inches of coal, overlain and underlain by sandy shale. Location 549 marks a burned-out coal bed. Location 550 is on the east side and near the bottom of Bell Rock Gulch.

Farther east than location 550, in the bottom of a small gully on the hillside, is an old prospect at location 551. Here 4 feet 2 inches of coal was measured, but the bottom of the bed could not be obtained. The coal is overlain by sandstone. The highest coal beds observed in this locality were measured at locations 552 and 553, in the northeast corner of sec. 27.

About 75 feet above this section another bed of coal was opened at location 553. This bed contains 4 feet 9 inches of good coal, overlain and underlain by brown shale. Location 554 is believed to be on the upper part of the bed that is exposed at location 552.

Some coal is also exposed at location 555, about 75 feet below the bed just described, but a satisfactory measurement could not be obtained.

COAL IN THE BELL ROCK DOME

The lowest coal bed measured in the Bell Rock dome occurs at location 556, in the SE. ¼ sec. 4. This bed contains 1 foot 5 inches of coal, overlain by sandstone and underlain by brown shale. The base of the coal is about 4 feet above a thick bed of white sandstone. Another thin coal bed occurs about 60 feet above this bed, at location 557. It contains two benches of coal, separated by 6 inches of brown shale. The upper bench measures 4 inches in thickness and the lower one 9 inches. Evidently only the top of the bed was found at this point, for at location 558, at apparently the same horizon, the measurement shown in Plate VIII was made.

At location 559 a still higher coal bed lies immediately above a bed of white sandstone. The coal bed contains two benches of coal separated by 10 inches of brown shale. The upper bench measures 1 foot 6 inches and is overlain by drab shale, and the lower bench contains 3 feet 11 inches of coal, underlain by sandy black carbonaceous shale. Location 560 is probably on the same coal bed as location 559, but if so the upper bench is replaced by shale, for here the bed contains 3 feet 6 inches of coal overlain by gray shale and underlain by brown shale. From the structure it seems that this bed is about 50 feet higher than it should be if it were a continuation of the bed showing at location 559, although below the coal bed there is a sandstone very similar to the sandstone noted below the coal at location 559. This sandstone was traced southeastward as far as location 561. Throughout this distance the overlying coal bed is believed to maintain a fairly uniform thickness, for at location 562 it contains 4 feet 4 inches of coal and at location 561 it contains 4 feet of coal. In each place the coal is overlain by brown shale and underlain by brown shale grading downward into sandstone. A very conspicuous white sandstone still higher in the formation was traced most of the distance from location 563, in sec. 4, southeastward to location 564, in sec. 11. Like the sandstones previously mentioned, this one is overlain by a coal bed, which also maintains a fairly uniform thickness, as indicated by the following measurements. At location 565 the bed contains 3 feet 7 inches of coal overlain by brown shale and underlain by a few inches of brown shale immediately above the white sandstone. At locations 566 and 567 the bed contains 4 feet 1 inch of coal. At location 568 it contains 4 feet 1½ inches of coal with a ½-inch shale parting 1 foot 10 inches below the top. The last measurement was obtained at location 564, where the bed measures 3 feet 11¾ inches in thickness and has a brown shale parting 2 feet 2 inches below the top. In all the sections observed the bed is overlain by brown shale or brown sandy shale and underlain by a few inches of brown sandy shale immediately above the white sandstone.

It may be said in brief that the part of the Williams Fork formation present in this locality is characterized by at least three prominent white sandstones and above each sandstone is a coal bed of more or less importance.

QUANTITY OF COAL

The tonnage of coal in the Fairfield group of coal beds in this township was computed upon the basis of the amount of coal measured in the stratigraphic section 1 mile southeast of Lay, as shown in the columnar section in T. 7 N., R. 93 W. (Pl. XVIII); that in the Twentymile group of coal beds was computed upon the basis of the coal measured in Horse Gulch, in T. 6 N., R. 93 W., as shown in the columnar section (Pl. XVIII).

The coal included in the Fairfield coal group in this township as thus estimated amounts to 4,539,639,000 tons, and that included in the

Twentymile coal group amounts to 721,600,000 tons, making a total of 5,261,200,000 tons of coal in the township.

POSITION OF COAL BEDS IN RELATION TO MINING

Yampa River has intrenched its course in the rocks involved in the Williams Fork anticline in such a manner that the coal beds above the Trout Creek and Twentymile sandstones are readily accessible from the river valley, so that any of the beds can be mined by either a slope or a drift from the outcrop. Bell Rock Gulch, leading north from Round Bottom, cuts down into the west flank of the Williams Fork anticline, and owing to the presence of several deep side gulches considerable coal is exposed. Although there are no thick beds of coal associated with the white sandstones of the Bell Rock dome, those present contain coal of good quality which may at some future time be used for fuel by the settlers in that locality.

T. 6 N., R. 93 W.

TOPOGRAPHY

The most conspicuous surface feature in T. 6 N., R. 93 W., is the deep canyon which Yampa River has cut into the rocks of the Mesaverde group near the south edge of the township. The township is drained entirely by the Yampa and its small northern tributaries. These tributaries are Sand Spring Gulch, Horse Gulch, and the long gulch that opens into the river three-quarters of a mile above the Government bridge, in T. 6 N., R. 94 W. By means of these gulches the entire township is tributary to the main potential artery of transportation through it. As is pointed out on page 40, it seems probable that the coal beds in Horse Gulch and Sand Spring Gulch could be reached by a short spur extending south from the proposed route of the Denver & Salt Lake Railroad, at the head of Sand Spring Gulch, and that the grade would not be much in excess of 1 per cent. It would also be feasible to extend a spur up Yampa River into this township from the point where the proposed route of the Denver & Salt Lake Railroad crosses the river about 2 miles west of Little Juniper Mountain.

STRATIGRAPHY

The beds that crop out in this township are chiefly of Upper Cretaceous age and include from the base upward the Mancos shale and the Iles, Williams Fork, and Lewis formations. Besides these there is on some of the high ridges a thin mantle of conglomerate which may represent the basal beds of the Browns Park formation, of Tertiary

(Miocene?) age. The nature of these formations and their stratigraphic relations are described in Chapter II. The Mancos, Iles, Williams Fork, and Lewis formations represent a long period of continuous sedimentation. In composition the Mancos shale and the Lewis shale are very similar, and the same is true of the Iles and Williams Fork formations, but there is a marked difference in composition between the shale formations and the rocks of the Mesaverde group, and this difference has a very important economic significance, as is set forth on page 14.

The Trout Creek sandstone, the top of which is the plane of separation between the Iles and Williams Fork formations, was traced continuously from the SE. ¼ sec. 34 northwestward to the township line on the west side of sec. 18. As the map shows, Yampa River has cut down into the Mesaverde group in such a way as to expose most of the beds above the Trout Creek sandstone. Although this part includes the principal group of coal beds, very little coal is exposed owing to the extent to which the beds have burned at the surface.

STRUCTURE

The structure in this township is comparatively simple. The underlying beds, forming the northeast limb of the Axial Basin anticline, have an average dip in the southeastern part of the township of about 7° or 8°. Westward, however, the strike rapidly approaches north and the angle of dip increases, reaching 26° in the northwestern part of sec. 7. Down the dip from the outcrop the angle of dip appears to decrease slightly, amounting to only 5° or 6° in the northeastern part of the township.

COAL

The coal that crops out in this township occurs almost entirely in the Williams Fork formation. The coal beds that were found in the Iles formation are thin and as a rule interbedded with brown and black carbonaceous shale, so that they are of little value.

COAL IN THE WILLIAMS FORK FORMATION

The thickness and stratigraphic relations of the coal beds that were measured in this township are shown in the four columnar sections prepared on the basis of the coal beds measured in Horse and Sand Spring gulches, and also the first long gulch to the west of Horse Gulch as well as the small gulch crossing secs. 6 and 7. These sections are shown in Plate XVIII. They indicate that coal occurs rather uniformly from the Trout Creek sandstone (the topmost member of the Iles formation) up to within about 200 feet of the top of the Williams Fork formation.

Coal in the gulch in secs. 6 and 7.—Location 107 is on a sandstone about 100 feet above the Trout Creek sandstone. Location 108 marks the first exposure of coal seen above the Trout Creek sandstone. The bottom of this section is about 40 feet above the sandstone.

About 160 feet above these beds coal was found exposed in an old prospect at location 109. Only a portion of the bed is exposed in the opening, but just outside of the entry the bed was opened up and found to contain 11 feet 8 inches of good coal. A bed 1 foot 6 inches thick was found about 20 feet below the main bed. Several hundred feet northeast and up the gulch is another exposure of coal at location 110. The bed contains 3 feet 3 inches of coal overlain and underlain by brown shale. This bed is believed to be about 150 feet above the bed at location 109. Still farther up the gulch is another exposure of coal at location 111 on a bed which is estimated to lie about 100 feet above the bed at location 110. This bed (111) is 12 feet 9 inches thick and is overlain by 12 inches of shale, which in turn is overlain by a 3-foot bed of sandstone. The coal is underlain by brown shale. The strike at this point is about N. 20° E., and the dip is about 21° S. 70° E. At location 112, which is believed to be 40 feet above the bed at location 111, another bed of coal was opened.

The highest bed found in this gulch occurs at location 113. This bed contains 4 feet 7 inches of coal overlain by grayish-brown shale and underlain by brown shale. It is estimated to lie about 150 feet above the bed at location 112, but there was no opportunity to make a direct measurement across the beds. Comparison of the section at Lay described on page 53 and shown in columnar section in Plate XVIII, suggests that only a small proportion of the total coal present in the formation is exposed in this gulch.

Coal in and near the first long gulch west of Horse Gulch.—Some coal was found in the gulch that opens into the long gulch on the west side of sec. 19. Location 114 marks the top of the Trout Creek sandstone. At 75 to 100 feet above this sandstone a coal bed is exposed at location 115 in an old prospect. It contains 2 feet 10 inches of badly weathered coal, overlain by gray shale and underlain by brown shale. Another bed was opened at location 116 which is estimated to be 50 feet above the one at location 115. It contains 2 feet 6 inches of coal overlain and underlain by brown shale. Another coal bed containing 2 feet 7 inches of impure coal overlain and underlain by brown shale was measured at location 117. This bed is about 75 feet above the bed at location 116. Evidence of more coal was seen below this bed, but the abundance of débris made thorough prospecting very difficult. The highest coal bed seen in this gulch occurs at location 118, about 1,600 feet northeast of location 117 and up the gulch. This bed, which is probably 675 feet above the Trout Creek sandstone, contains 11 feet 4 inches of coal overlain by about 2 feet of brown shale, which itself underlies a bed of sandstone about 20 feet thick. The coal is underlain by brown shale. Location 119 is on the first bed above the Trout Creek sandstone in the main gulch. The bed contains 5 feet 8 inches of coal overlain by 8 inches of brown shale, which in turn is overlain by brown sandstone and sandy shale. The coal bed is underlain by brown shale and is about 6 feet above the top of the Trout Creek sandstone. The next bed above was seen at location 120. This bed, which is about 75 feet above the Trout Creek sandstone, contains 3 feet of coal overlain by 10 feet of shaly sandstone and underlain by brown shale. Throughout the next 200 feet of strata several beds of coal were measured. Location 121 is on a bed about 35 feet above the one at location 120. This bed contains 6 feet 5 inches of coal overlain by gray shale and underlain by brown shale. Location 122 is on another coal bed which lies about 35 feet above the bed at location 121 and which measures 3 feet 4 inches of coal overlain and underlain by brown shale. Location 123 marks the top of a section which is about 45 feet higher than the coal bed last mentioned.

Location 124 marks a coal bed exposed in the bottom of the gulch. This bed, which is about 75 feet above the one at location 123, contains at least 2 feet 6 inches of coal overlain by black carbonaceous shale streaked with coal. Because the coal is exposed in the bottom of the gulch the base of the bed was not found. From all appearances a large amount of coal has burned out at the surface between locations 124 and 128. Locations 125, 126, and 127 each mark places where there has been intense burning. It is evident that the large bed exposed at location 118 has been burned out in this gulch. Location 128 marks a bed that contains 2 feet 1 inch of coal overlain and underlain by brown shale. Locations 129, 130, and 131 are on beds which are close together.

Another bed was opened and measured at location 132, which is estimated to be from 40 to 50 feet above the highest bed (131) of the section given above. This bed contains 4 feet 8 inches of coal overlain by gray sandy shale and underlain by brown shale. Location 133 marks an exposure of a bed about 20 feet higher, which contains 4 feet 1 inch of coal overlain and underlain by brown shale.

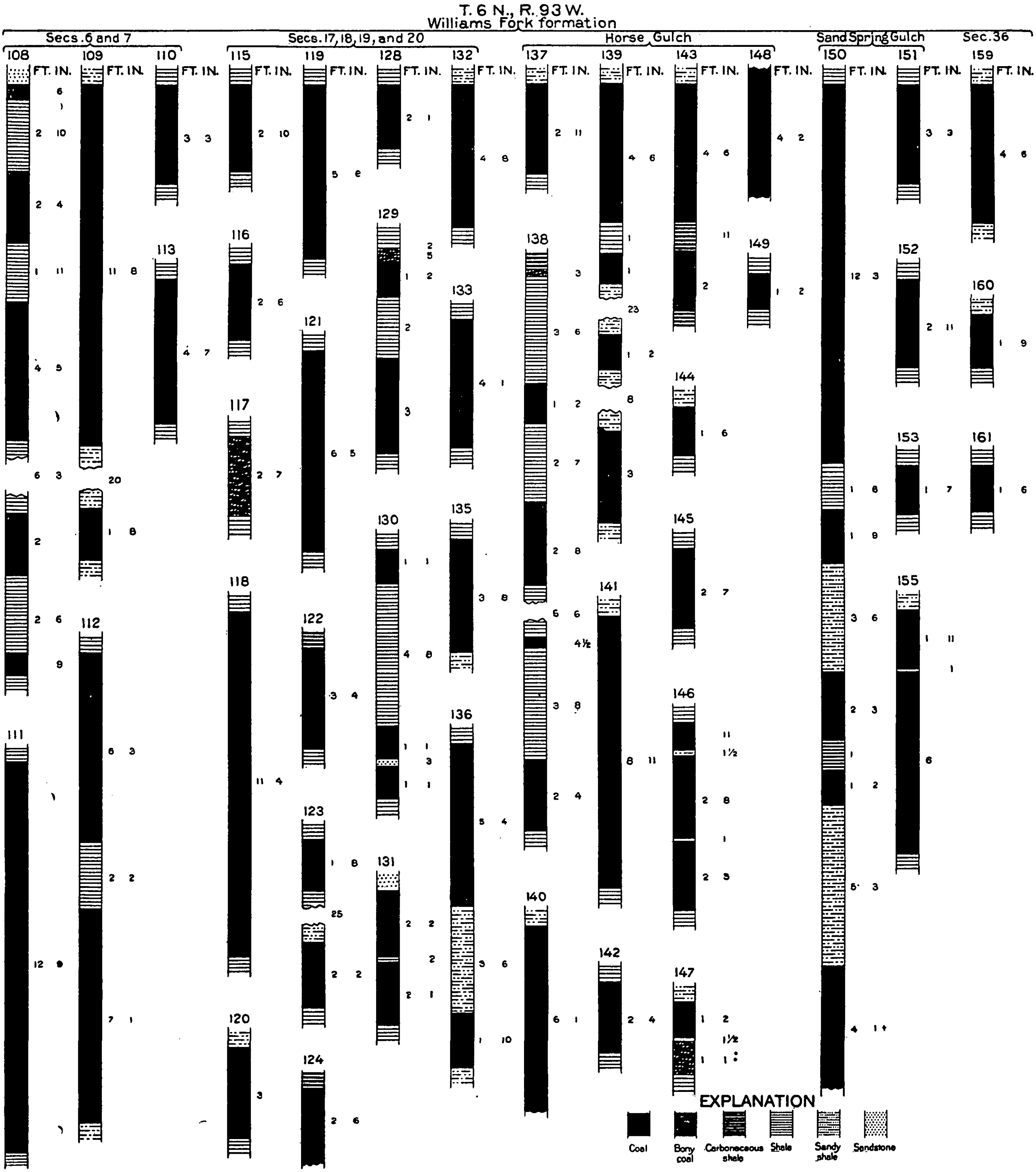
Location 134 is on the Trout Creek sandstone in the SW. 1/4 sec. 20. About 20 feet above the Trout Creek sandstone is a bed of coal 3 feet 8 inches thick as measured at location 135. Up the gully northwest of location 135 a section was measured at location 136, about 230 feet above the Trout Creek sandstone.

Coal in Horse Gulch.—The lowest coal bed exposed in Horse Gulch was measured at location 137, about 200 feet above the Trout Creek sandstone. It contains 2 feet 11 inches of coal overlain by shaly sandstone and underlain by brown shale. About 50 feet above the bed at location 137 the section shown in Plate IX was measured; location 138 is at the top of the section.

Approximately 130 feet above this section are the beds measured at location 139. From location 139 to the top of the hill on the northwest the rocks are well exposed. Apparently a large amount of coal has burned at the surface throughout the next several hundred feet of beds. Location 140 is on an old prospect. The drift goes into the hill on the east side of the gulch, but it was impossible to determine its length because the roof had caved about 15 feet from the opening. The bed is 6 feet 1 inch thick and is overlain by shaly sandstone. Coal was found to underlie the material in the bottom of the drift. The next coal observed occurs about 2,000 feet farther up the gulch, at locations 141 and 142. The bed at location 141 contains 8 feet 11 inches of coal overlain by gray sandy shale and underlain by brown shale. About 20 feet above it is another bed (142) that contains 2 feet 4 inches of coal.

Location 143, about 1,500 feet farther up the gulch, marks a bed which comprises two separate benches of coal separated by 11 inches of brown to black carbonaceous shale containing thin streaks of coal. The upper bench of coal is 4 feet 6 inches thick and is overlain by gray sandy shale. The lower bench is 2 feet thick and is underlain by brown to black carbonaceous shale containing thin streaks of coal. This lower bench is traversed by a layer of sandstone ranging in thickness from 1 inch to 10 inches, which cuts across the coal at an angle of about 30° with the bedding. The next four beds above are very closely related and were measured at locations 144, 145, 146, and 147. About 80 feet above the upper bed (147) of these sections there is an exposure of coal at location 148. This bed contains at least 4 feet 2 inches of coal. The top of the bed is not well defined, and the bottom extends below the bottom of the valley. The highest bed that was found in this gulch occurs at location 149. It is a thin bed, however, measuring only 1 foot 2 inches, and is overlain and underlain by brown shale.

Coal in Sand Spring Gulch.—Some coal was found at location 150, in a small gully extending south from the main valley of Yampa River in the NW. ¼ sec. 35. At that point the bottom of the section was estimated to be about 180 feet above the Trout Creek sandstone. The lower coal bed continues downward into the bottom of the gulch, so that its bottom was not found. At location 151, about half a mile up the gulch from Yampa River and about 700 feet above the Trout Creek sandstone, there is a coal bed containing 3 feet 3 inches of good coal overlain and underlain by brown shale. Location 152, in the northwest corner of sec. 25, is on a bed that con-



SECTIONS OF COAL BEDS IN T. 6 N., R. 93 W.

tains 2 feet 11 inches of coal overlain by 2 feet 6 inches of brown and gray sandy shale. The shale underlies a bed of sandstone about 15 feet thick. The coal is underlain by brown shale. Location 153 is on another bed, about 100 feet higher, which contains 1 foot 7 inches of coal overlain and underlain by brown shale. Locations 154 and 155 are on a bed which, from all appearances, lies below the one at location 153. This bed is 8 feet thick and is overlain and underlain by brown sandy shale. The only impurity in the bed consists of a parting 1 inch thick 23 inches from the top. Location 156 is believed to be about 100 feet above where this bed should crop out. By means of certain sandstones closely related to the bed at location 155 the horizon of the coal bed was traced southeastward to location 157, where it is burned out, and also to location 158.

Coal in sec. 36.—Location 159, in the SW. ¼ sec. 36, marks a bed 4 feet 6 inches thick, overlain and underlain by brown shale. Locations 160 and 161, near the east line of sec. 36, mark two thin coal beds which are about 40 feet apart. The lower bed (160) is 1 foot 9 inches thick and is overlain by shaly sandstone and underlain by brown shale. The upper bed (161) is 1 foot 6 inches thick and is overlain and underlain by brown shale.

Many of the thick coal beds underlying this township are burned at the surface. The thinner beds have apparently escaped the burning and are the only ones now available for measurement.

QUANTITY OF COAL

The tonnage of coal in this township was computed upon the basis of the amount of coal measured in the stratigraphic section 1 mile southeast of Lay and also in Horse Gulch, in T. 6 N., R. 93 W. (See p. 53.) The total area included within an outcrop line drawn at a horizon representing the center of weight of the Fairfield group of coal beds amounts to 23.34 square miles. That included within an outcrop line drawn at a horizon representing the center of weight of the Twentymile group of coal beds amounts to 17.9 square miles. In computing the tonnage the depth limit was taken to be 3,000 feet, but in this township none of the coal beds are believed to exceed that depth. It is accordingly estimated that the total quantity of coal in the Fairfield and Twentymile coal groups in this township amounts to 3,620,100,000 tons.

POSITION OF THE COAL BEDS IN RELATION TO MINING

Most of the coal exposed in the township occurs in the sides of the principal gulches. Drifts can be driven in on all these coal beds, and a considerable tonnage of coal can be mined up the rise beneath the ridges. By carrying the main drift at a slight angle with the strike of the beds it will have sufficient fall to drain the mine and also to assist materially in the haulage of loaded cars. In mining the coal on a large scale a shaft could be sunk at some point in the northeastern part of the township. The depth of shaft necessary to reach the Trout Creek sandstone at any point could be ascertained by subtracting the altitude of the structure contour from that of the surface contour at the same point. At any point within the Lewis shale area the shaft would pass through all the coal beds in the Williams Fork formation. As was pointed out in Chapter IV under the heading "Accessibility," a shaft in the northeastern part of the township would be readily accessible to the main line of the Denver & Salt Lake Railroad if that line is extended on the projected route west of Craig.

T. 6 N., R. 94 W.

TOPOGRAPHY

T. 6 N., R. 94 W., does not present any very striking surface features, though there is considerable contrast between the broad valley of Yampa River, whose altitude is about 6,000 feet above sea level, and the upland occupied by the Browns Park formation (Miocene?) whose highest ridges rise about 6,600 feet. This township is drained entirely by Yampa River and its tributaries. The gulches that open into the broad valley of the Yampa contain running water only while snow is melting or for a short time after a shower of rain. The largest tributary is Temple Gulch, which drains the southwestern part of the township.

STRATIGRAPHY

More than half the township is covered by flat-lying Browns Park beds (Miocene?) and by the alluvium along the river. Pennsylvanian rocks crop out in Little Juniper Mountain, in the western part of the township; the Dakota sandstone and some underlying beds are poorly exposed near Juniper Hot Springs. Eastward from the Dakota sandstone is the only outcrop of the entire thickness of Mancos shale to be found in these quadrangles, but unfortunately the exposures are rather poor except those of the basal part. Rocks of the Mesaverde group lie above the Mancos shale and occupy only a small area in the eastern part of the township. The lithologic character of the Mesaverde and the reasons for separating it into the Williams Fork and Iles formations are stated in Chapter II. The Trout Creek sandstone, on the top of which the plane of separation is drawn, crops out a few hundred feet west of the east line of the township.

STRUCTURE

The uplifting of the rocks in the northwestern part of this township has raised the Carboniferous beds to as high an altitude as that of the Williams Fork formation north and south of Axial Basin. Inasmuch as there is between these older and younger beds, in all probability, from 10,000 to 15,000 feet of strata, the assumption of at least that amount of uplift is justified. From the outcrop of older rocks the beds dip in a general easterly direction at an angle of about 15°. At Juniper Hot Springs the dip is from 28° to 31°. The angle of dip decreases within a short distance, however, for at location 571, a few hundred feet to the east, the dip is only 22°. Across the valley toward the east the basal member of the Iles formation dips east at an angle of only 15°.

The beds of the Browns Park formation throughout the township lie almost horizontal.

COAL

No exposures of coal above the Trout Creek sandstone were found in this township. The only coal beds of any importance found in the Iles formation occur near its base in secs. 13 and 24. At location 162, in the SE. ¼ sec. 24, a bed contains 3 feet 4 inches of coal that was considered of fair quality. The coal bed is overlain by gray shale and underlain by brown shale.

At location 163, in the SW. ¼ sec. 13, the following section was measured:

Section of coal beds at location 163, in the SW. ¼ sec. 13, T. 6 N., R. 94 W.

	Ft.	In.
Coal	1	2
Shale, brown, sandy	2	9
Shale, black, carbonaceous		8
Shale, brown, sandy	4	9
Shale, black, carbonaceous		8
Coal	1	8
Total section	11	8
Total coal	2	10

The section given above, like the one at location 162, occurs immediately above the sandstone that forms the "rim rock."

T. 5 N., R. 94 W.

TOPOGRAPHY

There are no very prominent surface features in T. 5 N., R. 94 W. The township is drained by several more or less parallel valleys that head on the north slope of the Danforth Hills and after crossing the township in a northeasterly direction open out into Morgan Gulch and the alluvial flat along Yampa River. These gulches furnish easy routes of travel between Yampa River and the Danforth Hills and may at some future time become of considerable economic importance in the transportation of coal north to Yampa Valley.

STRATIGRAPHY

The rocks that crop out in this township are of Cretaceous and Tertiary age and include the Mancos shale and the Iles, Williams Fork, and Browns Park formations. The Mancos shale and Iles and Williams Fork formations are conformable and represent a long period of continuous sedimentation during Upper Cretaceous time. The Browns Park formation, which rests unconformably upon the upturned and eroded edges of the Upper Cretaceous beds, is regarded as of Tertiary (probably early Miocene) age.

STRUCTURE

The coal-bearing rocks of this township lie on the south flank of the Axial Basin anticline and dip 23°–35° S.

COAL

The beds of coal found in this township are associated with the sandstone and sandy shale of the Mesaverde group.

COAL IN THE WILLIAMS FORK FORMATION

As shown on the map there is very little of the Williams Fork formation exposed at the surface of this township. The Trout Creek sandstone member of the underlying Iles formation crops out on the north side of Red Cone, near the township line, on the south edge of sec. 32. The peak gets its name from red rock produced by the burning of coal beds a few feet above the Trout Creek sandstone. The outcrop of this sandstone enters the township again where it swings around the ridge in the SE. ¼ sec. 31. Location 55 is on a bed of coal 1 foot 7 inches thick, overlain by drab shale and underlain by brown shale. This bed is about 35 feet above the Trout Creek sandstone. Location 105 is believed to be on the Trout Creek sandstone on the west side of Maudlin Gulch. Very little coal is exposed in the slopes here, and it is difficult to trace the Trout Creek sandstone with certainty for some distance west and north of location 105.

COAL IN THE ILES FORMATION

A section measured in Red Cone Gulch indicates a fair idea of the character of the coal in the Iles formation. Although there are numerous streaks of coal a few inches thick, very few of them are sufficiently thick and pure to pay to work while other more valuable coals are so near at hand. The beds appear to be lenticular. From observations elsewhere it is the writer's belief that the best beds within this township occur in a zone about 300 feet thick below the Trout Creek sandstone. Location 106 marks a prospect on the east side of Maudlin Gulch where a drift has been carried in on a coal bed for about 10 feet. This bed measures 5 feet 7 inches in thickness and is overlain by gray sandy shale and underlain by shaly sandstone. The upper 4 feet 10 inches of the bed consists of coal that exhibits a rather platy structure. The lower 9 inches of the bed contains considerable carbonaceous shale.

T. 5 N., R. 93 W.

TOPOGRAPHY

The greater portion of T. 5 N., R. 93 W., is drained by the stream in Morgan Gulch which heads near Magnetic Mountain, on the top of the divide between White River and Yampa River, and flows in an almost straight northeasterly course down the north flank of the Danforth Hills to Axial Basin and thence northwestward into Yampa River. This creek is supplied by numerous small springs along the north slope of the Danforth Hills and carries running water the year round throughout most of its course, but owing to the decrease in supply from tributaries and the increase in evaporation the lower part is dry part of the time. Morgan Gulch is separated from the valley of Yampa River on the northeast by a great compact mass of sandstone and associated beds commonly known as Duffy Mountain. These beds when viewed from the northeast do not present a striking appearance, as they are inclined gently from the mountain top down toward the valley of Yampa River, and the gulches in the northeast slope of the mountain closely conform to the dip of the beds. When viewed from the southwest, however, their appearance is very striking in contrast with Axial Basin, for they form a continuous escarpment several hundred feet high entirely across the township. The solid wall of this escarpment is interrupted to some extent in the southeastern part of the township by subordinate escarpments formed by thin-bedded sandstones in the Mancos shale a few hundred feet below the base of the Iles formation.

STRATIGRAPHY

The rocks that crop out in this township are chiefly of Upper Cretaceous age. The only Tertiary beds are outliers of the Browns Park formation (Miocene), which merely cap the higher hills. The Upper Cretaceous rocks represent a long period of uninterrupted sedimentation and comprise from the base upward the Mancos shale and the Iles and Williams Fork formations. Practically all the coal of this township is included in the lower part of the Williams Fork formation, which overlies the Trout Creek sandstone. From the map it will be seen that this sandstone crops out in secs. 1, 2, 3, and 12.

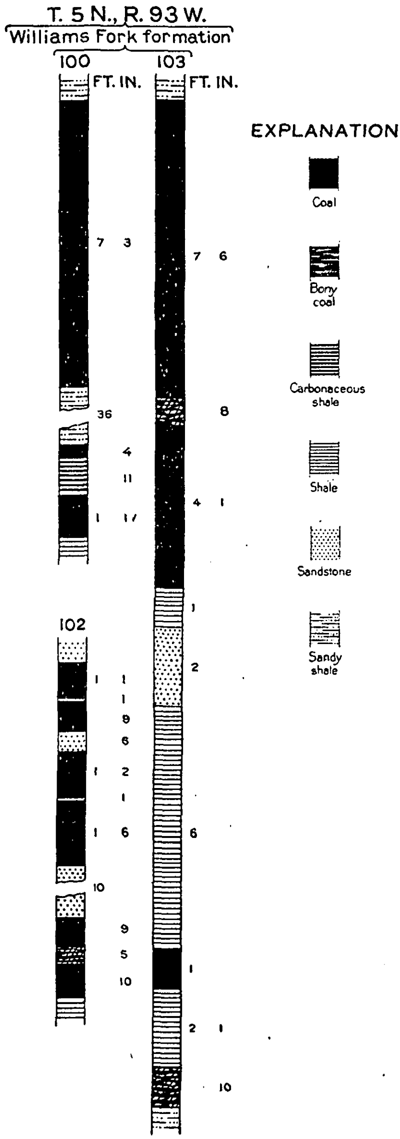


FIGURE 6.—Sections of coal beds in T. 5 N., R. 93 W.

STRUCTURE

The structure in this township is very simple. The main structural feature is the unsymmetrical Axial Basin anticline, whose axis crosses the southwestern part of the township. The rocks of the Mesaverde group in the northeastern part of the township lie on the flank of the great anticline and dip about 7° NE. The same beds south of Axial Basin dip 30°–35° SW.

COAL

COAL IN THE WILLIAMS FORK FORMATION

But little of this township is underlain by rocks of the Williams Fork formation. The only coal beds found occur in sec. 1, where the slopes above the Trout Creek sandstone are steep and where the beds are for that reason not covered deeply by surface rocks. Location 99 is on the Trout Creek sandstone, which is exposed in the bottom of the gulch for a distance of about 1,200 feet. Location 100 is about 75 feet above the Trout Creek sandstone.

Location 101 marks the point where the Trout Creek sandstone dips under the flood plain of Yampa River. Sections were measured at locations 102 and 103. (See fig. 6.) A large proportion of the coal contained in the lower part of the Williams Fork formation has burned out at the surface west of location 101.

COAL IN THE ILES FORMATION

For information concerning the amount and character of the coal in the Iles formation the reader is referred to the detailed section on the east side of Milk Creek where it enters the south side of Axial Basin (pp. 15–17). From that section it is seen that, though considerable coal is interbedded with the sandstone and sandy shale, the coal beds are thin. Owing to the thinness of the beds and the character of the slopes in this township very little coal is exposed. Location 104, in sec. 10, is about 50 feet below the beds composing the "rim rock," as described on page 12. A few hundred feet north and east of location 104 some coal has burned immediately above the "rim rock." About 100 feet above the "rim rock" is another prominent sandstone ledge, and immediately above this ledge is a belt of gray and brown shale containing some thin streaks of coal. About 40 feet higher is another shale bed, which is black and carbonaceous but contains no coal. There are probably some thin coal beds in the Iles formation in this township, as indicated by the sections previously referred to, but no further exposures were found.

QUANTITY OF COAL

The quantity of coal in this township was computed upon the basis of the thickness actually measured in the section 1 mile southeast of Lay, in T. 7 N., R. 93 W., as shown in Plate XVIII. It was found that the different beds of coal underlying the several tracts are equivalent to 117.6 feet of coal underlying 264 acres, or 0.41 square mile, and the total quantity of coal in this township is estimated to be 56,000,000 tons.

T. 5 N., R. 92 W.

TOPOGRAPHY

When viewed from Axial Basin the most conspicuous surface feature in T. 5 N., R. 92 W., is the abrupt escarpment formed by the basal beds of the Iles formation and the uppermost beds of the Mancos shale. From the valley of Stinking Creek the ground rises rapidly for about 400 feet to the massive sandstones at the base of the Iles formation, but thence to the summit of Iles Mountain these sandstones form a practically vertical wall about 500 feet in height. Although highly dissected by numerous gulches, the surface in general slopes north from the top of the mountain to Yampa River, which has intrenched its meanders deep into the coal-bearing rocks of the Williams Fork formation. As the principal resource of this township is coal, the relation of the coal-bearing beds to Yampa Valley, the main artery of transportation through the coal field, is very important. It seems reasonable to suppose that most of the coal mined in this township will be taken out by a railroad extending down Yampa Valley from the main line of the Denver & Salt Lake Railroad, or some other line extending west from Craig. The most feasible routes from the main line into this field and the grades involved are given under "Accessibility" in Chapter IV.

STRATIGRAPHY

The rocks that crop out in this township belong to the Upper Cretaceous series and include from the base upward the Mancos shale and the Iles and Williams Fork formations. These formations represent a long period of uninterrupted sedimentation, the only change recorded being one from marine to brackish and fresh water conditions. The nature and stratigraphic relations of these formations are described in Chapter II.

The Mancos shale crops out in a narrow belt immediately south of Iles Mountain.

The rocks of the Mesaverde group (Williams Fork and Iles formations) rest upon the Mancos shale and occupy almost the entire township. There are three rather distinct types of land in this township. The rich alluvium along Yampa River consists of fine sediment brought down to the main valley by the smaller streams. Each of the other two types is intimately related to the formation from which it is derived. (See p. 14.)

Nearly all the coal of this township is included in the lower part of the Williams Fork formation, which overlies the Trout Creek sandstone. That sandstone bed was traced continuously from a point near the center of the west side of sec. 7 southeastward to the east line of sec. 25. There the strike of the rocks changes abruptly, in obedience to the synclinal structure. From the sharp turn the outcrop was traced northwestward for several miles into the valley of Yampa River. The outcrop finally leaves the township at its northeast corner. The Twentymile sandstone was also traced with very little difficulty and mapped from the center of the north side of sec. 6 and then north as a very prominent sandstone along the crest of the ridge in sec. 2.

STRUCTURE

The structure in this township is clearly brought out by the structure contours, which show the altitude of the top of the Trout Creek sandstone, or base of the Williams Fork formation, above mean sea level. From them it is seen that the beds throughout most of the township dip 8°–12° N. The northeastern part of the township includes a well-defined synclinal fold whose axis crosses the township from the northeast corner of sec. 24 to the center of the north side of sec. 3. On account of this syncline the strike of the Trout Creek sandstone changes very abruptly from somewhat south of east to northwest. The syncline is unsymmetrical, the dips being much steeper on the northeast side of the axis than on the southwest side.

COAL

The beds of coal in this township occur only in the Mesaverde group, and the principal beds are included in the upper or Williams Fork formation.

COAL IN THE WILLIAMS FORK FORMATION

Although there is known to be an abundance of coal in the Williams Fork formation, favorable exposures for measurement are scarce in this township for two reasons—because of the extent to which the coal is burned on the outcrop and because most of the slopes conform closely to the dip. In the few places where the abundantly coal-bearing strata above the Trout Creek sandstone member of the Iles formation are exposed along the steep slopes the conditions have been especially favorable to combustion.

Location 405, in sec. 6, is on a prospect where some coal has been taken out. The coal bed contains 6 feet 8 inches of coal having an intense black color and vitreous luster. The coal breaks out in rectangular masses due to jointing. The joint planes are coated with selenite. The coal is overlain by light-gray thin-bedded shaly sandstone containing thin streaks of coal. South of location 405, on the steep slope east of Fuhr Gulch, there is evidence of considerable burning. Some coal is exposed a few feet above the Trout Creek sandstone at location 406, near the point where Milk Creek empties into Yampa River. The total thickness of the coal is 3 feet 2 inches. The upper 15 inches and the lower 19 inches of the bed consist of coal free from partings, but the 4 inches of coal between contains some thin streaks of shale. The bed is overlain by brown shale and underlain by shaly sandstone. On the steep slope up from Milk Creek at location 407 and farther east the formation is well exposed, except that the coal beds have burned along these outcrops. Three coal beds were seen immediately above the Trout Creek sandstone at location 408.

Near the bottom of a narrow gulch running east from Milk Creek is a bed of coal 4 feet 2 inches thick. The only impurity in the bed is a 1-inch parting of sandstone about 23 inches from the bottom.

As the position of this outcrop was not accurately determined the writer can give only an approximate location. In the northern part of sec. 20 a section was measured at location 409, immediately above the Trout Creek sandstone.

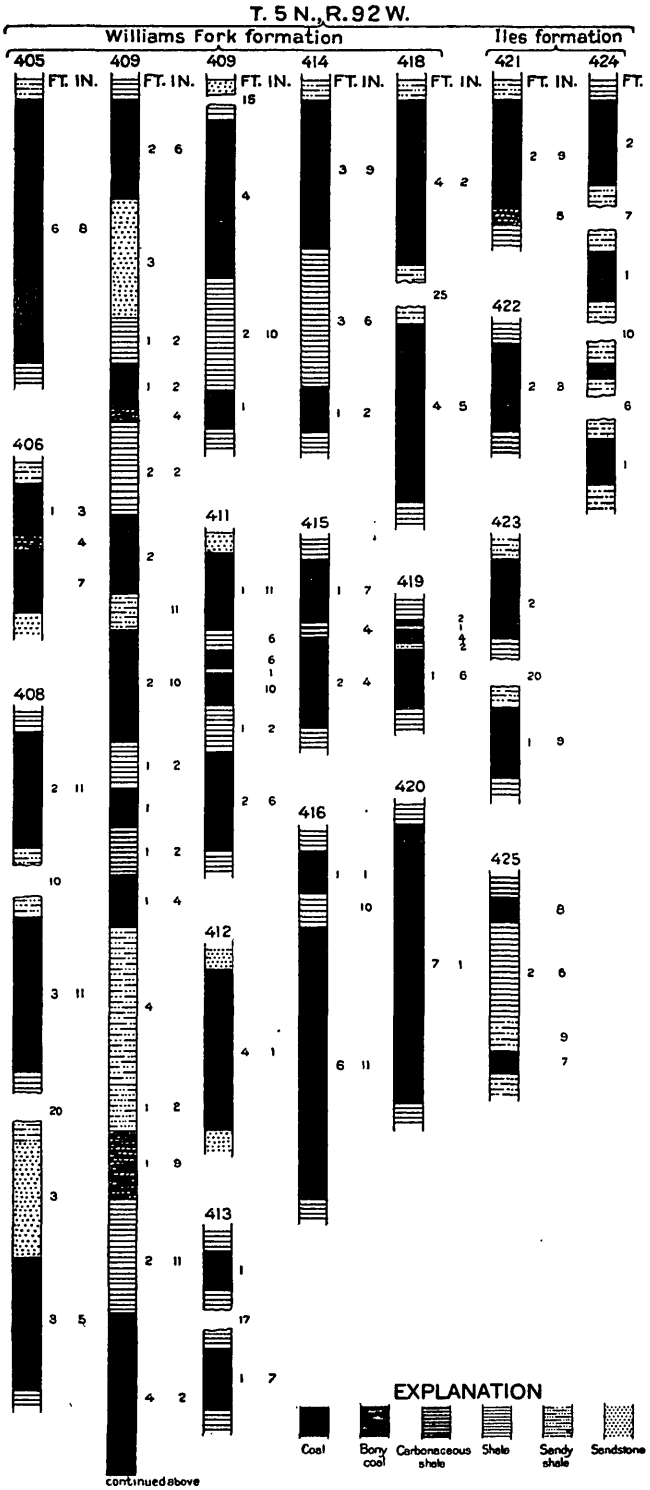
Owing to the character of the slopes no other coal is exposed between this point and sec. 12. In sec. 12 the beds dip so steeply that most of the surface débris has been removed. It was possible, however, to measure only a small proportion of the coal, as most of the beds had burned out at the surface. At location 410 a thick bed was uncovered, the bottom of which is about 10 feet above the top of the Trout Creek sandstone. From the width of the horizontal exposure the bed was computed to be about 9 feet 4 inches thick. A few hundred feet farther southwest, at location 411, the section shown in Plate X was measured; the bottom of the section is about 40 feet above the Trout Creek sandstone.

At location 412, a short distance to the west, a coal bed measuring 4 feet 1 inch is about 60 feet above the section at location 411. The coal that was seen is merely what is left of a partly burned coal bed. It is underlain by burned sandstone and ashes. Several hundred feet to the northwest, at location 413, two thin beds of coal separated by about 17 feet of shale and sandstone were uncovered. The upper bed is 1 foot and the lower one is 1 foot 7 inches in thickness. There is abundant evidence of burning throughout the zone included between the Trout Creek sandstone and the main gulch immediately west of location 413. Three points were found on the slope above the Twentymile sandstone in sec. 4 where some coal is exposed, and a section was measured at the lowest one of the three (location 414).

Several hundred feet farther northeast and up the gulch from location 414 another bed was opened at location 415. This bed contains two benches of coal separated by 4 inches of black carbonaceous shale. The upper bench contains 1 foot 7 inches of coal, overlain by brown shale, and the lower bench 2 feet 4 inches, underlain by brown shale. This bed is probably about 125 feet above the one at location 414. The highest exposure of coal occurs at location 416, where a section was measured.

At location 417, in the northwest corner of sec. 10, a bed of coal about 64 feet below the top of the Twentymile sandstone is burned at the surface. Some coal was also found at the edge of the valley near the center of sec. 3. The beds were measured at locations 418 and 419. Location 420, on the east side of sec. 2, marks an old coal prospect.

The roof of the opening has caved, and it is probable that no work has been done here for many years. The bed appears to contain about



SECTIONS OF COAL BEDS IN T. 5 N., R. 92 W

7 feet 1 inch of coal overlain by drab shale and underlain by brown shale. All but the upper 2 inches of the bed consists of good coal. Owing to the amount of débris and the extent to which the coal has burned out at the surface no other coal beds could be examined on the slope above location 420. It is known, however, that a large number of coal beds occur between the Trout Creek sandstone and the Twentymile sandstone, because of the beds that were measured in this zone on the west side of the river near the center of sec. 36, about 1 mile to the northeast.

COAL IN THE ILES FORMATION

The sections that were measured on the south side of Axial Basin and are given on pages 116–118 will give the reader a fairly good idea of the character of the coal beds in the Iles formation. Owing to the thinness of the beds they are rarely exposed in this township. Location 421, in the NW. ¼ sec. 30, is on a prospect that consists of a drift about 20 feet long. The bed contains 3 feet 2 inches of impure coal, overlain by shaly sandstone and underlain by brown shale.

This coal bed lies immediately above the "rim rock." On the opposite side of Milk Creek it is probably represented by a bed of black carbonaceous shale containing only thin streaks of coal. Some coal was also observed on the west side of Milk Creek at location 422. At that point the bed is 2 feet 3 inches thick and is overlain and underlain by brown shale. The lower 17 inches of the bed consists of good coal, but the upper 10 inches contains many thin streaks and lenses of brown shale. Two thin beds of coal were also found about 300 feet above the base of the Iles formation at location 423, on the south side of sec. 28. The lower bed contains 1 foot 9 inches of coal, overlain and underlain by brown sandy shale. The coal has a platy structure and contains thin streaks of shale. The upper bed is 20 feet higher and contains 2 feet of coal, overlain by sandy shale and underlain by brown shale.

Some coal was opened about 200 feet below the top of the Trout Creek sandstone at location 424, near the center of sec. 22.

At the point where the formation swings north toward Hamilton, about 1 mile east of the east line of the township, about 6 feet of brown and black carbonaceous shale occurs immediately above the "rim rock." The steep hillside above was prospected thoroughly, but only one bed of coal was found, which is 1 foot 9 inches thick. Another exposure of coal was found about 150 feet below the Trout Creek sandstone at location 425, in sec. 12.

QUANTITY OF COAL

The tonnage of coal in this township was computed upon the basis of the amount of coal actually measured in the section 1 mile southeast of Lay and also in Horse Gulch, in T. 6 N., R. 93 W. (See columnar sections in Pl. XVIII.) The total area in this township included within an outcrop line drawn at a horizon representing the center of weight of the Fairfield group of coal beds amounts to 15.38 square miles, and the area included within an outcrop line drawn at a horizon representing the center of weight of the Twentymile group of coal beds amounts to 2.23 square miles. In computing the tonnage the depth limit was taken to be 3,000 feet, but in this township none of the coal beds are believed to exceed that depth.

From the data presented the quantity of coal in the Fairfield coal group underlying this township is calculated to be 2,116,000.000 tons and that included in the Twentymile coal group is calculated to be 57,000,000 tons, making a total of 2,173,000,000 tons in the township.

RELATION OF TOPOGRAPHY AND STRUCTURE TO MINING

By referring to the map it will be seen that Yampa River has cut its channel in the Williams Fork formation. The attitude of the formation with respect to the course of the river indicates that a large tonnage of coal can be mined by drifts on the beds from the river valley. According to the writer's interpretation of the structure, a shaft sunk near the southwest corner of sec. 3 would reach the Trout Creek sandstone at a depth of about 800 feet. From the sections measured above the Trout Creek sandstone it is obvious that this shaft would pass through a large number of coal beds. From this shaft main haulageways could be opened east and west, deviating sufficiently from the strike of the beds to yield the necessary grade for haulage and drainage. The coal could then be mined up the rise, which ranges from 8° to 12°. The accessibility of Yampa Valley to the main line of the Denver & Salt Lake Railroad near Craig is pointed out under the heading "Accessibility" in Chapter IV.

T. 5 N., R. 91 W.

TOPOGRAPHY

The surface of T. 5 N., R. 91 W., is very rough and rugged and ranges in altitude from 6,150 feet above sea level in the bottom of Williams Fork canyon, in the northwest corner of the township, to 7,765 feet on the summit of the Williams Fork Mountains, in the northeast corner. The striking feature of this township, in an economic and commercial sense, is the great canyon of Williams

Fork, which crosses the township and furnishes an easy route of communication in an east-west direction, and the more open valley of its tributary Morapos Creek, which affords an outlet to the south.

As almost all the drainage leads into Williams Fork, and as each side stream has cut a deep gulch down to the level of the canyon floor, it follows that practically all of the township is naturally tributary to the main potential artery of transportation through it. Coal is the principal resource of the township and when mined will naturally be hauled down the side gulches to Williams Fork, where eventually there will be a railroad to transport it either to the west or east. At present it would probably go down the stream to Yampa River and thence to the Denver & Salt Lake Railroad. If the side gulches are too steep for railroad connection with the mines, then the coal could be taken on a tramroad along the sides of the gulches to some commanding spur and thence lowered to the main line by cable. A branch line of railroad could be extended down Yampa Valley and up Williams Fork from the main line of the Denver & Salt Lake Railroad near Craig without involving grades exceeding 0.4 per cent. The Trout Creek sandstone dips beneath the valley of Williams Fork about half a mile above the northwest corner of this township, rendering all the coal beds in the principal group accessible from the valley of Williams Fork near the point where it empties into Yampa River.

STRATIGRAPHY

The formations that crop out in this township are of Upper Cretaceous age and include the Mancos shale and the Iles and Williams Fork formations. These formations are believed to represent a period of continuous sedimentation during which there was merely a change from marine to brackish and fresh water conditions. A more complete description of these formations is given in Chapter II.

In certain localities zones of thin-bedded sandstone occur in the upper part of the Mancos shale. The zone that occurs about 800 feet below the top of the formation, which is herein named the Morapos sandstone member, completely encircles the Hamilton (Moffat) dome about 2 miles south of the Hamilton ranch. The strikes and dips recorded at different points on this sandstone are shown on Plate XIX.

By far the greater part of this township is occupied by the rocks of the Mesaverde group. In their composition these rocks are very different from those of the Mancos shale. (See p. 14. The ordinary agencies of erosion wear away the shale more rapidly than they do the more firmly consolidated sandstone, and in consequence the shale outcrop is reduced to a much lower level. Axial Basin illustrates this on a large scale, and the contrast in elevation between the Mancos shale and the rocks of the Mesaverde group would be more conspicuous in this township were it not for the degree of resistance offered by the Morapos sandstone. Interbedded with the massive sandstones of the Mesaverde group are zones of softer beds, such as sandy shale and numerous beds of coal. The effect of the agencies of erosion upon such beds is to carve them out into rough and rugged surfaces, where it is extremely difficult for sufficient soil to accumulate to support a growth of any kind of vegetation. The area from Williams Fork north to the crest of Williams Fork Mountains is partly of that nature, although on the gentler slopes and in valleys and along the ridges there are considerable quantities of grass for stock.

The coal in this township occurs almost entirely in the lower part of the Williams Fork formation, which overlies the Trout Creek sandstone. The sandstone is well exposed in this township. The axis of the Round Bottom syncline rises so rapidly in approaching the Hamilton dome from the northwest that only a small thickness of the Williams Fork formation is present in this township west of the river. It dips north beneath the valley of Williams Fork about half a mile south of the northwest corner of the township. Thence it extends eastward over the ridges and down into the gulches, as shown on the map. The Trout Creek sandstone forms a very prominent cliff on the west side of the old road leading up Castor Gulch from Hamilton to Craig. The Twentymile sandstone is well exposed at several places near the top of the south side of the main divide and is especially noticeable east of the old road leading up Castor Gulch, where it forms cliffs from 50 to 75 feet in height. That portion of the Williams Fork formation which lies above the Twentymile sandstone contains a number of valuable coal beds, but the upper part is eroded, and only the lower part crops out in this township. That part of the formation which lies between the Trout Creek and Twentymile sandstones contains the principal coal beds. The bright-red color due to the burning of the coal is very pronounced in this township and is usually present from 300 to 500 feet above the Trout Creek sandstone.

STRUCTURE

The structure of T. 5 N., R. 91 W., is more complicated than that of any of the neighboring townships, for the rocks have been involved in two separate anticlines as well as two separate synclines. The prevailing dip in the north third of the township is north toward the axis of the Big Bottom syncline, at angles of 7° to 10°. From the Hamilton dome northeast to the axis of the Badger Creek syncline the beds are inclined downward at a similar angle, but along the southwest side of the Hamilton dome the prevailing dip is as high as 28°. Farther northwest, between the axis of the Williams Fork anticline and that of the Round Bottom syncline the average dip is about 15°. The strike and dip recorded on the Morapos sandstone at different points indicate the size and shape of the Hamilton dome. The structure contours show that the beds at the top of the Hamilton dome are 3,250 feet higher than corresponding beds at the northwest corner of the township and about 1,800 feet higher than those at the lowest point in the Badger Creek syncline.

COAL

COAL IN THE WILLIAMS FORK FORMATION

The most important group of coal beds in this field occurs in the lower part of the Williams Fork formation, which rests on the Trout Creek sandstone. This sandstone was traced continuously from location 307, in the valley of Williams Fork, to location 260, in Horse Gulch near the east line of the township. Locations were made by instrument on the sandstone in the gulches and on the intervening ridges, and the outcrop of the sandstone between these accurately determined points was drawn on the basis of the surface features. From the field notes it was possible to determine the approximate stratigraphic relations of a great many of the coal beds measured in the township, and an attempt was made to express those relations by means of columnar sections. Most of the beds are shown in columnar sections in Plate XVIII. The sections show the coal beds measured in secs. 6, 7, and 8 and those measured near Ute and Castor gulches. Twenty-six different beds were measured on the steep slope leading down to Williams Fork and Yampa River in sec. 6 of this township and secs. 29, 30, and 31 of T. 6 N., R. 91 W. Eleven of these beds occur between the Trout Creek and Twentymile sandstones, and fifteen of them are above the Twentymile sandstone. The total coal included in the twenty-six beds amounts to 139 feet 2 inches. The thicknesses and stratigraphic relations of the various beds are shown in Plate XVIII. When two or more measurements were made on the same bed the average of the different thicknesses is given on the plate.

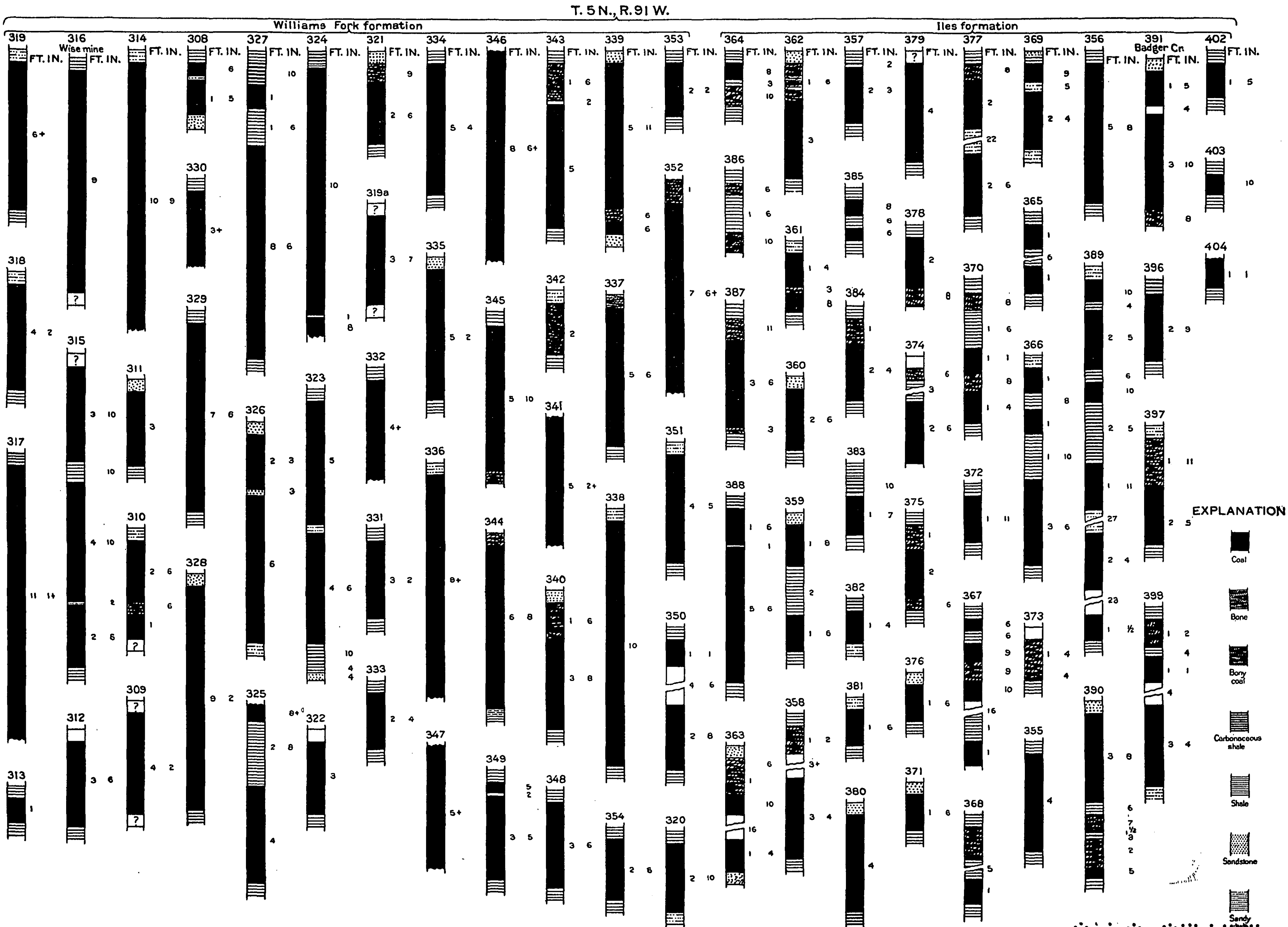
A total of 74 feet 9 inches of coal was measured between the Trout Creek and Twentymile sandstones, and nearly all the coal is included in beds between 6 and 11 feet thick. The approximate intervals between the beds are shown in Plate XVIII. Further details concerning the character of the coal and the overlying and underlying beds are given in sections 308 to 319, Plate XI.

Location 316 marks the Wise mine. The coal was sampled at the end of the main entry, 250 feet in from the mine mouth. The entire bed was sampled with the exception of the lower 6 inches, and the results of the analysis are shown under laboratory No. 9135 in the table on page 46.

The next good exposure of the coal beds east of Williams Fork is in the gulch in secs. 7 and 8, mainly in sec. 8. The coal beds that were measured in this gulch are shown in columnar section in Plate XVIII, and also in Plate XI, under Nos. 321 to 330. A bed containing 3 feet 7 inches of coal, overlain and underlain by shale, was measured west of the gulch at location 319a. The bed there is at about the same horizon as the one measured at location 321. Some isolated exposures of coal beds were seen in sec. 4 and near the north line of sec. 5. Locations 331 and 333 are probably on the same bed, which lies below the one at location 332. The old prospect opening was badly caved at location 331, but it was found that at least 3 feet 2 inches of coal is present. The top of the bed was not well defined at location 333, farther east, but from all appearances there is at this place at least 2 feet 4 inches of coal underlain by shale. At location 332, which is about 100 feet higher stratigraphically, is a bed of coal which is overlain by shale. It contains 4 feet or more of coal, the bottom of the bed not having been found.

Some coal beds were also measured at locations 334, 335, and 336, between the good exposures of coal in sec. 8 and those of Horse Gulch. At location 334 a bed contains 5 feet 4 inches of coal, overlain and underlain by shale. About 200 feet farther up the gulch there are two thin beds of coal separated by 14 inches of shaly sandstone. The upper bed is 8 inches thick, and the lower one 6 inches. At locations 335 and 336, on the ridge about half a mile farther southeast, two beds of coal were measured. The lower one of the beds (335) is about 15 feet above the Trout Creek sandstone and contains 5 feet 2 inches of coal, overlain by sandstone and underlain by brown shale. The upper bed (336) is about 110 feet above the sandstone. The exact thickness of the bed is not known, as the bottom was not seen, but it contains at least 9 feet of coal.

The coal beds that were measured farther east in Ute and Castor gulches are represented graphically in columnar section in Plate XVIII, and are also shown with more detail in Plate XI as sections 339 to 347. The lowest bed of the series, which was measured at location 339, is about 60 feet above the Trout Creek sandstone. The bed measured at location 340 was thought to be at about the same horizon as the one at locations 337 and 338, but if it is the same bed it is much thinner. Its thinness is probably due to burning, for it contains 3 feet 8 inches of coal, underlain by shale and overlain by ashes of burned coal. At location 338, where the full thickness of the bed is present, it contains 10 feet of coal, overlain



SECTIONS OF COAL BEDS IN T. 5 N., R. 91 W.

and underlain by shale. At location 337, where it contains only 5 feet 6 inches of coal, it is also partly burned, for there it is overlain by the ashes of burned coal.

The uppermost bed in this locality was measured at locations 346 and 347, near the head of Ute Gulch. Owing to the abundance of débris it was impossible to locate either top or bottom of the bed at these places, but at location 346 the bed was found to contain at least 8 feet 6 inches of coal.

Comparatively little coal was seen above the Trout Creek sandstone in Horse Gulch. The four beds measured there are shown in columnar section in Plate XVIII, and also in more detail under Nos. 348 to 354 in Plate XI. The lowermost bed, which is about 15 feet above the Trout Creek sandstone, was measured at four different places, and the details of the measurements are shown in coal sections 348, 349, 350, and 351. The coal bed at location 354 is about 200 feet above the Twentymile sandstone.

The Round Bottom syncline causes the outcrop of the Trout Creek sandstone to enter this township for a short distance on the west side. Location 320 is the only place where coal was seen. At that location a coal bed was measured which lies about 80 feet above the Trout Creek sandstone and which contains 2 feet 10 inches of coal, overlain and underlain by sandy shale.

COAL IN THE ILES FORMATION

The group of coal beds which throughout this field is commonly included in a zone of the formation extending from 200 to 400 feet below the Trout Creek sandstone, is very little exposed in this township. One bed was measured at location 364, on the west side of Castor Gulch and two in Horse Gulch.

Two coal beds were measured at locations 386, 387, and 388, on the west side of Horse Gulch. The lower bed is composed of two thin benches of coal, as shown by coal section 386, Plate XI. The upper bed, which was measured at locations 387 and 388, is much thicker.

The thickness and stratigraphic relations of the beds described above are shown graphically in the columnar sections in Plate XVIII. The group of coal beds near the base of the Iles formation is much better exposed, for the reason that the massive sandstones with which the coal beds are associated crop out at many places along the steep slopes leading down to Williams Fork. The formation is also well exposed near the lower ends of some of the deeper gulches—for example, Horse Gulch, Castor Gulch, and the gulch leading back into the hills from the Hamilton ranch. Five coal beds were measured in Castor Gulch and five in Horse Gulch, but, as is common with the beds of this group, they are all comparatively thin and of very little economic importance. Their stratigraphic relations are shown in the columnar sections in Plate XVIII. The thickness of the different coal beds and the nature of the overlying and underlying beds in Castor Gulch are shown in sections 357 to 363 and those of the beds in and near Horse Gulch in sections 379 to 385.

It is clear from Plate XI that locations 360 and 361, in Castor Gulch, are on the same coal bed as locations 362 and 363, also that locations 381 and 382, in Horse Gulch, and locations 383 and 384 are on the same coal bed, about 50 feet higher in the formation. None of the coal beds in either gulch exceed 4 feet in thickness, and most of them are much thinner.

The coal bed measured on the point of the ridge at location 378 is in all probability higher in the formation than those previously described. It contains 2 feet of good coal, overlain by shale and underlain by bony coal.

Measurements of coal beds were made at locations 374, 375, 376, and 377 on the steep slope up from Williams Fork west of Horse Gulch, but the relation of the beds is not definitely known. It seems probable, however, that the sections measured at locations 376 and 377 are on the same bed. This is indicated by the fact that each section shows two thin coal beds separated by a considerable interval of sandstone and shale.

Location 374 is also on a coal bed composed of two thin benches of coal, but the interval between them is much less. A few hundred feet farther southeast, at location 375, a coal bed was measured and found to contain 2 feet of coal, overlain by shale and underlain by bone. The next good exposures of coal beds toward the west are along the steep slope north of the gulch that extends up into the hills from the Hamilton ranch. Three separate coal beds were measured in that locality, and the details of the measurements are shown in sections 365 to 373, Plate XI. The beds are about 40 feet apart, and each one was measured at three different places. The character of the lowest bed is indicated by coal sections 370, 371, and 372. The coal ranges in thickness from 1 foot 6 inches to 1 foot 11 inches, and ordinarily it is overlain by 4 or 5 inches of shale beneath a bed of sandstone and underlain by brown shale. The middle bed is shown by sections 367, 368, and 369. As indicated by section 367, it is composed of at least four thin benches of coal separated by brown shale. The nature of the upper bed is shown by coal sections 365, 366, and 373. Like the middle bed, it also is composed of thin benches of coal separated by shale, and the entire group lies beneath a massive bed of sandstone.

Two coal beds were measured on the steep slope on the east side of Williams Fork about a mile northwest of Castor Gulch. The lower one of the two beds at location 356 contains 5 feet 8 inches of impure coal, overlain and underlain by shale. The upper bed (location 355) contains 4 feet of coal of fair quality, overlain and underlain by shale.

COAL SOUTH OF WILLIAMS FORK

Only about 1 square mile of the beds above the Trout Creek sandstone is exposed on Iles Mountain in this township, and the slopes are of such a character that almost no coal is exposed, although it is quite evident from conditions elsewhere that there are numerous beds above the Trout Creek sandstone. The only coal bed that was found occurs at location 320, near the west line of the township. The bed at this point contains 2 feet 10 inches of coal overlain and underlain by brown shale.

It is apparent that the coal beds of the Iles formation increase in thickness toward the east, for in this township there are thicker coal beds than were observed farther west. At locations 389 and 390, in the southeastern part of the township, sections were measured. The upper part of the section at location 389 was correlated with the section measured at location 390 by tracing the bed around the hill.

The most valuable coal bed in the Iles formation in this township occurs at location 391, which marks the Hamilton mine. This coal bed is at about the same horizon as the sections measured at locations 389 and 390. The drift runs northwest for a distance of about 190 feet.

The coal bed was sampled at the end of the main entry, 150 feet from the mine mouth, and the results of the analysis are shown under laboratory No. 9136 in the table on page 45. At the point where the sample was taken the bed measured 5 feet 8 inches. As nearly as could be ascertained, the coal bed 74 feet in from the opening strikes N. 55° E. and dips about 6° S. 35° W. Location 392 is on the top of a very conspicuous sandstone, which is about 150 feet above the bed at the Hamilton mine. This sandstone was traced northwest to location 393 and south to location 394, where it dips beneath the valley of Badger Creek. It soon rises to the surface again, however, and was traced along the west side of Badger Creek and up the side of the bluffs to location 395. The lowering of the beds from this point down to the Hamilton mine is about 266 feet.

Location 396 is on a coal bed which, from its relation to the sandstone, is in all probability the same as that opened in the Hamilton mine. This bed consists of 2 feet 9 inches of coal, underlain by brown shale and overlain by about 8 feet of black carbonaceous shale containing thin streaks of coal. At location 397, on the east bank of Badger Creek, there is 4 feet 4 inches of coal, overlain by sandy shale and underlain by brown shale. The lower 29 inches of this bed consists of fair coal, but the upper 23 inches contains much earthy material, highly stained by oxide of iron. The top of the previously mentioned sandstone bed is not well defined at this point, so that the relation of the sandstone to the coal bed is uncertain. Location 398 is on the same coal bed as that measured at location 396. At this point, however, the coal is all burned out at the surface. Some coal was measured at location 399, which is also probably the same bed as that measured at location 396.

From surface indications some coal has burned out at location 400. A rather prominent bed of sandstone was traced from a point a few hundred feet north of location 401 south around the top of the high peak and north along the west side of the deep gulch immediately to the east. About 6 feet above this sandstone is a coal bed at location 402 which contains 1 foot 5 inches of coal, overlain and underlain by brown shale. About 50 feet higher, at location 403, another thin bed of coal measures 10 inches. At location 404, about three-quarters of a mile farther south, there is about 13 inches of impure coal, and this is probably the same bed as the burned-out coal bed at location 400. The details of the different measurements made in this township are shown in Plate XI.

QUANTITY OF COAL

On the basis of the total number of coal beds, the thickness of each bed, and the area underlain by it, it is estimated that about 803,700,000 short tons of coal underlies the portion of this township north of Williams Fork. For the area of Mesaverde rocks in the southeastern part of the township it was decided to assume a thickness of 6 feet of coal, as this thickness is indicated by several sections measured near the base of the Iles formation. Assuming that amount and making a small allowance for the fraction of a square mile of beds above the Trout Creek sandstone in the western part of the township it is estimated that there are 22,900,000 short tons of coal south of Williams Fork, making 826,600,000 short tons for the entire township.

POSITION OF THE COAL BEDS IN RELATION TO MINING

Williams Fork has established its channel in this township in such a manner that an immense tonnage of coal can be mined merely by running drifts in on the coal beds east of this stream and mining all the coal up the rise above the principal haulageways. Again, as most of the coal beds crop out in the steep south slope of the Williams Fork Mountains, slopes could be run into the hill on any of the beds. Shafts could be sunk at certain points on the north slope of the Williams Fork Mountains which would be accessible to the main line of the Denver & Salt Lake Railroad. The amount of coal available from any one shaft would, of course, depend upon its depth. From the writer's interpretation of the structure a shaft at the southeast corner of sec. 33 of the next township to the north would reach the Trout Creek sandstone at a depth of about 1,250 feet.

T. 5 N., R. 90 W.

TOPOGRAPHY

The western part of T. 5 N., R. 90 W., is very rough. Much of the township, as the map shows, is occupied by the abrupt escarpment formed by the massive sandstones at the base of the Iles formation, which occurs immediately north of Williams Fork and also just west of Waddle Creek. In contrast with the valley of Williams Fork and the low area of Mancos shale, the summit of the Williams Fork Mountains and Harper Hill, farther south, form two rather prominent surface features. With the exception of about half a square mile immediately north of the crest of the Williams Fork Mountains, the entire western part of the township is drained by Williams Fork. Much of the drainage from the south slope of the mountains reaches Williams Fork through Deal Gulch, and that from the southwestern part of the township reaches Williams Fork by way of Waddle Creek. The valleys of Williams Fork and Yampa River form the principal artery of communication between this portion of the coal field and the proposed route of the Denver & Salt Lake Railroad, or any other line of railroad that may extend east or west from Craig, and as the coal is the chief economic resource of this township, this natural and more or less direct outlet to the proposed railroad is of great importance. In Chapter IV it is pointed out that the valley of Williams Fork in this township could be reached by rail from the main line of the Denver & Salt Lake Railroad by a grade not exceeding 0.4 per cent. The grade up Horse and Deal gulches from Williams Fork to the Trout Creek sandstone would amount to about 5 per cent. If any of the side gulches prove too steep for a railroad connection with the mines, then the coal could be taken on a tramroad along the sides of the gulches to some commanding spur and thence lowered to the main line by cable.

STRATIGRAPHY

The strata that crop out in this township are of Upper Cretaceous age and include the Mancos shale and the Iles and Williams Fork formations. As set forth in Chapter II, alluvial tracts are also present along Williams Fork, and these tracts, together with those underlain by the soft, fine-grained Mancos shale, are cultivated to a greater or less extent. Nearly all of the surface occupied by the rocks of the Mesaverde group in the western part of this township is of the rugged type and adapted only to mining and stock raising.

The Trout Creek sandstone, which lies at the base of a valuable group of coal beds, is very conspicuous across the whole of the township and forms massive ledges from 50 to 100 feet thick in many localities. The Twentymile sandstone, which occurs about 900 feet above the Trout Creek, is well exposed in the upper branches of Horse Gulch and is very prominent in outcrop where it is cut by Deal Gulch about half a mile south of the divide. That portion of the Williams Fork formation above the Twentymile sandstone contains a number of valuable coal beds, but as a result of erosion only the lower part of it is present in this township. The bright-red color due to the burning of the coal and the consequent oxidation of the iron in the neighboring sandstone and shale is very pronounced here and is usually present for 300 to 500 feet above the Trout Creek sandstone. The Iles formation contains several important coals near the top and some minor coals near the base.

STRUCTURE

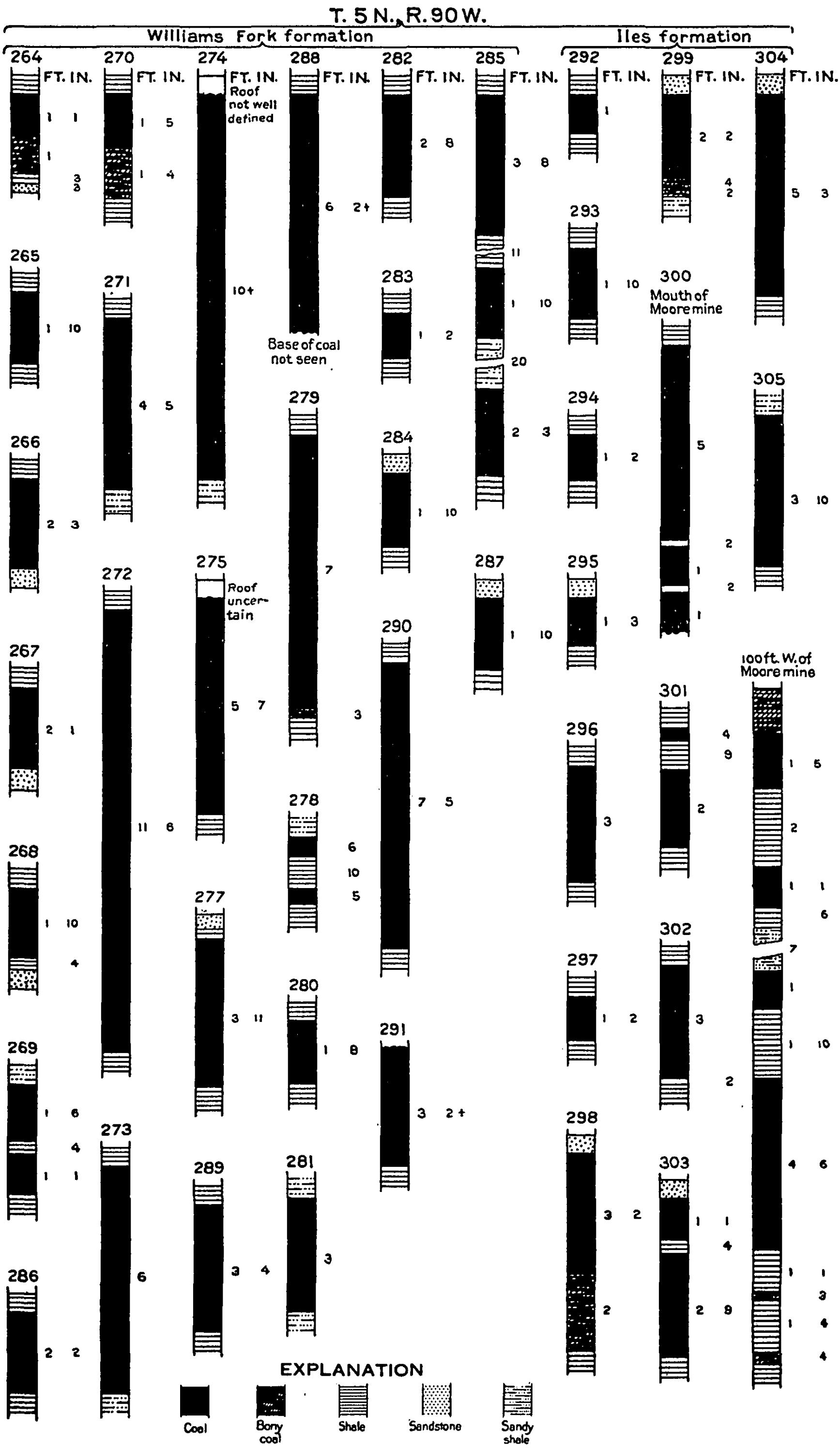
The rocks of the western part of this township form the western part of the Beaver Creek anticline. At the west line of the township the limbs of the anticline are closely compressed, but farther southeast they separate rapidly, the southwest limb dipping steeply west toward the axis of the Badger Creek syncline and the north limb dipping less steeply northward beneath the Williams Fork Mountains. The beds of Harper Hill dip as steeply as 22°, but those north of Williams Fork have a prevailing dip of 5° to 8°.

COAL

Most of the coal beds in the western part of this township have the thicknesses and stratigraphic relations shown in a columnar section in Plate XVIII. The detailed measurements of these and some additional beds are shown in Plate XII.

COAL IN THE WILLIAMS FORK FORMATION

The top of the Trout Creek sandstone, on which the Williams Fork formation rests, is designated by locations 260, 261, 262, and 263. The steep slopes extending from the sandstone up to the top of Williams Fork Mountains are characterized by an abundance of



SECTIONS OF COAL BEDS IN THE WESTERN PART OF T. 5 N., R. 90 W.

brick-red sandstone and baked shale, caused by the burning of coal on the outcrop. Most of the coal exposures in the western part of the township occur along the steep slopes on either side of Deal Gulch. The thickness of the different coal beds and the average thickness where more than one measurement was made on the same bed, as well as their relations to one another, are shown in columnar section in Plate XVIII. A coal bed having an average thickness of 1 foot 10 inches, as shown by five measurements, lies upon the Trout Creek sandstone in Deal Gulch. The thicknesses of the coal beds at five different points are shown in coal sections 264, 265, 266, 267, and 268. The lowest of these beds was measured at location 269, on the west side of Deal Gulch, and again at location 268, on the east side. That bed is about 25 feet above the Trout Creek sandstone. At location 268 it contains 2 feet 2 inches of coal, overlain and underlain by shale, but at location 269 it contains 4 inches of brown shale between two separate benches of coal.

About 200 feet east and up the hill from location 286 another coal bed was measured at location 270. That bed, which is about 15 feet higher in the formation than the one described above, contains 1 foot 5 inches of good coal overlain by shale. Below the coal is 1 foot 4 inches of bone, underlain by shale. The next higher bed was measured at location 271, on the point of the ridge west of Deal Gulch. The bed, which measures 4 feet 5 inches at that point, is about 50 feet above the Trout Creek sandstone. The coal there is overlain by shale and underlain by sandy shale. A large bed of coal about 110 feet above the Trout Creek sandstone was also measured about 300 feet east of Deal Gulch at location 272. It contains 11 feet 6 inches of coal, overlain and underlain by shale. About 190 feet above the Trout Creek sandstone a thick bed of coal was measured at locations 273 and 274, both on the steep-sided hill east of Deal Gulch. The two locations are probably on the same bed, although the thicknesses differ considerably. At location 273 there appeared to be only 6 feet of coal, overlain by shale and underlain by sandy shale. At location 274 there is at least 10 feet of coal. The coal is underlain by gray sandy shale, but the top of the coal was not seen, so there may be considerably more than 10 feet of coal at the point of measurement.

At a point on the steep slope of the hill west of Deal Gulch a still higher bed containing 5 feet 7 inches of coal was measured at location 275. The coal is underlain by shale, but the top was not determined with absolute certainty. As near as could be determined, the bed is about 270 feet above the Trout Creek sandstone.

Another coal bed was measured at location 277, on a sharp spur of the hill west of Deal Gulch, and from its relation to certain sandstones it is believed to be the same bed as that measured near the top of the ridge at location 289, east of the gulch. At location 277 the bed contains 3 feet 11 inches of coal, underlain by shale and overlain by 3 inches of shale underneath a bed of sandstone, but at location 289, just east of the edge of the Monument Butte quadrangle, there is 3 feet 4 inches of coal, overlain and underlain by shale. About 20 feet below location 277 is another bed, not located on the map, which contains at least 3 feet of coal, but the top and bottom are not well defined. About the same distance below the bed at location 289 is another at location 288, which contains 6 feet 2 inches of coal, overlain by shale. The bottom of the bed was not seen.

The next coal beds seen in the vicinity of Deal Gulch occur about 250 feet higher in the formation. The middle bed of the three present at this horizon is about 200 feet below the Twentymile sandstone and is marked by location 279. It contains 7 feet of coal, overlain by gray shale and underlain by 3 inches of bony coal followed by 2 feet or more of brown shale. Location 278 is on a section measured about 30 feet below the bed at location 279.

The highest one of the three beds was measured at locations 280 and 281. At location 280 it was found to contain 1 foot 8 inches of coal, overlain by hard sandy shale and underlain by shale. Farther southeast, at location 281, it contains 3 feet of coal, overlain and underlain by shale.

Two coal beds were measured near Deal Gulch above the Twentymile sandstone. The lower bed, which is about 35 feet above the sandstone, was measured at three different places. At location 282 it contains 2 feet 8 inches of coal, overlain and underlain by shale. At the other two places the bed contains 3 feet 10 inches and 3 feet 11 inches of coal. A thin bed of coal about 90 feet higher in the formation was measured at locations 283 and 284. At location 284 it contains 1 foot 10 inches of coal and at location 283 1 foot 2 inches. The coal is overlain and underlain by shale in each place. Two coal beds about 25 feet apart were measured at locations 290 and 291, at the head of Jeffway Gulch. The lower one of the two beds (291) contains at least 3 feet 2 inches of coal, and the upper one (290) 7 feet 5 inches. Both beds are underlain by shale. The upper bed is overlain by shale, but the top of the lower bed was not located with certainty.

Some coal was also measured on the east side of Horse Gulch, in this township; for example, at location 285 a coal bed 1 foot 10 inches thick, overlain by sandstone and underlain by shale, was measured farther southeast on the point of the hill at location 287. From its relation to the Trout Creek sandstone it may correspond to the middle bed in the section at location 285.

COAL IN THE ILES FORMATION

Seven thin beds of coal near the base of the Iles formation were measured in the first gulch west of Deal Gulch. Most of these beds are thin, ranging in thickness from 1 to 3 feet, as shown in coal sections 292, 293, 294, 295, 296, 297, and 298 in Plate XII. The uppermost bed seen in that locality was measured at location 298. It contains 3 feet 2 inches of coal, underlain by 2 feet of impure coal and shaly sandstone and shale.

Several beds were measured in Deal Gulch and are shown in columnar section in Plate XVIII. The middle of the group is about 300 feet below the Trout Creek sandstone. The lowermost bed was measured at location 299 and found to contain 2 feet 2 inches of good coal beneath a massive sandstone. The coal is underlain by 6 inches of bony coal, which in turn is underlain by sandy shale.

About 25 feet higher in the formation is the series of coal beds commonly known as the "Moore bank." One of the beds was at one time mined at the Moore mine, at location 300, on the east side of the gulch. Where sampled at the face of the workings it is composed of an upper bench 2 feet 6 inches thick and a lower bench 2 feet 2 inches thick, separated by 6 inches of sandy shale, which was excluded from the sample. The results of analysis are shown under laboratory No. 9134, on page 45.

A thicker section was measured about 100 feet west of the Moore mine. (See Pl. XII.)

About 40 feet higher is a coal bed that was measured at two different places. At location 301 it is composed of two benches of coal, the upper one 4 inches thick and the lower 2 feet. They are separated by shale, and the lower bench is also underlain by shale. At location 302 the bed contains 3 feet of coal, overlain by shale and underlain by bone. The highest coal bed in the group was measured at locations 303 and 304, which are only a few hundred feet apart. At each place the bed is overlain by sandstone and underlain by brown shale. At location 304 the bed is 5 feet 3 inches thick, but at location 303 the total thickness is only 4 feet 2 inches, and it includes an upper bench of 1 foot 1 inch and a lower bench of 2 feet 9 inches. The two benches of coal are separated by 4 inches of brown shale.

Location 305 is on one of the coal beds of this group about 700 feet east of Horse Gulch. The bed at that location contains 3 feet 10 inches of coal, overlain by sandy shale and underlain by brown shale.

QUANTITY OF COAL

On the basis of the total number of coal beds observed, the thickness of each bed, and the area underlain by it, it is estimated that

399,700,000 tons of coal is present in that portion of the township included in the Monument Butte quadrangle north of Williams Fork. For the area south of Williams Fork it was decided to assume a thickness of 6 feet of coal wherever the lower portion of the Iles formation is present. As that portion of the formation underlies 0.88 square mile in this township the total quantity of coal south of Williams Fork amounts to about 300,000 tons, making a total of 400,000,000 tons as the estimated quantity of coal in that portion of the township included in the Monument Butte quadrangle.

POSITION OF THE COAL BEDS IN RELATION TO MINING

The western part of T. 5 N., R. 90 W., is tributary to Williams Fork by means of Deal Gulch and Horse Gulch. Inasmuch as these gulches cut deep into the rocks of the Mesaverde group, a large tonnage of coal could be mined by running drifts in on the beds from the outcrop. By deviating slightly from the strike of the beds sufficient slope would be obtained to provide for drainage and haulage. From the main drifts the coal could be mined up the rise. The coal could also be mined on a large scale by sinking a shaft at some point on the north slope of Williams Fork Mountains. The depth of shaft necessary to reach the Trout Creek sandstone, the base of the principal group of coal beds, may be determined at any point by subtracting the altitude indicated by the structure contour from the altitude of the surface.

TPS. 3 AND 4 N., R. 90 W.

TOPOGRAPHY

About half of T. 4 N., R. 90 W., and only about 3 square miles of T. 3 N., R. 90 W., are included in the Monument Butte quadrangle. The most conspicuous surface feature of the portions included is the high divide between Deer Creek and Waddle Creek, the highest peak of which has an altitude of 8,855 feet. The difference in altitude between this peak and Waddle Creek at the north line of T. 4 N., R. 90 W., is about 2,255 feet. The principal resource of these townships is coal, and therefore the problem of transportation is all important. It seems reasonable to suppose that most of the coal mined in these townships in the future will be taken out by way of a branch line of railroad leading down Yampa Valley and up Williams Fork canyon from the main line of the Denver & Salt Lake Railroad, or any other road leading west from Craig. Whether most of the coal included in the Hart syncline will be taken down Morapos or Waddle Creek valley will depend upon relative costs, but either route seems feasible. The railroad grades required in order to reach this great body of coal by way of Yampa

River, Williams Fork, and either Morapos or Waddle Creek are pointed out in Chapter IV.

STRATIGRAPHY

The rocks that crop out in these townships are of Upper Cretaceous age and are included in the Mancos shale and the Iles and Williams Fork formations. The nature and stratigraphic relations of these formations are described on pages 10–20. The portions of the townships here described are occupied almost entirely by the rocks of the Mesaverde group, which comprises the Iles and Williams Fork formations. The economic significance of the character of these rocks is pointed out on page 14. Most of the coal of these two townships is included in the lower part of the Williams Fork formation. The outcrop of the underlying Trout Creek sandstone is represented by a continuous line from the southeast corner of the Monument Butte quadrangle northwest to the west line of T. 4 N., R. 90 W. It was again recognized on the slope west of Waddle Creek and about a mile northwest of the Hart mine. Although the individual sandstone could not be recognized with certainty southeast of the Hart mine, its position could be inferred from that of the principal group of coal beds. Certain other sandstones that are higher in the geologic column are described in relation to some of the principal coal beds.

STRUCTURE

The principal structural feature in these townships is the Hart syncline, a well-defined fold whose axis is more or less coincident with Hart Gulch. In T. 4 N., R. 90 W., the axis rises rather steeply toward the southeast. The main fold is modified by a minor syncline whose axis extends south from the Hamilton mine, on Williams Fork, crossing the main fold near the west line of the township and causing the main syncline to widen out in its middle portion. The beds dip much more steeply along the north limb of the fold than along the south limb. The angle of dip increases along the north limb from 9° in the northern part of T. 4 N., R. 90 W., to 45° at the east edge of the quadrangle. South of the axis the beds have a fairly uniform dip of 4°–6° N.

COAL

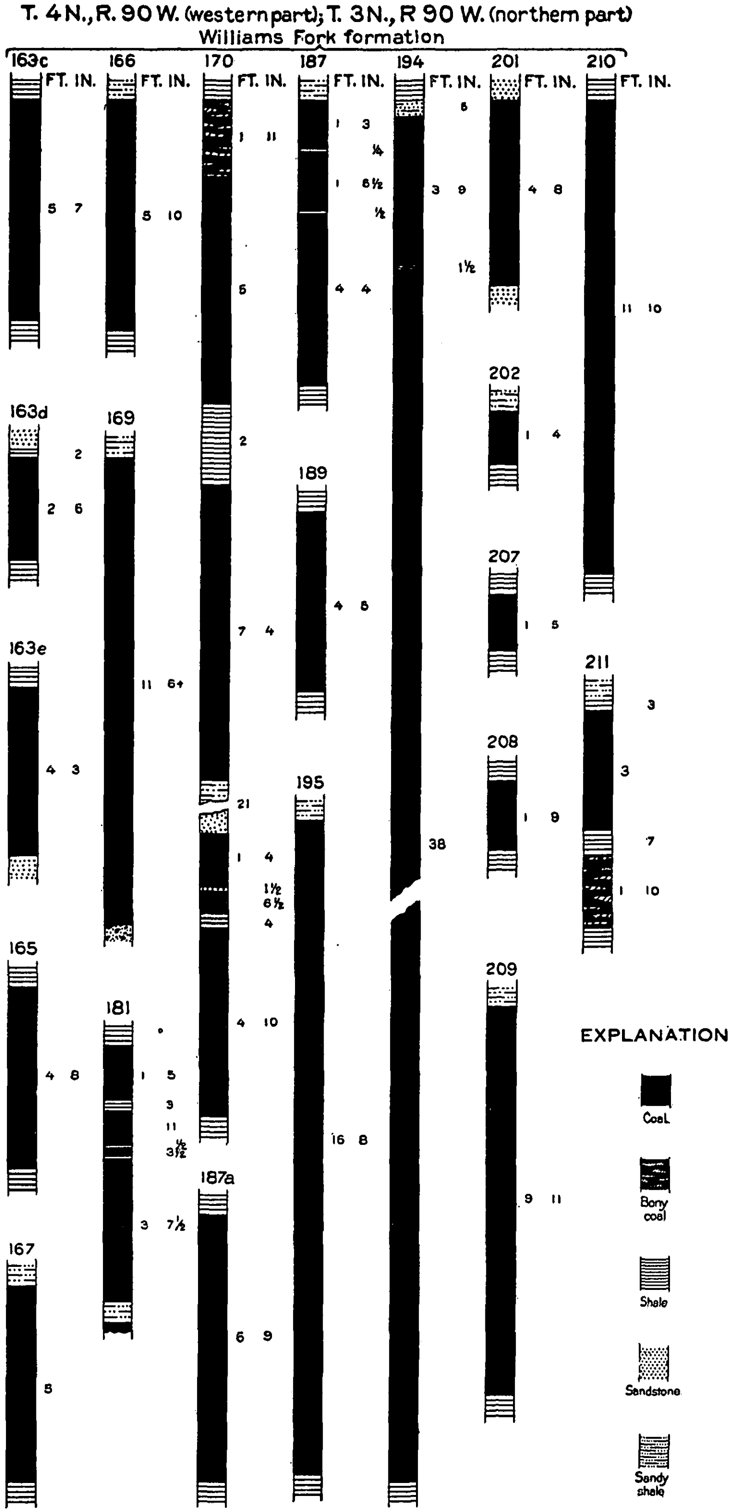
The beds of coal that were found in these townships occur almost entirely in the Williams Fork formation. Some thin beds occur in the Iles formation, but these are of little economic importance. The stratigraphic relations of the important coal beds are shown in columnar section in Plate XVIII, and sections of the beds are given in Plate XIII.

COAL IN THE WILLIAMS FORK FORMATION

Locations 163a, 163b, 163c, 163d, 163e, and 163f mark exposures of coal near the southeast corner of the Monument Butte quadrangle, in the northern part of T. 3 N., R. 90 W. Locations 163a and 163b designate points on the ridge where some coal was seen, but there was little chance to obtain reliable measurements. At location 163c a bed containing 5 feet 7 inches of coal is overlain and underlain by shale. A coal bed 40 feet higher in the formation contains at location 163d 2 feet 6 inches of coal underlain by shale and overlain by 2 inches of shale and this in turn overlain by a thin-bedded sandstone. A few hundred feet farther north a bed of coal 4 feet 3 inches thick overlain and underlain by thin-bedded sandstone was opened up at location 163e. At location 163f evidence that much coal has been burned is afforded by a thick zone of brick-red sandstone and shale so thoroughly baked that the entire mass is very resistant, forming a conspicuous cliff.

Location 164, near the south line of T. 4 N., R. 90 W., is on a ledge of white sandstone that from its lithologic character and relation to the main belt of burning in this locality is believed to be the Trout Creek sandstone, which underlies the Williams Fork formation. A coal bed that lies about 18 feet above the Trout Creek sandstone was measured at location 165. This bed contains 4 feet 8 inches of coal, overlain by brown shale and underlain by black carbonaceous shale. What is in all probability the same bed was measured at location 166, a short distance west of location 165. Here the bed contains 5 feet 10 inches of coal, overlain by shaly sandstone and underlain by brown shale. A bed similarly situated with regard to the sandstone was measured at location 167, about one-third of a mile to the northwest, across the gulch, where it contains 5 feet of coal, overlain by sandy shale and underlain by brown shale, and is correlated with the bed at location 166. The rocks forming the hillside above location 167 have been burned to a bright-red color, presumably indicating the presence of a thick bed of coal, and there is a more prominent burned zone at location 168. No further exposures of coal above the Trout Creek sandstone were found in this part of the township, but a short distance south of Hart Gulch some thick beds were measured at locations 169 and 170. Location 169 is at an old prospect almost filled by caving. The bed at this prospect contains 11 feet 6 inches of coal, overlain by gray sandy shale and underlain by a mixture of gray shale and burned material. At location 170, on the opposite side of the gully, a section measured showed a total of 21 feet 8½ inches of coal.

A 16-foot sandstone in this section seems to be the same as the sandstone overlying the coal bed at location 171, about a mile to the



SECTIONS OF COAL BEDS IN THE WESTERN PART OF T. 4 N., R. 90 W., AND THE NORTHERN PART OF T. 3 N., R. 90 W.

southwest, in T. 4 N., R. 91 W. This sandstone, which stands out prominently along the west side of the long gulch running southwest from location 169, loses its identity a short distance south of location 169, and so its relation to the coal bed at this location could not be ascertained. It is probable, however, that the coal beds at locations 169, 170, 171, 172, and 173 occur at about the same horizon. Location 174, immediately north of Hart Gulch, is on a very prominent sandstone. Locations 175 and 176, east of Hart Gulch, are thought to be on this sandstone. The presence of a belt of brick-red sandstone about 40 feet above this sandstone indicates the burning out of a coal bed at that horizon. Locations 177, 178, 179, and 180, about half a mile south of the northwest corner of the township, are all on the same sandstone. At location 181 a section was measured immediately above this sandstone.

Locations 182 to 186 are also on a prominent sandstone, which, owing to its massive structure and white color, is believed to be the Trout Creek sandstone.

Location 187, a few hundred feet west of the Hart ranch, is on the Hart mine, which consists of a drift run in on the bed N. 39° W. for 100 feet. The width of the drift ranges from 8 feet at the mouth to 28 feet at the face. The main drift rises slightly from the mouth to the face, so that its direction does not represent the true strike of the formation. The strike of the prominent sandstone underlying the coal is N. 53° W., and the dip 27° S. 37° W. The coal bed was sampled at the face of the drift, 100 feet in from the mouth of the mine, and the result of the analysis is shown under laboratory No. 17782 on page 44.

The prominent sandstone that underlies the coal bed at the Hart mine was traced as far north as location 188. It is believed that this is the same sandstone as the one which underlies the coal bed at location 181 and that the overlying coal beds are the same. The boundary line on the map extending southeastward from location 185 is believed to represent the base of the main coal group and therefore the approximate position of the top of the Trout Creek standstone. If this is true the bed opened at the Hart mine occurs about 200 feet below the top of the Iles formation and corresponds to the Black Diamond group of coal beds near Meeker. Most of the coal along the north side of Hart Gulch above the assumed position of the Trout Creek sandstone has burned out at the surface. At location 189 there is 4 feet 5 inches of coal overlain and underlain by shale. The steep south slope is characterized by numerous burned areas, and the most intense burning has occurred at locations 190 and 191. Locations 192 and 193, about half a mile to the southeast, also mark belts of intense burning. The beds throughout a thickness of about 100 feet at location 193 are characterized by brick-red sandstone and baked shale, and it is believed that this is at the position of the thick coal bed which was measured at location 194. At location 195 a thick bed was uncovered and found to contain 16 feet 8 inches of coal. A definite correlation of this bed with the thick bed at location 194, described below, is impossible owing to the abundance of overburden along the steep slope. It may lie above or below that bed, or, on the other hand, it may represent a part of that bed. Some coal was seen near the west edge of the reservoir at location 196, which, on the evidence of strike and dip, was thought to be a part of the bed that was measured at location 194. An unusually thick coal bed is exposed on the crest of a narrow ridge at location 194. A horizontal trench was cut along the lower thick portion of this bed, and near the base a section was cut at right angles to the dip, near the bottom of which brown shale containing streaks of coal was found. If this is taken as the bottom of the bed and the thickness is computed on the basis of dip and horizontal outcrop, the lower portion of the bed is 38 feet thick.

Locations 197 and 198, a few hundred feet north of the coal bed just described and lower in the formation, each marks the position of a burned-out coal bed, as shown by the abundance of brick-red sandstone and baked shale. What has the appearance of being a thick coal bed occurs at location 199, near the bed of Waddle Creek. The coal appears to be badly disturbed, probably as a result of slumping, and on this account an accurate measurement could not be made. Along the steep south slope northeast of location 200 the beds dip as high as 44°. Only two thin coal beds were found, one at location 201 and the other at location 202. The bed at location 201 contains 4 feet 8 inches of coal, overlain and underlain by thin-bedded sandstone; that at location 202 contains only 1 foot 4 inches of coal, overlain by shaly sandstone and underlain by brown shale.

On the east side of Deep Rock Gulch there are some rather conspicuous sandstones and with them are associated coal beds. The lower one of the two sandstones was traced from location 203 northwestward as far as location 204. The upper sandstone was traced from a point a few hundred feet north of location 205 southeastward around the point of the hill. It was also observed at location 206. Two measurements were made on a thin coal bed 8 feet above the upper sandstone, at locations 207 and 208. At location 207 the bed contains 1 foot 5 inches of coal, and at location 208 it contains 1 foot 9 inches. In each place it is overlain and underlain by shale. A much thicker coal bed occurs immediately above the lower sandstone, for at location 209 it shows 9 feet 11 inches of coal, overlain by sandy shale and underlain by a few inches of brown shale. The same bed contains 11 feet 10 inches of coal at location 210, about a quarter of a mile northwest of location 209. The coal is overlain by drab shale and underlain by brown sandy shale, which grades off rapidly into the underlying sandstone.

COAL IN THE ILES FORMATION

The only coal beds found in the Iles formation in these townships occur at locations 211, 212, and 213, on a prominent point of the hill immediately west of Waddle Creek, near the north line of T. 4 N., R. 90 W. The bottom of the section at location 213 is about 125 feet above the base of the Iles formation.

QUANTITY OF COAL

As there are no complete sections available in the isolated area of coal-bearing rocks in Tps. 3 and 4 N., R. 90 W., it was necessary in computing the tonnage of coal to take into account some sections measured in neighboring portions of the field. Thirty coal beds, having a total thickness of 127 feet, are known to occur in a similar belt of the formation 1,200 to 1,400 feet in thickness on the north side of Williams Fork in T. 6 N., R. 91 W. (See columnar section in Pl. XVIII.) Considerable coal is known to have been burned on the outcrop between the Trout Creek and Twentymile sandstones, and it is possible that if no burning had occurred a well-exposed section would reveal a zone between the two sandstones as abundantly coal bearing as the one near Lay. (See columnar section in Pl. XVIII.) It was assumed that a total thickness of 120 feet of coal is present in the first 1,200 feet of rocks above the Trout Creek sandstone. The total area underlain by the Trout Creek sandstone is about 10.6 square miles, and the average thickness of coal in the Williams Fork formation within this area is 47.5 feet. The average thickness of coal in the different sections measured near the base of the Iles formation in the coal basin south of Williams Fork is 6 feet, and the Iles formation underlies 15.5 square miles in these townships within the Monument Butte quadrangle. It is therefore calculated that the quantity of coal in the Williams Fork formation in this area amounts to 585,000,000 tons, and that occurring near the base of the Iles formation amounts to 105,000,000 tons, a total of 690,000,000 tons.

RELATION OF STRUCTURE AND TOPOGRAPHY TO MINING

The relation of the structure and topography to mining in these townships is identical with that in Tps. 3 and 4 N., R. 91 W., set forth on page 113.

TPS. 3 AND 4 N., R. 91 W.

TOPOGRAPHY

The principal surface feature of Tps. 3 and 4 N., R. 91 W., is the combination of deep gulches and long, narrow ridges that extend southwestward from the high divide between Waddle and Deer creeks. The portions of the two townships here described exhibit a difference of more than 2,000 feet in altitude, ranging from 8,538 feet on the main divide to 6,375 feet in the bed of Morapos Creek near the northwest corner. The western parts of these townships are drained by Morapos Creek and Deer Creek, which have their sources in the hills southeast of this township and flow northwestward and northward, discharging their contents into Williams Fork near the Hamilton ranch. A very small part of T. 4 N., R. 91 W., is drained by Waddle Creek, which also flows north into Williams Fork. Moody Gulch and the numerous gulches leading northeastward from Deer Creek toward the main divide furnish the most favorable routes for travel from Deer Creek up to the outcrop of the principal group of coal beds above the Trout Creek sandstone. It is also possible to approach the main coal area from the east by way of Waddle Creek and Hart Gulch. The most favorable routes from the main line of the Denver & Salt Lake Railroad to this township are pointed out on pages 38–40.

STRATIGRAPHY

The strata that crop out in these townships are of Upper Cretaceous age and include the Mancos shale and the Iles and Williams Fork formations. The character and relations of these formations are described in considerable detail on pages 10–20.

The Mancos shale occupies a small area in the northwestern part of the township and all the low land southwest of the escarpment formed by the lower beds of the Iles formation—in fact, Morapos Creek and Deer Creek have each eroded their channels in the soft shale of the Mancos formation. The courses of these two streams have been established parallel to the strike of the beds, and the streams are separated by a zone of thin-bedded sandstones in the Mancos shale. In certain localities (see p. 11) thin-bedded sandstones occur about 800 feet below the top of the formation. In this township these beds are so resistant in comparison with the overlying and underlying shale that they form a rather pronounced escarpment. The position of this zone and the strikes and dips of the beds are shown in the northwestern part of T. 4 N., R. 91 W., and in the southwestern part of the same township and the northern part of T. 3 N., R. 91 W. The geographic position of the outcrop of this zone of thin beds has suggested the name Morapos sandstone member, which has been adopted in this report.

Rocks of the Mesaverde group occupy the central and eastern parts of T. 4 N., R. 91 W., and form all of the inner portion of the Hart syncline. (See pl. XIX.) They differ materially in composition from the Mancos shale, and on this difference depend not only the mineral value of the land but also its adaptability to different kinds of agriculture, as is explained on page 14.

Nearly all the coal of these two townships is included in the lower part of the Williams Fork formation. The Trout Creek sandstone, the top of which separates the Williams Fork from the Iles formation, was traced continuously from location 221 southeastward to the east line of the townships. From location 221 northward the sandstone could not be recognized with certainty, but its position was inferred from that of the principal groups of coal beds. Certain other prominent sandstones are referred to in connection with some of the thick coal beds. The massive sandstones at the base of the Iles formation have been deeply dissected, so that the formation is now characterized by a number of steep-walled gulches between narrow ridges, all of which extend in a southwesterly direction from the high ridge north of the valley of Deer Creek.

STRUCTURE

Folds.—The most pronounced structural feature in this township is a well-defined synclinal fold, whose axis is more or less coincident with Hart Gulch, leading west from the Hart ranch, and with the course of the Monument Butte fault. This fold will be called the Hart syncline. From the east line of T. 4 N., R. 91 W., its axis rises steeply toward the west.

The highest point on the Round Bottom synclinal axis is about 1¼ miles east of the northwest corner of T. 4 N., R. 91 W. From that point the limbs of the syncline separate rapidly and its axis descends gradually southward toward the Monument Butte fault. The relation of the Round Bottom syncline to the northeast branch of the Axial Basin anticline is described on pages 30–31. The axis of the Badger Creek syncline (p. 33) extends southward from a point near the Hamilton mine, crossing the Hart syncline at right angles near the east line of T. 4 N., R. 91 W., as shown by the structure contours in that locality.

As brought out in the structure section, the beds in the southwestern part of the township dip northeast at a uniform angle of about 8°. In the vicinity of the upper end of Moody Gulch the strike is somewhat north of east and the dip 18°–23° S. From this locality east the strike swings somewhat more to the north and the dip decreases slightly, amounting to 17°–19°. In passing eastward the strike changes very rapidly from northeast to southeast and the dip is about 16° SW. Farther southeast the dip of the beds comprising the northeast limb of the Hart syncline gradually becomes steeper; at the Hart mine the dip is 27° SW., and about 2 miles farther southeast, on the northeast side of Waddle Creek, the dip in places is as much as 44°. The structural feature known as the Hamilton dome is described in Chapter IV. Only the southern part of the dome lies in T. 4 N., R. 91 W., as is shown by the strike and dip locations on Plate XIX.

Faults.—There are two faults in the western part of T. 4 N., R. 91 W. The Monument Butte fault passes a few degrees north of east from a point near the center of sec. 26, T. 4 N., R. 92 W., through the gulch just south of Monument Butte. The evidence that points toward the existence of this fault as indicated is presented in considerable detail in Chapter III. The second fault lies north of the Monument Butte fault and roughly parallel to it.

COAL

Nearly all the coal that was found in these townships occurs in the lower part of the Williams Fork formation, although some minor beds were found in the Iles formation. The stratigraphic relation of some of the important coal beds is shown in columnar sections in Plate XVIII.

COAL IN THE WILLIAMS FORK FORMATION

As Tps. 3 and 4 N., R. 91 W., have not been sectionized, the occurrences of coal can be referred to only by location numbers. The most careful search revealed only a very small proportion of the coal beds that are believed to be present above the Trout Creek sandstone, the top member of the Iles formation. This failure is due mainly to two conditions—an unusually large proportion of the coal has burned out at the surface, and most of the coal-bearing area in these townships is covered by a dense growth of oak brush and small trees, and the exposures are not only very few but difficult to find. The coal-bearing rocks represent the uneroded portion of the Williams Fork formation, which has been folded down in the form of a trough. The best exposures are on the outer rim of the basin, where in places the formation dips at a high angle. Beginning in the southeastern part of T. 4 N., R. 91 W., the first indication of coal was observed at location 214, where a bed was uncovered and measured that is at least 12 feet thick. The bed showed evidences of having been disturbed and the presence of some burned material near the top suggested that originally the bed was thicker and that a portion of it had been burned away. Another bed about 50 feet above the Trout Creek sandstone was measured at location 215. This bed contains 4 feet of coal, overlain and underlain by brown shale. Between these two beds considerable brick-red sandstone and baked shale was observed, indicating the burning out at the surface of considerable coal.

The next coal noted occurs about three-quarters of a mile north-northeast, at location 173, immediately south of the crest of the ridge. The bed contains 8 feet of coal, overlain by sandstone and underlain by brown shale. A few hundred feet to the northwest there is another exposure of coal in a steep bank just north of the crest of the ridge at location 172.

At location 171, about half a mile northwest, there is another exposure of coal.

The sandstone above the coal at location 171 may be seen as a continuous ledge extending northeastward to location 216 and on down to location 170, where it separates the two coal beds described on page 103. The relation of the coals exposed at locations 171, 172, and 173 to one another could not be satisfactorily determined. The best evidence regarding it seems to be their position with reference to a prominent sandstone that crops out a short distance northeast of location 172, on the west side of the long, narrow ridge that extends northward. This sandstone appears to be above the coal bed at location 172, and the dark-red color of its lower portion indicates that at least a part of the coal of bed 172 has been burned a short distance to the east. Although the prominent sandstone bed, on account of the dense growth of trees and underbrush, could not be seen or traced all the way from location 172 to location 171, yet it is believed that the coal beds at these locations lie below the same sandstone and are therefore the same bed and that the coal bed measured at location 173 is above that sandstone.

A bed of coal at least 3 feet 4 inches thick was found about 100 feet above the Trout Creek sandstone on the narrow ridge extending southwestward from location 173. Although the top of the bed is not well defined it appeared to be overlain by sandy shale and underlain by black carbonaceous shale containing thin streaks of coal.

At location 218 and throughout the hillsides at the head of the main gulch immediately west the entire formation for several hundred feet above the Trout Creek sandstone has been reddened by burning of outcropping coal beds.

Location 219, near the head of the gulch mentioned above, is at the Roby mine, which has recently been opened. The mine consists of a drift that runs into the hill N. 56° W. for 75 feet. It ranges from 5 to 12 feet in width and averages about 7 feet in height. The coal bed is apparently from 30 to 40 feet above the

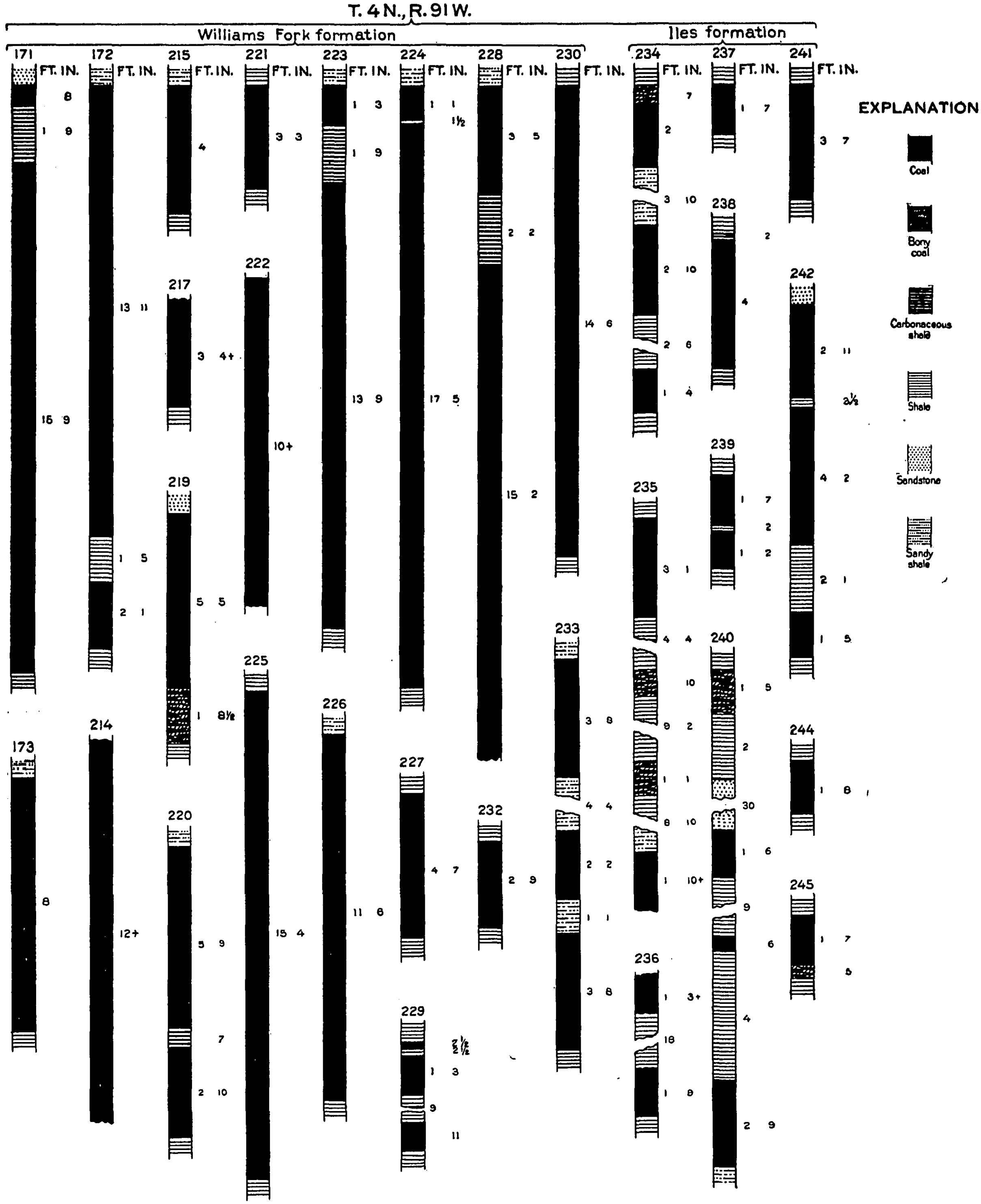
Trout Creek sandstone. About three-quarters of a mile to the west, in the next gulch, there is an old caved-in prospect at location 220, which is on a bed that occurs at about the same horizon as the one at location 219. The bed consists of two separate benches of coal, separated by 7 inches of black carbonaceous shale containing streaks of coal. The upper bench contains 5 feet 9 inches of coal, overlain by sandy black carbonaceous shale, and the lower one 2 feet 10 inches of coal, underlain by brown shale. The coal in this bed has a shiny black color and a vitreous luster and appears to be of excellent quality but running through it are streaks of red ashes, indicating that a portion of the bed has burned.

At location 221, about half a mile farther west, a coal bed 3 feet 3 inches thick, which lies about 25 feet above the Trout Creek sandstone, is overlain and underlain by brown shale. Owing to the complicated structure and the lack of exposures it was impossible to trace the Trout Creek sandstone with any degree of certainty northward from this point.

Location 222, about a mile farther north, is on an old prospect that was opened on the steep north slope of the hill. At present the coal is almost obscured by caving. The depth of surface débris, together with the disturbed condition of the coal due to slumping, made it imposible to obtain an accurate measurement. The bed contains at least 10 feet of coal and in all probability considerably more. About three-quarters of a mile to the northeast is another prospect (location 223) where a timbered drift has been carried S. 77° E. for 28 feet 6 inches. As nearly as could be ascertained the formation at this point strikes N. 65° E. and dips 26° SE.

Location 224 marks an opening on what is commonly known as the Kellogg coal bed. Here considerable coal has been taken out for local use. The mine consists of a drift 230 feet long which runs in S. 43° E. from the mouth but gradually curves around to N. 85° E. near the face. The floor of the drift is nearly horizontal, indicating an abrupt change in the strike of the beds in the mine. The width of the drift ranges from 7 feet near the mouth to 20 feet at the face, and the height from 7 to 10 feet. The main body of coal, as exhibited in the walls of the drift, has an intensely black color and a vitreous luster and is very hard and apparently unweathered, although the mine has been abandoned for several years.

The dense growth of trees and underbrush, the almost total lack of exposures, and the complex structure in this locality all increase the difficulty of correlation. It is reasonably certain, however, that the coal bed at location 222 lies a considerable distance below those at locations 223 and 224. It is the writer's belief that the Kellogg bed lies above the bed measured at location 223, although future devel-



SECTIONS OF COAL BEDS IN T. 4 N., R. 91 W.

opment may show them to be the same bed. Three thick coal beds were prospected on the south slope of the main ridge immediately north of Moody Gulch, at locations 225, 226, and 227. The lowest of the three beds (226) contains 11 feet 6 inches of coal, overlain and underlain by brown shale. At location 225, which was estimated to be about 200 feet higher in the formation, another bed contains 15 feet 4 inches of coal. The highest of the three beds in the formation, at location 227, contains 4 feet 7 inches of coal. Another prospect occurs at location 228. Here a timbered slope runs in N. 67° E. on a dip of 13½°. The original length of the slope is not definitely known, as the roof is caved at the lower end and the slope is partly filled with water.

Where the section shown in Plate XIV was measured, the sills and ties were covered with water, but in all probability they rest upon the shale below the coal. Considering the position of this bed both horizontally and vertically with respect to the one measured at location 223, together with the similarity in the section of the bed, it is quite possible that locations 228 and 223 are on the same bed, although the bed can not be traced from one point to the other. At location 229, which is somewhat higher, two thin coal beds were measured.

About three-quarters of a mile farther east there is a recent prospect on a coal bed at location 230. This bed was opened by Edward Werner for domestic fuel. A slope runs in on the bed S. 9° W. for about 20 feet and then swings slightly toward the west for about 15 feet. The coal is badly weathered throughout the distance that it is exposed. The slope runs under a low hill, and from the highest exposure of the coal under a cap of clay shale down to the brown shale, which underlies the coal, the bed has a thickness of 14 feet 6 inches. The only parting observed is a streak of shaly sandstone averaging about one-eighth of an inch in thickness but locally pinching out entirely and rarely exceeding half an inch. The bed appears to dip about 7½°, although the character of the opening would not permit an accurate determination of strike and dip. Location 231, about a mile to the northeast, is on a burned coal outcrop. Location 232, on the same ridge farther northwest, is on a bed that contains 2 feet 9 inches of coal, overlain and underlain by sandy shale. Some coal is also exposed at location 233, on the opposite side of Badger Creek.

COAL IN THE ILES FORMATION

A rather prominent thin-bedded sandstone occurs about 200 feet below the Trout Creek sandstone in the southern part of T. 4 N., R. 91 W. It was traced from location 236, near the southeast corner of the township, northwestward as far as location 235. Immediately below this sandstone is a mass composed of sandy shale, shaly sandstone, and thin coal beds, which was measured at location 236. A bed having a similar broken character seen at location 234 appears to belong just below the Trout Creek sandstone. A much more complete section was measured at location 235, about 1½ miles still farther northwest, on the narrow ridge.

A thin bed of coal was also found at location 237 a few feet above the "rim rock." The bed at that point contains 1 foot 7 inches of coal, overlain and underlain by sandy shale. A thin bed of brick-red sandstone was observed above the bed at location 237, indicating that some coal had burned at the surface. Some coal was also found on the north side of the fault running east from Monument Butte. Location 238, for example, is on an old prospect. It consists merely of a small drift which has been carried in about 40 feet and at present is partly filled by caving. The coal on the north side of the drift contains lenticular masses of brown shale, which cut across the coal at various angles to the bedding. At location 239, a few hundred feet to the west, another coal bed 2 feet 11 inches thick was found. At the point of measurement there is a 2-inch parting of brown shale 14 inches above the bottom of the bed. Location 240 is probably about 200 feet above the base of the Iles formation.

Farther north and immediately west of Deer Creek some coal was also found at location 241, but only a few hundred feet farther east the coal has been burned out at the surface. Where measured the bed contains 3 feet 7 inches of coal, overlain and underlain by brown shale. The coal has a rather pronounced platy structure, and it is regarded as somewhat inferior in quality to most of the coal in this field. At location 242, about half a mile to the north, on the opposite side of Deer Creek, there is 8 feet 6 inches of coal.

A shale at location 243 contains thin seams of coal, none of which are of much value. Two thin beds of coal were also found at locations 244 and 245, on the south slope immediately north of Moody Gulch, which are believed to lie below the Trout Creek sandstone and therefore near the top of the Iles formation. The bed at location 244 contains 1 foot 8 inches of coal, overlain and underlain by brown shale. That at location 245 is about 20 feet higher.

QUANTITY OF COAL

The quantity of coal in Tps. 3 and 4 N., R. 91 W., was computed on the same basis as that in Tps. 3 and 4 N., R. 90 W. (p. 105). It was assumed that there is a total thickness of 120 feet of coal in the first 1,200 feet of strata above the Trout Creek sandstone. The total area underlain by the Trout Creek sandstone in Tps. 3 and 4 N.,

R. 91 W., is 7.02 square miles, and allowing for partial erosion of the William's Fork formation within this area it is estimated that a reserve of 475,000,000 tons of coal exists in the parts of these townships lying within the Monument Butte quadrangle. Similarly it is estimated that the coal-bearing beds of the Iles formation underlie 14.68 square miles and contain 105,000,000 tons of coal, making a total of 580,000,000 tons.

RELATION OF STRUCTURE AND TOPOGRAPHY TO MINING

The great mass of coal-bearing rocks in these townships lies in the form of a canoe-shaped structural basin, the lowest point of which coincides with Hart Gulch. A large quantity of coal can be mined out by running drifts in on the coal beds from any of the prominent gulches—for example, Hart Gulch, Moody Gulch, or any of the deep gulches leading up into the coal-bearing formation from the valley of Deer Creek. This has been done in a small way at the Hart mine (location 187), in T. 4 N., R. 90 W., and also at the Roby mine (location 219), the old Kellogg mine (location 224), and the old prospects marked by locations 228 and 223, all in T. 4 N., R. 91 W. If the structure is accurately interpreted a shaft sunk somewhere in Hart Gulch near the center of the basin would pass through a considerable number of thick coal beds and would reach the Trout Creek sandstone at a depth of about 1,100 feet. The coal beds could be mined in any direction from the main shaft, and the prevailing dip of 5° to 8° throughout most of the basin would provide for the drainage and make the haulage of the coal to the shaft an easy task. The grades involved if a spur were extended from the main line of the Denver & Salt Lake Railroad into this locality are described in Chapter IV. Although the grade from Williams Fork up to this locality would amount to about 2 per cent, the moving of the loaded cars would be in the direction of down grade.

TPS. 3 AND 4 N., R. 92 W.

TOPOGRAPHY

In Tps. 3 and 4 N., R. 92 W., there are two surface features that stand out prominently in contrast with Axial Basin, which occupies the greater part of these townships. These surface features are Monument Butte and Thornburgh Mountain and the adjacent ridges and the hills composed of Mesaverde rocks in the southwestern part of the townships. Both of these features are rough and rugged in comparison with the gentle slopes of Axial Basin. The surface of these townships ranges in altitude from 6,225 feet where Milk Creek crosses the north line to 7,630 feet in Thornburgh Mountain. The streams that drain them all flow north toward Yampa River. As their principal resource is coal, the valley of Milk Creek will probably become very important in a commercial and economic sense, because it has cut a moderately deep canyon into the coal-bearing rocks and leads directly and with a low gradient to the valley of Yampa River, the principal artery of communication with the proposed route of the Denver & Salt Lake Railroad or any other road that may eventually extend westward from Craig. The most feasible routes by rail from any such railroad into this township and the grades involved are stated under the heading "Accessibility" in Chapter IV.

STRATIGRAPHY

The strata that crop out in these townships are of Upper Cretaceous age, including the Mancos shale and the Iles and Williams Fork formations. The character of these formations and their relations to one another are described in Chapter II. The Mancos shale occurs at the surface throughout the greater portion of these townships, but the rocks of the Mesaverde group (Iles and Williams Fork formations) contain many thick beds of coal and are therefore economically the most important. In many places a few hundred feet below the top of the Mancos shale there are thin-bedded sandstones, which locally give rise to low ridges with steep faces on the side next to the basin and very gentle slopes on the opposite side. Such a ridge occurs about 800 feet below the top of the formation in T. 4 N., R. 92 W., and forms a well-defined escarpment from the east side of sec. 13 southwest to the center of sec. 26, where it is interrupted by the Monument Butte fault.

The Trout Creek sandstone, above which the principal coal beds lie, was traced almost continuously from the NW. ¼ sec. 31, T. 4 N., R. 92 W., north around the hill and thence southeast to the southwest corner of sec. 33.

STRUCTURE

FOLDS

Except in the part of these townships which is underlain by the rocks of the Mesaverde group, the outcropping beds dip at comparatively low angles. The Mesaverde group is present within the Elkhorn syncline, whose axis trends in general in a southwesterly direction, crossing the east side of the Danforth Hills, farther south, almost at right angles to the general direction of the folds of this region. The axis of the syncline pitches south from location 581 at a rather steep angle, but the pitch decreases rapidly as it approaches the lowest point in the synclinal trough. At the Shafer mine (location 249), in the NE. ¼ sec. 31, the beds strike N. 40° E. and dip 34° S. 50° E. Northeast of this point the dip gradually diminishes toward the axis of the syncline, and near that line it is in places as low as 5°, but on the east limb of the syncline the dip rapidly steepens and finally becomes as high as 60° at location 586, in sec. 4, T. 3 N., R. 92 W.

As shown by Plate XIX, these townships are crossed by the forking axis of the Axial Basin anticline and by several faults, two of which bound a down-dropped block of the Mesaverde in the northern part of sec. 4, T. 3 N., R. 92 W.

COAL

The sections of coal beds measured in these townships are shown on Plate XV. The location of each section is shown on the geologic map (Pl. XIX) by number, and the character of the coal bed is shown by the corresponding number on Plate XV. All the coal found in these townships occurs in the Mesaverde group within the Elkhorn syncline. As is usual in this field, the greater portion of the coal found in the Mesaverde beds occurs in the lower part of the Williams Fork formation, which overlies the Trout Creek sandstone. Farther south, in the vicinity of Meeker, the group of coal beds immediately above the Trout Creek sandstone was designated the Fairfield coal group, from the Fairfield mine, which is working one of the beds of this group.

COAL IN THE WILLIAMS FORK FORMATION

Beginning on the west side of these townships the coal that was studied first occurs on the east side of Milk Creek in sec. 31, T. 4 N., R. 92 W. The stratigraphic relation of the important coal beds is represented in columnar section in Plate XVIII. The lowest bed measured was estimated to be about 75 feet above the Trout Creek sandstone member of the Iles formation. The amount of coal found is indicated by the section measured at location 246.

Above this section the rocks for a distance of 10 feet consist of shaly sandstone, above which are the beds measured at location 247.

A few hundred feet farther south, at location 248, another bed of coal is exposed which is thought to be about 175 feet above the Trout Creek sandstone. Owing to the amount of débris and the possibility of slumping, a reliable measurement could not be made, but there is believed to be at least 15 feet of coal. This coal bed lies about 50 feet below a thick bed of sandstone, and between this sandstone and another bed still higher lies the coal bed that is being worked at the Shafer mine, at location 249.

The Shafer mine consists of a drift which runs in northeast from the opening for a distance of 189 feet. Laboratory sample No.

14909, described on page 44, was taken at the face of the drift, where the bed measured as shown in section 249. This bed was sampled from top to bottom where the middle 6-inch seam was almost pure coal. The strike of the bed is N. 40° E., and the dip 34° S. to 50° E.

About half a mile south of the mine, on the opposite side of Milk Creek, some coal was observed at location 250.

The next exposure to the east occurs at location 251, which is on a newly opened prospect. The coal bed lies about 35 feet above the Trout Creek sandstone. The drift runs in S. 10° E. for a distance of 40 feet, and at the face the bed measured 7 feet 6 inches with coal roof and coal floor. The coal itself, which is badly weathered, contains some selenite along joint planes and also a few nodules and lenses of shaly sandstone from a quarter of an inch to 4 inches in length.

The bed is believed to crop out at location 252, where 12 feet 7 inches of coal was measured. The bed at this point is overlain by gray sandy shale and underlain by 8 inches of brown shale, which rests upon sandstone. This bed is 25 to 30 feet above the Trout Creek sandstone.

The best exposures of coal found in this locality occur in the deep gulch near the southeast corner of sec. 32. Not only was coal found in this gulch but there is evidence that a large amount of coal has burned at the surface. At location 253, up the side of the hill north of the gulch, the section shown in Plate XV was measured, which is probably about 150 feet above the Trout Creek sandstone.

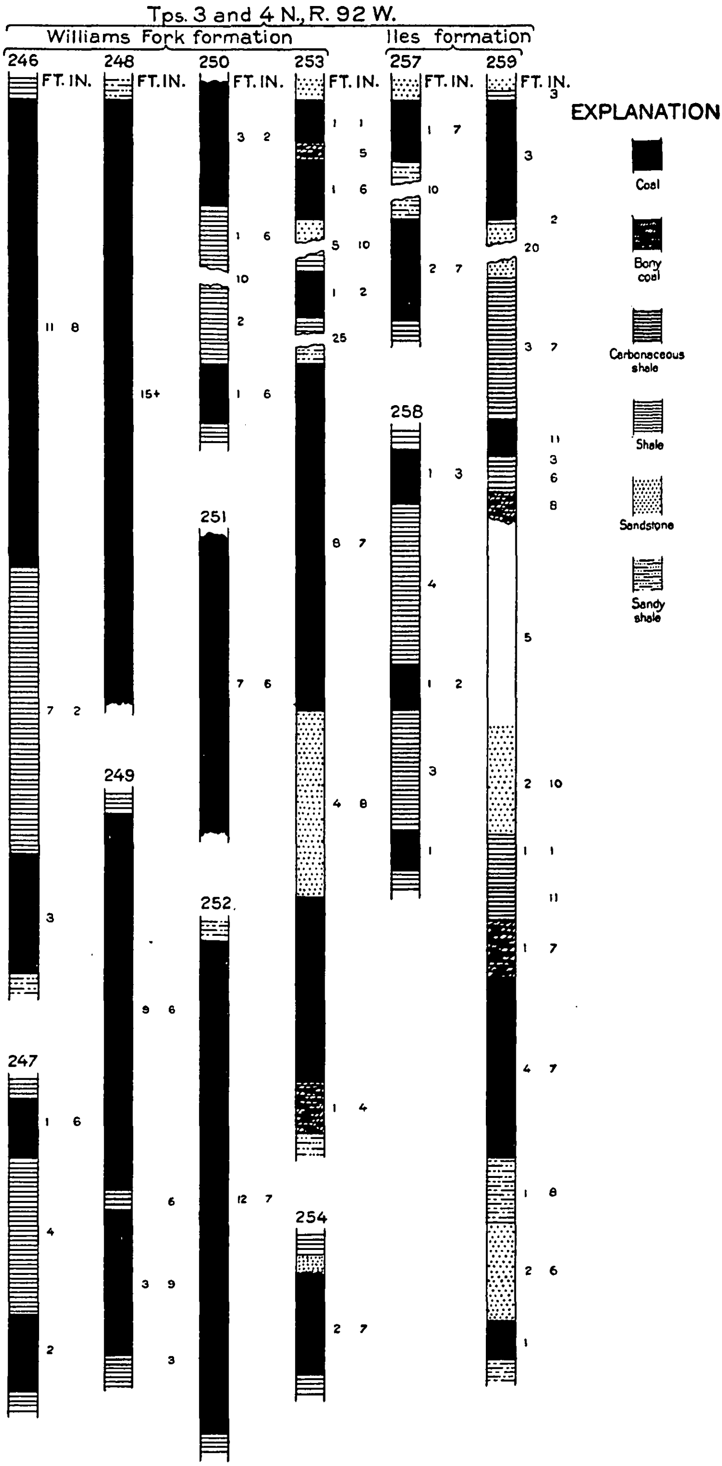
Location 254, which is several hundred feet above the section at location 253, is at a point where a coal bed has burned at the surface. About 40 feet below the main belt of burning is a partly burned coal bed which contains 2 feet 7 inches of coal underlain by brown shale and overlain by ashes of burned coal. From all appearances a large amount of coal has burned at the surface between locations 255 and 256.

COAL IN THE ILES FORMATION

The quantity and general character of the coal in the Iles formation is well shown in the detailed stratigraphic section on page 15, measured on the east side of Milk Creek at its opening into Axial Basin. At location 257 in this section, 157 feet above the base of the Iles formation, the coal beds shown on Plate XV were measured.

The beds at location 258, higher up in the section, are also shown in a section on Plate XV.

At a point 135 feet below the Trout Creek sandstone (see section on p. 15) the following section was measured:



SECTIONS OF COAL BEDS IN TPS. 3 AND 4 N., R. 92 W.

Section of coal beds 135 feet below the Trout Creek sandstone in the NE. ¼ sec. 30, T. 4 N., R. 92 W.

	Ft.	in.
Shale, gray, sandy.		
Coal		8
Shale, brown		1
Coal	1	11
Shale, black, carbonaceous		2½
Coal, much selenite along bedding plane	1	9
Shale, brown	3	
Sandstone, shaly	17	
Coal		6
Shale, brown	1	5
Coal	1	
Shale, sandy	11	
Shale, brown	1	
Coal, impure		9
Shale, brown	2	9
Shale, brown, sandy	15	
Sandstone, iron-stained, rectangularly jointed	3	6
Shale, brown	1	6
Coal		8
Shale, brown	3	
Coal	1	
Shale, brown.		
Total section	67	8½
Total coal	8	3

This group of coal beds occurs in about the same position with reference to the Trout Creek sandstone as the bed that is being worked at the Black Diamond mine, near Meeker, and therefore is thought to be the representative of the Black Diamond group of coal beds in this locality.

At about the same horizon a section was measured at location 259, immediately south of the township line, near the southwest corner of sec. 33.

Some coal was seen near the top of the ridge east of location 259, but it was not located on the map. At the prospect, which has been only recently opened, the following section was measured:

Section of coal beds about a quarter of a mile east of location 259, in T. 4 N., R. 92 W.

	Ft.	in.
Shale, sandy.		
Coal, somewhat platy in structure	2	5
Shale, brown.		
Interval, mostly concealed	10	
Coal, platy		8
Shale, brown; contains streaks of coal		6
Shale, brown	1	2
Shale, black, carbonaceous; contains streaks of coal		10
Shale, brown.		
Total section	15	7
Total coal	3	1

From the preceding sections it will be observed although there are certain zones in the Iles formation that contain coal beds, these beds are almost universally thin, of somewhat inferior quality, and associated with numerous layers of brown and black carbonaceous shale.

QUANTITY OF COAL

On the basis of the area underlain by coal-bearing rocks and the observed thickness of the coal beds, estimated to aggregate 62 feet of coal in the complete Fairview coal group, it is computed that the parts of Tps. 3 and 4 N., R. 92 W., within the Axial and Monument Butte quadrangle contain a reserve of 280,000,000 short tons of coal.

TPS. 3 AND 4 N., R. 93 W.

TOPOGRAPHY

The long gulches that cross Tps. 3 and 4 N., R. 93 W., are the most striking features of the area in an economic and commercial sense, because through them practically the entire area is tributary to the main artery of communication, namely, Yampa River. They are sharply V-shaped, and the sides slope up gently to the broad ridges, which are characterized by long, gentle northeastward slopes. It is also a feature of considerable economic importance that these long gulches cut across the coal-bearing formation almost at right angles, thereby exposing at the surface a great thickness of beds. The most feasible routes into this area from the proposed route of the Denver & Salt Lake Railroad, or any other railroad extending west from Craig, and the grades involved, are stated on pages 38–40.

STRATIGRAPHY

The rocks that crop out in Tps. 3 and 4 N., R. 93 W., are of Upper Cretaceous age and include the Mancos shale and the Iles and Williams Fork formations. The different formations and their relations to one another are described on pages 10–20, and the erosional and soil characteristics on page 14. The coal beds associated with the sandstone and sandy shale are in many places burned for some distance from the outcrop. The resulting brick-red sandstone, baked shale, and masses of clinker, like ordinary sandstone, do not disintegrate as readily under the action of the agencies of erosion as the Mancos shale and naturally give rise to steeper slopes. The Trout Creek sandstone, the upper surface of which separates the coal-bearing Williams Fork formation from the Iles formation, was traced continuously from a point near the northeast corner of sec. 36 northwestward to a point a few hundred feet south of the northwest corner of sec. 19.

STRUCTURE

The Collom syncline crosses these townships (see Pl. XIX) and contains the coal-bearing rocks. The unsymmetrical character of the syncline is brought out clearly by the structure contours, which indicate the altitude of the Trout Creek sandstone above mean sea level. On the north side of the syncline the beds, as a rule, rise northward to the Axial Basin anticline at angles of 23° to 30°; on the south side they rise southward at angles of 6° to 8°.

COAL

All the coal in these townships is included in the Mesaverde group. The greater part of it occurs in the lower part of the Williams Fork formation and is in the same group of coal beds that occurs along the main road about 2½ miles west of Meeker. This group includes the coal bed worked at the Fairfield mine, which has been operating near Meeker for many years, and is designated the Fairfield coal group. The locations of coal beds measured in these townships are shown by numbers on the geologic map (Pl. XIX) and the details of the measurements are shown under the corresponding numbers on Plate XVI.

COAL IN THE WILLIAMS FORK FORMATION

The greater part of the coal included in the Williams Fork formation in these townships has been burned along the outcrop. Beginning on the east side of the townships the first exposures found occur in the valley of Good Spring Creek. At location 1, on the west side of the valley, a section was measured immediately above the Trout Creek sandstone member of the Iles formation.

About half a mile northwest of location 1 a portion of this same group of beds was opened up and measured at location 2, in the southwest corner of sec. 26.

A few hundred feet farther south, in the bottom of the gully, another bed was found at location 3 which contains 3 feet 1 inch of coal overlain by black carbonaceous shale and underlain by gray sandy shale. This bed is about 75 feet above the Trout Creek sandstone.

In the gully southwest of location 3 two coal beds were seen. The upper of the two beds (location 4) is partly burned and is in such a position that no adequate idea could be obtained of its thickness. The lower bed (location 5) contains 4 feet 2 inches of coal overlain and underlain by brown shale.

The first coal bed noted above the Trout Creek sandstone on the east side of Good Spring Creek occurs at location 6. This bed is reported to have been opened by W. H. Miller and later by a man named Smith. At the time of the writer's visit the opening was filled up as a result of caving. H. S. Gale,[19] who made a preliminary survey of the field in 1906, reports that the entry consists of a simple prospect drift running in a distance of 120 feet. Gale measured the following section at a point 15 feet from the face of the entry:

Section of coal bed at location 6, in sec. 35, T. 4 N., R. 93 W.

	Ft.	in.
Roof, clay.		
Coal	3	
Coal, impure		4
Coal	5	
Bone		1
Coal, base not reached.		
	8	5

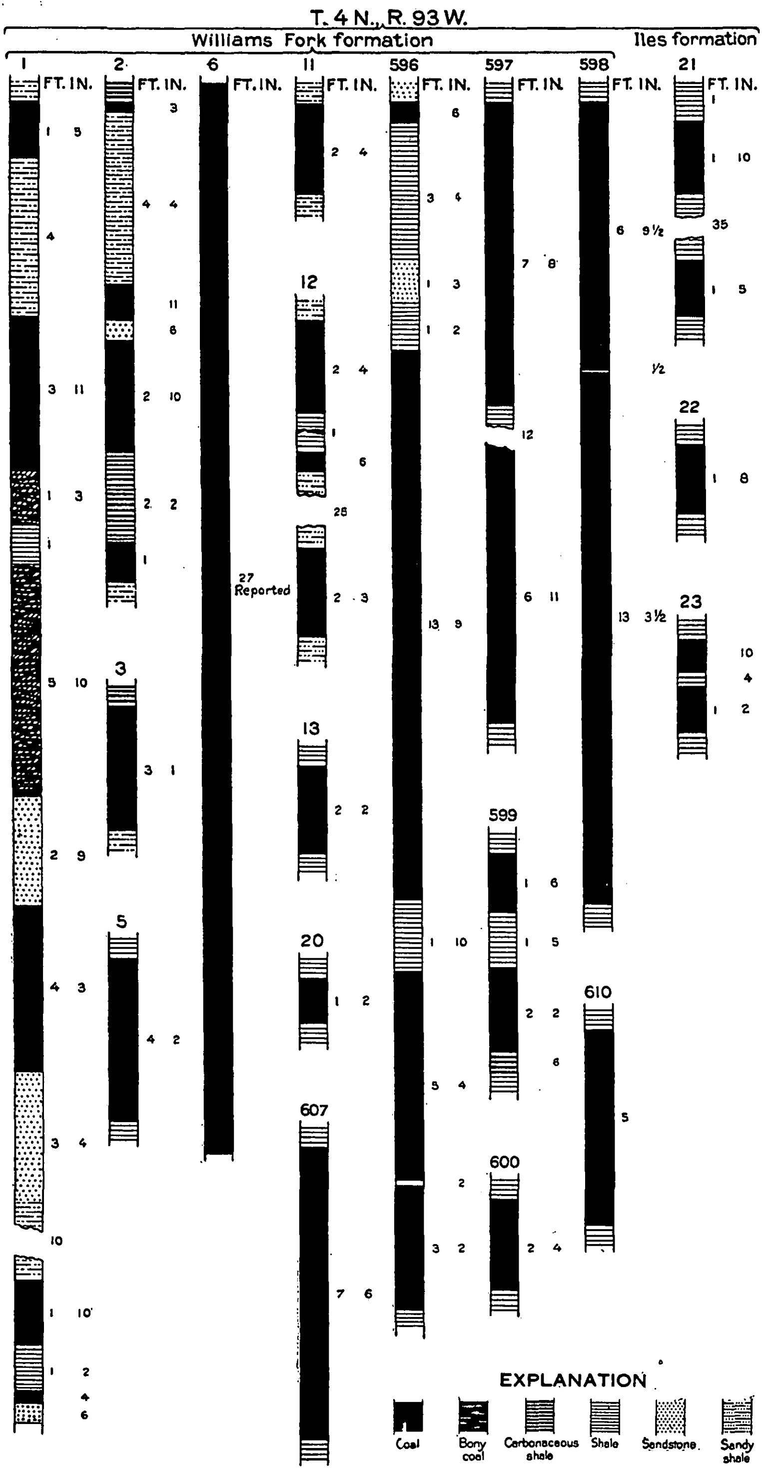
He reports that this section represents only a part of the lower half of the bed. The entire bed was measured as accurately as the conditions would permit and reported to have a total thickness of 27 feet. The bed itself is probably about 350 feet above the Trout Creek sandstone.

The best exposures of coal along Good Spring Creek are near the Mount Streeter (Joseph Collom) mine, in sec. 2, T. 3 N., R. 93 W. The columnar section in Plate XVIII shows the relative positions of the coal beds measured near the mine. At location 596 a coal bed that lies immediately below a thick bed of sandstone has the section shown on Plate XVI. Several of the locations—603–606 and 608, 609, 611, and 612—represent outcrops in a steep hillside, and as the numbers would have been crowded on the map (Pl. XIX) they have been omitted.

Several hundred feet to the northwest, across the valley, another bed was measured at location 597, which appeared to be at about the same horizon as the bed at location 596, but a definite correlation could not be made.

Location 598 is on the Mount Streeter mine, formerly operated by Joseph Collom, one of the most widely known coal mines in the entire coal field. The main drift runs into the hill N. 62° W. for 433 feet. For about 75 feet from the opening the drift is 7 feet 6 inches wide, but thence to the face it varies from 11 to 16 feet. From a point 150 feet from the opening to the end of the main drift entries have been opened on both sides at uniform distances. These side entries range in length from 18 to 47 feet and are of about the same width as the main drift. The floor of the main drift from the opening to the face is almost level, and its height ranges from 8 feet 10 inches to 11 feet

[19] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, p. 172, 1910.



SECTIONS OF COAL BEDS IN T. 4 N., R. 93 W.

8 inches. A sample for analysis was taken about 400 feet from the opening and 40 feet south of the main drift. A section of the entire bed as exposed on the hillside near the opening is given in Plate XVI.

At the point where the sample was taken the bed appears to dip S. 29° W. at an angle of 3½°. On sighting across the valley from the Mount Streeter mine in the direction of strike the mine bed appears to be about 60 feet stratigraphically above the one at location 596. Immediately above the coal bed at location 596 is a ledge of sandstone about 35 feet thick, above which is a belt of more or less broken down sandstone burned to a brick-red color. The writer believes that this belt marks the position of the Mount Streeter bed on the east side of the valley. The character of the surface is such that neither of these coal beds nor the prominent sandstone ledges could be traced with any degree of certainty far north from the Mount Streeter mine. About 25 feet above the Mount Streeter bed another bed was examined at location 599.

At 35 feet above this bed, at location 600, another coal bed was measured having a thickness of 2 feet 4 inches. This coal bed is about 100 feet below the top of a prominent key sandstone, which is marked by locations 601 and 602. An attempt to determine the distance between this sandstone and the Trout Creek sandstone, the top of which marks the base of the Williams Fork formation, was attended with considerable difficulty. By leveling up from the Trout Creek sandstone to higher beds, tracing these a certain distance south, and then leveling up to still higher beds, and so on, the stratigraphic interval was finally calculated to be about 1,200 feet. This is, however, only the writer's best estimate from the data at hand. The best exposures of coal above the key sandstone of locations 601 and 602 in this vicinity occur on Good Spring and Elkhorn creeks about three-quarters of a mile south of the Mount Streeter mine. The thickness and stratigraphic relations of these beds are shown in columnar section in Plate XVIII, prepared to show the character and relation of the coal beds on Good Spring and Elkhorn creeks. The only two additional beds of the section occurring in the Axial quadrangle are those at locations 607 and 610, which measured 7 feet 6 inches and 5 feet, respectively.

The next coal bed of importance was seen in the valley of Wilson Creek above the Trout Creek sandstone, where the beds dip steeply toward the south.

At location 7, on the west side of Wilson Creek, 1 foot 3 inches of impure coal lies about 12 feet above the Trout Creek sandstone. From the abundance of brick-red sandstone and burned shale it is believed that large coal beds have been burned out in a zone extending from a horizon 100 feet above the Trout Creek sandstone up for a distance of 600 or 700 feet. Locations 8 and 9 appear to be where the most extensive burning has occurred. Location 10 also marks a very extensive burn. Here the sandstone and shale are baked throughout a thickness of 100 feet or more, indicating that a number of coal beds have been burned. Location 11 is on a coal bed a short distance above the large burn. This bed, measuring 2 feet 4 inches in thickness, is overlain by gray sandy shale and underlain by brown shale. About 1,500 feet to the south, on the west side of the valley, sections were measured at locations 12 and 13. The beds included in these sections seem to dip about 3½° S. Locations 14 and 15, which are on a prominent sandstone, indicate a dip of 6° to 7° N., denoting the position of the axis of the Collom syncline.

The coal beds of the Fairfield group have been extensively burned along their outcrops on the west side of Jubb Creek. Locations 16, 17, 18, and 19 are all on areas of intense burning, but almost the entire outcrop of the rocks included between the Trout Creek sandstone and location 19 is a mass of brick-red sandstone and baked shale. With the exception of a thin bed of coal 14 inches thick at location 20, no further exposures of coal were seen on Jubb Creek.

COAL IN THE ILES FORMATION

Very little coal was found in the Iles formation in these townships. Some thick beds of black carbonaceous shale were seen 200 or 300 feet above the base of the formation on the hill east of Axial, but they contain only thin streaks of coal. At locations 21 and 22, on the west side of Wilson Creek, beds that occur at about the top of the Black Diamond group of coal beds, as developed near Meeker, have the section shown in Plate XVI.

Location 23, on the west side of Jubb Creek, is on a thin bed of coal that consists of an upper bench 10 inches thick and a lower bench of splintery coal 1 foot 2 inches thick. The two benches are separated by 4 inches of brown shale. Several beds of brown and black carbonaceous shale stratigraphically below location 23 were examined, but only thin streaks of coal were seen. The writer does not believe that the beds near the base of the Iles formation, which locally in this field contains coal of economic importance, are of much value in these townships. The Black Diamond coal group, which south of the Danforth Hills comprises some very thick coal beds, is also of very little value here.

QUANTITY OF COAL

Only a portion of these townships is underlain by the coal-bearing formations, and it was calculated that the different thicknesses of coal underlying the several tracts were equivalent to 62 feet of coal underlying 15.8 square miles. Therefore the total quantity of coal in these townships is estimated to be 1,125,000,000 short tons.

POSITION OF COAL BEDS WITH RESPECT TO MINING

The best exposures of coal in this area occur at the lowest point underlain by the Williams Fork formation, namely, in the immediate vicinity of the Mount Streeter mine, in the N. ½ sec. 2, T. 3 N., R. 93 W. As the structure contours show, the mine is only about half a mile north of the axis of the syncline. A drift could be run either east or west from Good Spring Creek on any one of the coal beds exposed, and a slight deviation from the direction of strike would provide sufficient fall so that a large quantity of coal could be mined up the rise without any difficulty with respect to drainage and haulage. Similarly, a shaft sunk in the valley of Wilson, Jubb, or Taylor Creek near the synclinal axis would pass through a great many coal beds and reach the Trout Creek sandstone at a depth of about 1,200 feet. Entries could be carried in on any one of the coal beds, the coal could be mined out up the rise, and all the water would be conducted down the dip to the main shaft.

TPS. 3 AND 4 N., RS. 94 AND 95 W.

TOPOGRAPHY

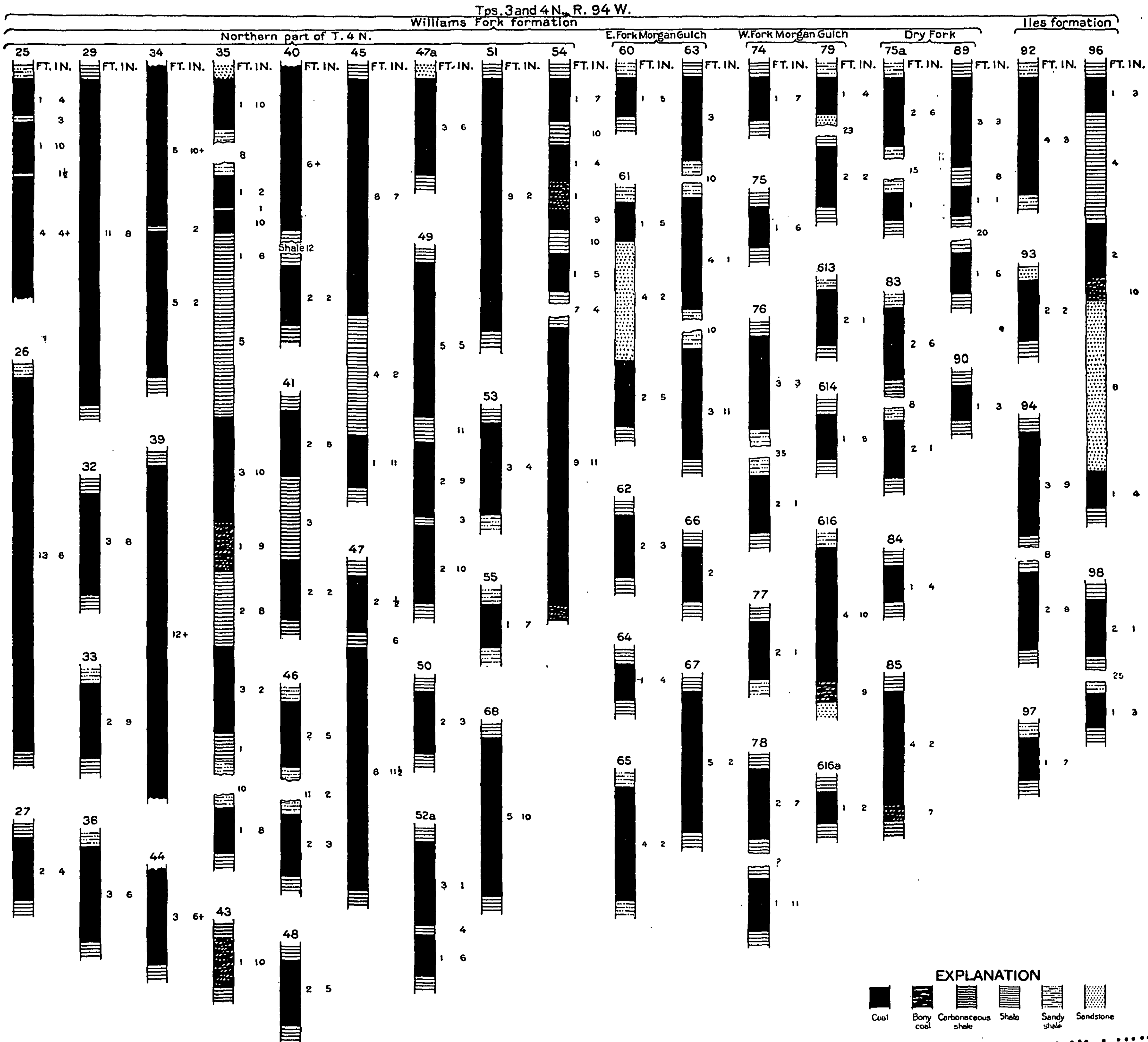
Those portions of Tps. 3 and 4 N., Rs. 94 and 95 W., included in the Axial quadrangle form part of the long gentle slope that extends from the Danforth Hills northward to Axial Basin. They are drained principally by streams that head in the vicinity of the divide between White and Yampa rivers and flow northeastward across Axial Basin into Yampa River. A very striking feature is the parallelism of these streams. The gulches are V-shaped, and the sides slope rather steeply to the broad ridges, which are characterized by long, gentle northeastward slopes. The accessibility of these gulches is explained on pages 38–40. Not only are they easily accessible from the valley of Yampa River, but they can also be utilized as routes for travel from Axial Basin southwest to the Danforth Hills. Practically the only exposures of coal in this area occur on the steep slopes of these gulches, where the beds are partly uncovered. It is apparent that through Collom, Morgan, and Boxelder gulches and their branches the entire area is tributary to Yampa Valley, the main artery of transportation through the Axial and Monument Butte quadrangles. As the principal resource of this area is coal, the exploitation of which is largely dependent on transportation facilities, this fact is of great importance.

STRATIGRAPHY

The rocks that crop out in these townships are of Upper Cretaceous age and include the Mancos shale and the Iles and Williams Fork formations. The details of these formations and their relations are described on pages 10–20. The Trout Creek sandstone, the top of which separates the Williams Fork and Iles formations and forms the base of the Fairfield group of coal beds was traced from a point near the northeast corner of sec. 24, T. 4 N., R. 94 W., northwest and west to the northwest corner of the township, and thence, with a fair degree of certainty, southward along the east side of Maudlin Gulch. Other sandstones much higher than the Trout Creek were traced along the different forks of Morgan Gulch, and altitudes on them were obtained at many places in order to determine the structure. The sandstone, sandy shale, and coal beds of the Williams Fork and Iles formations occur at the surface throughout almost the entire area. The Iles formation and several hundred feet of beds at the base of the Williams Fork formation are steeply upturned to form the north limb of the Collom syncline. South of the synclinal axis the surface slopes northward and eastward, in general at about the same angle as the beds, so that along Dry Fork, West Fork, and East Fork there is no great thickness of beds exposed. The surface of these townships is well adapted to grazing, and some of the principal gulches contain running water fed by springs at numerous places on the gentle north slope of the Danforth Hills.

STRUCTURE

In general these townships occupy the broad dip slope of the northern flank of the Danforth Hills dome. Except in a belt on the north and west sides the rocks dip at very low angles. They form a structural basin opening toward the east. The gentle northerly dip is terminated rather sharply just south of Axial Basin by the upturning of the beds on the southern flank of the great Axial Basin anticline. The Collom syncline has been further modified by the axis of depression that passes northeastward across the Danforth Hills, transverse to the general trend of the principal axes of the folds. On the west side of the area the beds dip 8°–20° E. On the north side they dip 20°–35° S. About 1,700 feet southeast of the southwest corner of sec. 33, T. 4 N., R. 94 W., the beds appear to strike N. 55° E. and dip 11° N. 35° W. This dip is thought to be unusually high for the rocks in the southeastern part of the township. The structure was determined wherever it was possible from two or more altitudes on the same bed of sandstone.



SECTIONS OF COAL BEDS IN TPS. 3 AND 4 N., R. 94 W.

COAL

The locations of the different coal beds measured in these townships are indicated by numbers on the geologic map (Pl. XIX) and the thickness and composition of the beds are shown under the corresponding numbers on Plate XVII.

The Mesaverde group includes all the coal beds in these townships. The greater portion of the coal occurs in the lower part of the Williams Fork formation, which overlies the Trout Creek sandstone. This group of coal beds occurs along the main road about 2½ miles west of Meeker and is designated the Fairfield coal group.

COAL IN THE WILLIAMS FORK FORMATION

Most of the coal beds included in the Williams Fork formation that would naturally crop out in these townships have been burned at the surface. The outcrops are confined to the tops of the ridges and the steep slopes next to the streams. Owing to the extent of burning and the abundance of débris it was impossible to follow an individual bed for any considerable distance along the sides of the valleys or to follow the beds from one valley to another over the broad intervening ridge. The problem, therefore, was one of determining the relation of the coal beds to certain beds of sandstone and of tracing these beds as far as possible.

Coal near the north edge of T. 4 N., R. 94 W.—Beginning on the east side of the area the first exposures of coal were found at locations 24 and 25, near the east fork of Collom Gulch. Location 24 is on a bed that crops out in the bank of the creek but appears to have been affected by slumping, so that a thoroughly reliable measurement could not be made. It is the writer's belief, however, that there is at least 8 feet 2 inches of coal at this place. Location 25 is on another bed that also crops out in the bank of the creek and is believed to be below the bed at location 24. The amount of coal present is indicated by the section given in Plate XVII.

The high hill northeast of these two locations is covered by masses of brick-red sandstone and baked shale, indicating the burning of a large quantity of coal. About three-quarters of a mile farther west, on the west side of Collom Creek, the evidence of burning begins at the Trout Creek sandstone and continues throughout a zone fully 125 feet thick. A large bed or group of beds has also been burned out about 125 feet below the bed at location 26, the Ed. Collom mine.

The Ed. Collom mine consists of a single drift that runs into the hill N. 68° W. for 26 feet and continues N. 33° W. The width of the drift increases from about 6 feet at the mouth to 16 feet near the face. At the mouth of the mine the bed dips about 40° SW. Sample No. 14529 (p. 45) was taken near the face of the drift and represents the entire thickness of the bed. The bed contains 13 feet 6 inches of coal, with a roof of shaly sandstone and a floor of brown to black carbonaceous shale. The coal where exposed at the face of the drift is free from shale partings and has an intense black color and vitreous luster throughout. The only impurities noted are narrow streaks of pyrite and marcasite along joint planes. The coal has a rather characteristic series of joints normal to the dip, which cause it to break out in thin slabs across the bedding.

Location 27 is on a bed that contains 2 feet 4 inches of good coal overlain and underlain by brown shale. Location 28 is on a belt of 125 feet of strata that have been burned intensely and mark the probable position of a very large coal bed or group of coal beds. The coal next above this large burn was opened and measured at location 29, on the east side of Collom Creek. The bed, measuring 11 feet 8 inches, is overlain and underlain by brown shale. Locations 30 and 31 are on a sandstone bed that dips north 8.7 feet in 100 feet. Location 32 is on a bed that contains 3 feet 8 inches of coal overlain and underlain by brown shale. This coal bed, which is 75 feet below the sandstone, appears to be burned out below location 30. It is believed to be the same bed of coal as the one at location 33, on the opposite side of the gulch, which contains 2 feet 9 inches of coal overlain by sandy shale and underlain by brown shale.

Coal in Morgan Gulch.—By far the most complete section seen in the entire township occurs on the west side of Morgan Gulch between the Trout Creek sandstone and the first side drain leading down from the west. The thickness and stratigraphic relations of the different coal beds are shown in columnar section in Plate XVIII.

Location 34 is on what appears to be an old prospect. The bed consists of two benches separated by a 2-inch parting of hard gray sandy shale. The top of the bed is not well defined, but the upper of the two benches contains at least 5 feet 10 inches of coal. The lower bench consists of 5 feet 2 inches of coal underlain by black carbonaceous shale. This bed is about 35 feet above the Trout Creek sandstone. Approximately 200 feet above the Trout Creek sandstone a section was measured at location 35.

The next coal bed above that shown in the section was measured at location 36, where there is 3 feet 6 inches of coal overlain by gray sandy shale and underlain by brown shale. The presence of another bed 300 or 400 feet above is indicated by considerable brick-red sandstone and baked shale. Locations 37 and 38 are on belts of strata where the burning was the most intense.

From the bottom of the valley up to location 39, near the top of the hill, considerable coal has been burned along the outcrop. At location 39 the bed was measured on the basis of strike and dip and found to contain about 12 feet of coal.

From location 40 to location 47 there is a zone containing at least ten beds of coal. The bed at location 40 contains an upper bench which is at least 6 feet thick and a lower bench of 2 feet 2 inches, the two being separated by a bed of shale 12 feet thick. The beds above are shown in the section in Plate XVIII. They are thin up as far as the one at location 45. This location in reality marks a double bed separated by 4 feet 2 inches of brown shale. The upper bed contains 8 feet 7 inches of coal overlain by brown shale. The lower one contains 1 foot 11 inches of somewhat impure coal underlain by brown shale. Location 46 also in reality marks two beds separated by 11 feet 2 inches of shaly sandstone. The upper bed contains 2 feet 5 inches of coal overlain by sandy shale, and the lower one contains 2 feet 3 inches of coal underlain by brown shale. The upper bed included in this section was measured at the Battle Era mine at location 47. This mine consists of a drift that runs due east from the opening for 120 feet. The width increases from 5 feet at the mouth to about 15 feet near the face. At a distance of about 78 feet a lateral entry extends north for about 16 feet from the main drift and N. 70° E. for about 65 feet farther. The width of the side entry ranges from 8 to 18 feet. The average height of both the main and side entries is about 6½ feet. Laboratory sample 14528 (p. 45) was taken at a point on the side entry 58 feet from the center of the main east-west drift. A section of the bed at this point (location 47) is given in Plate XVII.

All the coal of the section was included in the sample. The coal has well-defined rectangular joints in places and shows a marked tendency to break from the wall in slabs. Many of the surfaces are coated with marcasite and pyrite, with some sulphur and selenite. The dip of the coal bed is about 8½° S.

Location 47a marks the position of a coal bed about a quarter of a mile south of the Morgan ranch house. It contains 3 feet 6 inches of coal overlain by sandstone and underlain by brown shale.

Location 48 is on a coal bed exposed about three-quarters of a mile southwest of the Morgan ranch house. This bed contains, at the point of measurement, 2 feet 5 inches of coal, overlain and underlain by brown shale.

Locations 56, 57, and 58 are on what is probably the same bed of sandstone. Location 59 marks the position of a burned-out coal bed. As a matter of fact, from this point down to the bottom of the valley there is evidence of other beds having been burned. At location 60, on the opposite side of the gulch, one thin coal bed was found that measures 1 foot 5 inches of coal and is overlain by sandy shale and underlain by brown shale. Farther up the gulch locations 61 and 62 are on two coal beds about 40 feet apart. The lower one of the two beds (62) contains 2 feet 3 inches of coal overlain by gray sandy shale and underlain by brown shale. The upper bed (61) is made up of two benches of coal separated by 4 feet 2 inches of thin-bedded sandstone. The upper bench contains 1 foot 5 inches of coal overlain by sandy shale, and the lower bench contains 2 feet 5 inches of coal underlain by brown shale. A short distance farther up the gulch some evidence of coal was seen near the center of sec. 33. Four beds of coal were opened and measured at locations 63, 64, 65, and 66. The lowest bed (65) contains 4 feet 2 inches of coal overlain by sandy shale and underlain by brown shale. About 35 feet above is another bed (64), containing 1 foot 4 inches of coal overlain and underlain by brown shale. Location 63 is at the base of the section given in Plate XVII and about 60 feet above the bed at location 64.

The highest bed of the four above mentioned (66) contains 2 feet of coal overlain and underlain by brown shale. About a mile farther south, on the same side of the gulch, coal was opened and measured at locations 67 and 68, about a quarter of a mile south of the township line. The lower of the two beds (67) contains 5 feet 2 inches of coal overlain by gray sandy shale and underlain by brown shale. About 100 feet above this bed another one (68) was opened that contains 5 feet 10 inches of coal. The upper 10 inches includes many thin streaks of shale, but the lower 5 feet is entirely free from shale. The bed is overlain and underlain by brown sandy shale.

Locations 56, 69, and 70, on West Fork of Morgan Gulch, are upon a single bed of sandstone, as are also locations 71, 72, and 73. Locations 74 and 75 are on a coal bed, which is 19 inches thick at location 74 and 18 inches at location 75. At location 74 the bed is overlain by gray sandy shale, but at location 75 mainly by sandstone. Location 75a marks the position of two coal beds separated by 15 feet of sandy shale. The upper bed measured 2 feet 6 inches and the lower bed 1 foot. Each bed is underlain by brown shale. Location 76 is upon a coal bed that contains 3 feet 3 inches of coal overlain by brown shale. Below this bed is a zone 35 feet thick consisting of sandy shale. Below this is another bed of coal 2 feet 1 inch thick underlain by brown shale. About 75 feet above location 76, at location 77, another bed was opened, which contains 2 feet 1 inch of coal overlain and underlain by brown sandy shale. Location 78 marks a coal bed which lies at about the same horizon as the one at location 77 and which measures 2 feet 7 inches of coal, with brown shale above and below. At an indefinite distance below location 78 another bed contains 1 foot 11 inches of coal. At location 79 there is a double coal bed, the upper bed containing 1 foot 4 inches of coal overlain by brown shale and underlain by shaly sandstone and the lower bed 2 feet 2 inches of coal. The two beds are separated by 23 feet of shaly sandstone and sandy brown shale. Location 80 marks a horizon where there appears to have been considerable burning.

Considerable evidence of coal was seen in sec. 6, T. 3 N., R. 94 W. Locations 611, 612, and 613 mark the top of a conspicuous white sandstone, which crops out along the east side of a narrow ridge. Location 614 is on a coal bed 1 foot 8 inches thick, about 20 feet above the sandstone. At location 613 a coal bed immediately below the sandstone has burned out, and about 50 feet lower down is another bed containing 2 feet 1 inch of coal overlain and underlain by brown shale. West of the narrow ridge a thick coal bed appears to have burned out at location 615, and at location 616 two coal beds were measured. The lower one of the two beds contains 4 feet 10 inches of coal overlain by shale and underlain by 9 inches of impure coal resting on sandstone. About 85 feet higher up the hill, at location 616a, a much thinner bed, containing only 1 foot 2 inches of coal, was measured.

Locations 81 and 82, on Dry Fork of Morgan Gulch, are on the same bed of sandstone. Above this sandstone there is a coal bed that at location 83 consists of two benches of coal separated by 8 feet of brown sandy shale. The upper bench contains 2 feet 6 inches of coal overlain by gray sandy shale, and the lower bench 2 feet 1 inch of coal underlain by black carbonaceous shale. About 60 feet above location 83 is another bed (location 84) 1 foot 4 inches thick, with brown shale above and below. About three-quarters of a mile to the southwest, near the south line of sec. 20, 4 feet 9 inches of coal is exposed at location 85. The upper 4 feet 2 inches of the bed is good coal, but the lower 7 inches consists of impure coal. The bed is overlain by brown shale and underlain by black carbonaceous shale. A small amount of coal was uncovered at location 86, but its occurrence on the dip slope prevented a reliable measurement. There is thought to be at least 14 inches of coal at that point. Some coal was also seen farther southwest, on the top of the ridge at locations 87 and 88. The upper one of these beds (87) contains 1 foot 4 inches of coal and the lower bed 2 feet 5 inches of coal, as computed on the basis of a dip of 14°. At location 89, on the ridge farther southwest and at a lower horizon, the section shown in Plate XVII was measured.

The base of the section given above is about 125 feet above the Trout Creek sandstone. The beds throughout this interval bear evidence of having been burned. Also from location 89 up to the top of the hill there is an abundance of brick-red sandstone and baked shale, indicating that considerable coal has burned along the outcrop. At location 90 there is 1 foot 3 inches of coal overlain and underlain by brown shale. At 70 feet above this bed is another one, which, at location 91, measures 1 foot 4 inches and is overlain and underlain by brown shale. This bed, according to hand-level measurement, is 256 feet above the Trout Creek sandstone. Therefore the beds at locations 90 and 91 both lie stratigraphically above the bed at location 89.

Coal in and near Boxelder Gulch.—Location 49, in sec. 16, on the east side of Boxelder Gulch, marks an old prospect. The entry has been driven in about 15 feet. This coal bed is probably about 320 feet above the Trout Creek sandstone.

A bed containing 2 feet 3 inches of coal, overlain and underlain by shale was opened at location 50, on the west side of Boxelder Gulch. At location 51, on the east side of the ridge in sec. 8, 9 feet 2 inches of coal was measured 30 to 40 feet above the Trout Creek sandstone. Location 52 marks the outcrop of a large coal bed some distance above the bed just mentioned. Several openings were made, demonstrating that this is a thick bed, but it was decided that the broken-down condition of the coal would not permit an accurate measurement. This bed probably contains at least 10 feet of coal. Location 52a is on a coal bed containing two benches of coal separated by 4 inches of shale. The upper bench contains 3 feet 1 inch of coal and the lower bench 1 foot 6 inches.

Coal also occurs on the west side of the gulch immediately east of Red Cone. A bed about 175 feet above the Trout Creek sandstone, at location 53, shows 3 feet 4 inches of coal overlain and underlain by brown shale. The coal beds at locations 52, 52a, and 53 are apparently at about the same horizon. At location 54, estimated to be about 375 feet above the Trout Creek sandstone, the section shown in Plate XVII was measured. This coal bed may be the same as the one measured at location 49 and given in columnar section in Plate XVIII, for it is about the same distance above the Trout Creek sandstone.

A thin bed of coal was also found just north of the north line of sec. 7. At location 55 this bed is 1 foot 7 inches thick and is overlain by drab shale and underlain by brown shale.

COAL IN THE ILES FORMATION

A few beds of coal were found in the Iles formation in this area, but most of them are comparatively thin and broken by shale partings. Some coal was found at location 92, near the township line, in the southeast corner of sec. 13. The bed at this point contains 4 feet 3 inches of coal overlain by sandy shale and underlain by brown shale. This coal does not seem to break out into rectangular masses when weathered like most of the other Mesaverde coals. The structure is more inclined to be platy. The next coal seen in the Iles formation occurs on the west side of Morgan Gulch. A thin bed was measured at location 93, which is believed to be about 400 feet above the base of the Iles formation. This bed contains 2 feet 2 inches of coal beneath a soft sandstone. The upper 18 inches of the bed consists of good coal; the lower 8 inches contains some impurities. The bed is underlain by brown shale. At a point several hundred feet above this bed two other coal beds, separated by 8 feet of brown shale, were found at location 94. The upper bed contains 3 feet 9 inches of coal overlain by gray sandy shale. The lower bed contains 2 feet 9 inches of coal underlain by brown shale. Exposures of coal were also found below the Trout Creek sandstone on the west side of Boxelder Gulch. The lowest bed observed was measured at location 95. At that point there is 1 foot 2 inches of impure coal overlain and underlain by brown shale. Approximately 400 feet above this bed a section was measured at location 96.

Still another bed was opened and measured at location 97, which is about 175 feet higher than the bed described and about 200 feet below the Trout Creek sandstone. The bed contains 1 foot 7 inches of coal overlain by brown sandy shale and underlain by brown shale. The upper 14 inches of the bed consists of good coal, but the lower 5 inches contains considerable earthy impurities. From the descriptions given above it will be seen that all the beds on Boxelder Gulch in the Iles formation are comparatively thin. About half a mile west of Boxelder Gulch, in the northeast corner of sec. 8, two coal beds are exposed at what is supposed to be about the same horizon as that exposed at location 96. The upper bed, marked by location 98, contains 2 feet 1 inch of coal overlain by drab shale and underlain by brown shale containing thin streaks of coal. At 25 feet below this bed is another which contains 1 foot 3 inches of coal having a roof of sandy shale and a floor of brown shale.

The coal sections in Plate XVII and the descriptions of the coal beds may give the impression that the coal beds underlying this township are thin. It must be borne in mind, however, that where the beds are dipping rather steeply southwest on the northeast side of the synclinal axis the thicker beds are doubtless burned out for some distance back from the outcrop. South of the synclinal axis the prevailing northeasterly dip is very little steeper than the gradient of the long parallel gulches, so that there is a comparatively small thickness of the coal-bearing formations exposed. Furthermore, the beds on the sides of the parallel gulches southwest of the synclinal axis are not as a rule very well exposed.

QUANTITY OF COAL

The greater portion of these townships is underlain by the coal-bearing formations, and it is calculated that the coal beds underlying the different tracts are equivalent to 62 feet of coal underlying 33.3 square miles, and therefore the total quantity of coal in these townships amounts to 2,380,000,000 short tons.

POSITION OF THE COAL BEDS WITH RESPECT TO MINING

The most complete section of coal beds to be found in these townships occurs on the west side of Morgan Gulch immediately north of the Morgan ranch. The coal beds measured at this locality are shown in columnar section in Plate XVIII. Practically the only coal beds exposed elsewhere in this township occur in the sides of the gulches. A drift can be run in on any of these beds, and the coal can be mined out up the rise. The lowest point in the broadened portion of the Collom syncline appears to be in the northern part of sec. 22. According to the writer's interpretation of the structure from the data at hand, a shaft sunk in the valley of Morgan Gulch at that point would reach the Trout Creek sandstone at a depth of about 1,100 feet. This shaft would pass through practically all the coal beds included in the Fairfield coal group and shown in columnar section in Plate XVIII. By means of a series of entries extended in all directions from the main shaft as many of the coal beds could be mined as is practicable, and as the beds in general all dip gently toward the main shaft, the problems of drainage and haulage would be very simple.

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