DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 748

THE TWENTYMILE PARK DISTRICT OF THE YAMPA COAL FIELD ROUTT COUNTY, COLORADO

BY

MARIUS R. CAMPBELL

WASHINGTON
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By Marius R. Campbell.

INTRODUCTION.

DEVELOPMENT OF THE YAMPA FIELD.

Although the Yampa coal field, in Routt and Moffat counties, Colo., has been known in a general way for a great many years, its development on a commercial scale dates only from the year 1906, when the "Moffat railroad" first reached its eastern border and gave it direct communication with Denver and the East. In anticipation of this event sufficient prospecting was done to establish the fact that the best coal lies at the extreme east end of the field, and consequently the first mines to be opened were situated on Oak Creek, a stream that heads on the margin of the White River Plateau and flows northward for some distance along the eastern border of the field.

As the railroad was subsequently extended westward from Steamboat Springs, it was realized that good coal could be obtained below that place on Yampa River and some of its tributary streams, and mines were opened at Mount Harris, at Bear River, and on Indian Creek. More recently operations have been undertaken in the vicinity of Milner, in the Twentymile Park district, where a synclinal trough of coal-bearing rocks, branching off from the main basin, crosses Yampa River. (See Fig. 1.)

With all of this development, however, there has been a dearth of reliable information regarding the correlation of the coal beds and the relative value of the coals mined at the different places, each operator claiming, naturally, that his coal is the best in the field.

FIELD WORK AND ASSISTANCE.

In order to obtain information on the relative value of these coals, on the continuity and correlation of coal beds, and on the tonnage of coal underlying whatever Government land may remain in this district, so that it could be appraised and made available for purchase, the writer made brief visits to the district in 1918, 1919, and 1921. The present paper contains the results of these investigations together with those obtained by E. T. Hancock and D. E. Winchester,

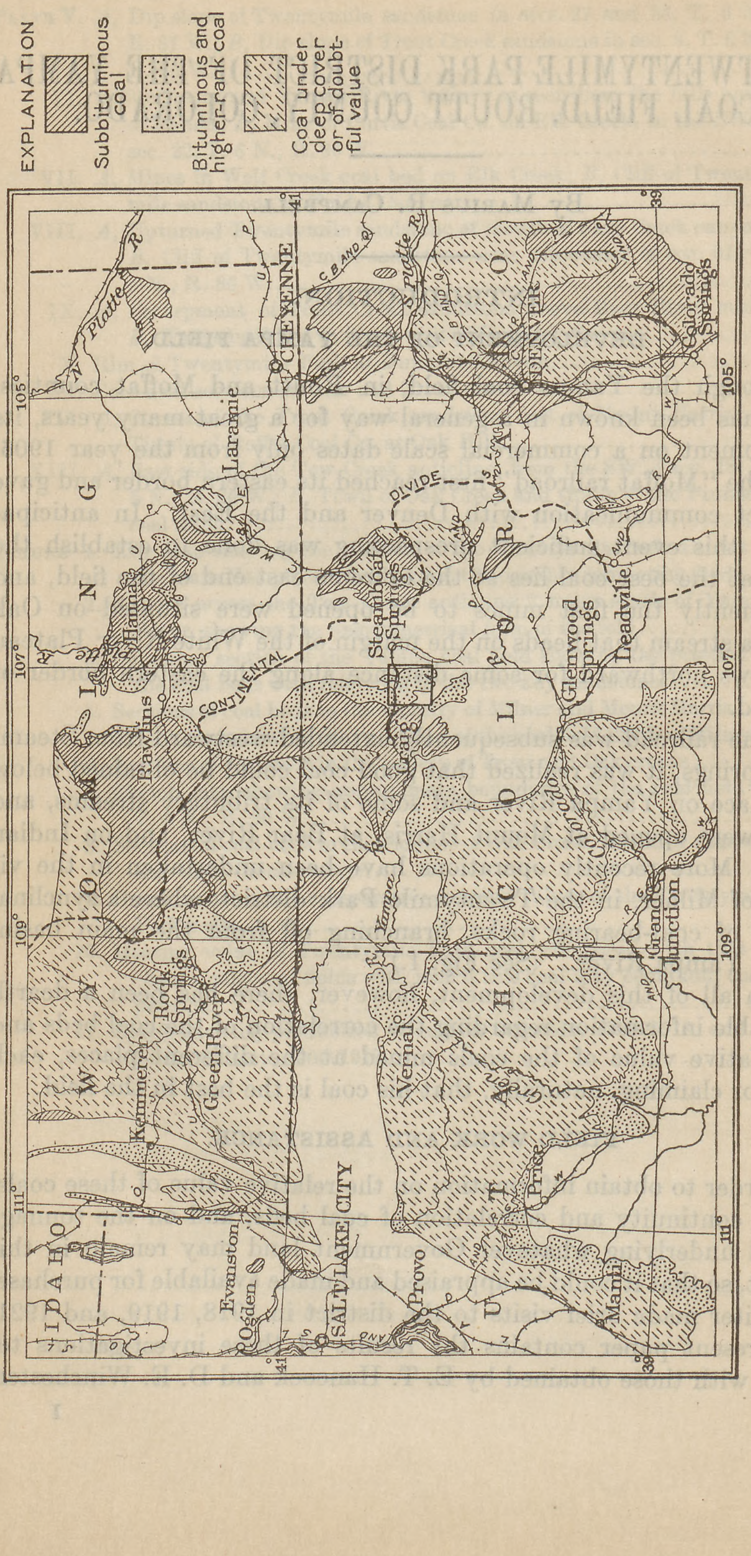


FIGURE 1.—Key map showing the relation of the Twentymile Park district (shown by the rectangle) to the main Yampa coal field and to the possibly competing fields.

geologists, of the United States Geological Survey, who had previously visited the field for the purpose of appraising certain small isolated tracts of land. The writer takes this opportunity to express his obligation to these geologists for the data supplied by them and also to the operators in the district examined, who have with one accord placed at his disposal valuable information regarding their operations. To the officials of the Moffat Coal Co. he is particularly indebted for a number of core-drill records, which have been invaluable in checking up the outcrop data and in presenting a graphic picture of the changes in the coal beds that occur in territory as yet unmined and but little prospected.

This statement would be incomplete without an acknowledgment of the valuable assistance rendered by Mr. M. D. Schafermeyer, of Steamboat Springs, who in addition to acting as chauffeur assisted in locating Government corners and measuring and sampling coal beds.

PREVIOUS WORK.

Up to the present time the only geologic report available on the Yampa coal field has been that of Fenneman and Gale.[1] The field work upon which that report was based was done in 1905, the year before the railroad reached the border of the field, and consequently before mines were opened or any other large development work had been undertaken. The authors of that report were dependent upon observations made in old prospect pits and on such natural exposures as could be found. In places these exposures were adequate to give a good idea of the character of the coal and of the number and thickness of the beds, but in most places they were not sufficient to make tracing of the individual beds or their correlation from place to place a feasible undertaking. In addition to these handicaps regarding the coal, it was difficult if not impossible to find Government land corners of the old Land Office survey, and the authors were compelled to spend most of their time in mapping the field by hasty methods in order to have some sort of base map upon which to present their results.

The present writer has drawn freely upon the published map and descriptions of Fenneman and Gale, and he is glad of this opportunity to acknowledge publicly his indebtedness to them and to express his high appreciation of the general accuracy of their report, considering the unfavorable circumstances under which it was prepared.

BASIS OF PRESENT WORK.

The present work is based entirely on the new surveys of the General Land Office, which were made about 1912. In many of the townships

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

the new survey consisted merely of a retracement of the lines of the old, but in others a complete new survey of the subdivisions was made. The corners are all marked by iron posts, and little difficulty was experienced in finding any particular corner desired.

In the writer's examination time did not permit a close instrumental survey of the district, but most observations were tied closely to the Government land corners. On the accompanying maps a solid line indicates boundaries of formations and outcrops of coal beds whose position is regarded as fairly accurate, but a broken line is used for outcrops that were not seen or were not carefully tied to land corners. The land net on the map is that of the recent survey of the General Land Office. The positions of surface features, such as roads, railroads, and towns, were transferred direct from the township plat of the General Land Office, were determined by field work done by the writer, or were taken from the map of Fenneman and Gale. As the surveyors of the General Land Office make no pretense of traversing roads and streams, the location of such features on the township plats is in the main very roughly sketched, being correctly placed only where they cross section or township lines. As a result, the map is not of uniform accuracy throughout, and not all the roads and streams are represented.

GEOLOGIC STRUCTURE AND ITS REFLECTION IN THE SURFACE FEATURES.

Twentymile Park is a broad, rolling treeless surface basin entirely surrounded by ridges of considerable height (see Pl. X), except where streams have cut narrow canyons through its bounding wall. It is drained by branches of Trout Creek, which in turn discharges its waters into Yampa River near Milner.

This park is really a big irregular syncline or structural basin as well as a surface basin (see Pl. I, in pocket), massive beds of white sandstone associated with the coal beds dipping under it from all directions. In general it may be considered a syncline with a nearly north-south axis which crosses Yampa River near Milner and which extends far to the south in the head of Foidel Canyon. In addition to the main basin there is a subordinate basin (the Argo syncline) on Trout Creek, which extends the point of the field southward to the Pinnacle mine in the southeast corner of T. 4 N., R. 86 W., and thence as a very shallow trough a few miles into T. 3 N., R. 86 W. The basin of Twentymile Park is separated from the main or Hayden basin of the Yampa field, to the northwest, by an anticline that enters the field from the north and dies out in Grassy Gap. This anticline is very pronounced where it crosses Yampa River between McGregor and Bear River, and as its axis north of the river coincides with Tow Creek it is generally spoken of as the Tow Creek anticline. On Yampa

River the fold is so large that all the coal-bearing rocks are brought above water level and the shale underlying them is exposed in the river bottom.

The southern margin of the Twentymile Park basin is indented by several anticlines which are developed south of the basin and which plunge under it at different points, making its rim a series of southward-projecting points and northward-reentrant angles. The most pronounced of these northward-plunging anticlines indents the rim of the field south of Hayden, and its anticlinal structure is clearly displayed in the canyons cut by the headwaters of Sage Creek. On account of this fact it is known as the Sage Creek anticline. This fold dies out soon after it plunges beneath the coal-bearing rocks, so that its effect is scarcely perceptible between the mouth of Sage Creek canyon and Yampa River.

A northward-plunging anticline of lesser magnitude indents the southern rim of the basin between Oak Creek and Dunkley Canyon,

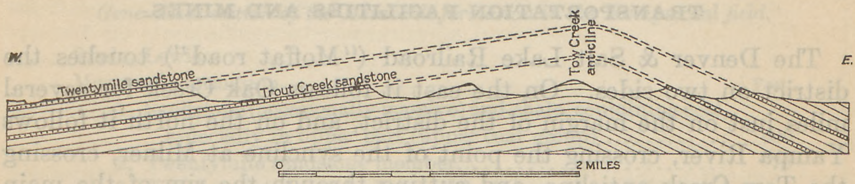


FIGURE 2.—Section across the Tow Creek anticline 2 miles south of Yampa River, showing the unsymmetrical form of the fold—steep dips on the east and gentle dips on the west.

affecting the rocks as far as the north line of sec. 28, T. 5 N., R. 86 W. Another small anticline (Williams Park) carries the rim of the basin to the center of sec. 8, T. 5 N., R. 87 W.

All these anticlines have one feature in common, and that is that in cross section they are unsymmetrical, the dips on the east side being much steeper than those on the west side. An anticline of this sort is represented in Figure 2, which is a cross section drawn to scale of the Tow Creek anticline, 2 miles south of Yampa River. This diagram shows the great dip slopes on the west side of the anticline in secs. 21, 22, and 23, T. 6 N., R. 87 W., which are caused by the weathering away of the soft shale and sandstone overlying the massive beds, leaving bare great inclined slabs of the sandstone, a characteristic feature of the region. The dip slope on the upper sandstone is well shown in Plate V, *A*. On the east side of the anticline the dip is much steeper and the sandstones make two pronounced ridges (Pl. XIII, *A*), which are generally present where the rocks dip steeply. The basins or synclines intervening between the anticlines have a corresponding structure, except that the eastern limb of each basin is gentle and the western limb is steeper.

The massive sandstones referred to above form the rim of the park, and generally they are well exposed, as are also some of the lower sandstone beds that in places form less pronounced ridges surrounding the park, but in Twentymile Park itself rock exposures are few and far between. The surface is composed almost entirely of shale, which weathers so readily that it forms a gently rolling country exhibiting no marked features of relief—no hills or ridges and no sharply cut canyons. (See Pl. XIII, *A*.) The surface is well adapted to farming, but the soil derived from the shale is a sticky clay upon which crops do not thrive. Also the rainfall in this part of the State is not always adequate for growing crops. The best agricultural land is on the "mesas," as the ridges which surround the park are generally called. The soil of these ridges is more sandy than the soil of the basin and it seems to conserve moisture better, for in years of drought good crops of grain can be grown on such land when crops on the adobe land in the central part of the basin fail completely.

TRANSPORTATION FACILITIES AND MINES.

The Denver & Salt Lake Railroad ("Moffat road") touches the district on two sides. On the east it follows Oak Creek for several miles just on the margin of the district, and on the north it follows Yampa River, crossing the point of the syncline at Milner, crossing the Tow Creek anticline, and cutting through the rim of the main Yampa basin at Mount Harris.

The oldest mines are on Oak Creek, where operations were begun in coal beds of the lower coal group, as recognized by Fenneman and Gale, as soon as the railroad reached this place; but recently considerable activity has been manifest on Yampa River, and several mines have been opened in the vicinity of Mount Harris, Bear River, and McGregor. Some of these mines are operating in beds of the lower group, and others in beds of the middle group. In parts of the district there are local mines which are operated in only a small way to supply fuel to the ranchers in the neighborhood. The principal wagon roads are shown on the map. Steamboat Springs, the largest town in this part of the State, is on Yampa River 13 miles east of Milner and is noted for its hot and bubbling springs. Oak Creek (see Pl. XIII, *B*) is the center of mining operations on the creek of the same name on the eastern margin of the field, and Mount Harris (see Pl. II) is the center of operations on Yampa River.

STRATIGRAPHY.

GENERAL FEATURES.

All the coal beds in the Twentymile Park district belong to the Mesaverde formation, which is one of the formations in the middle of the Upper Cretaceous series. Its position with reference to the other formations of the series in this region is shown in the following list:

"Laramie" formation.
Lewis shale.
Mesaverde formation.
Mancos shale.
Dakota sandstone.

The Mancos shale underlies Twentymile Park at a considerable depth and is well exposed on Yampa River from the mouth of Elk River to Steamboat Springs, at the southeastern point of the basin south of Oak Creek, and south of the basin on the wagon road from Yampa to Williams Fork. The Dakota sandstone crosses Yampa River at the Steamboat Cabin hotel, in Steamboat Springs, and is the formation from which issue the springs that have made the place well known.

Fenneman and Gale [2] gave a generalized section of the Mesaverde formation substantially as follows:

Generalized section of the Mesaverde formation in the Yampa coal field.

	Feet.
Shale, Lewis.	
Mesaverde formation.	
1. Sandstone (occasionally massive) and shale, containing coal, especially in upper part (upper coal group)	400
2. Twentymile sandstone member	75
3. Weak sandstone and shale, with frequently a prominent ledge-making yellow sandstone about 250 feet from the top	600
4. Sandstone (occasionally massive), shale, and coal beds of the middle group	400
5. Trout Creek sandstone member	75
6. Shale and weak sandstone, with few massive beds, containing in the lower part the upper beds of the lower group of coals	400
7. Massive sandstone, with subordinate shaly sandstone and shale, containing near the top the lower beds of the lower group of coal beds	750
8. Slabby or shaly sandstone with some shale, frequently having greater strength at two or three horizons; on erosion giving rise to hogbacks	750
Shale, Mancos.	
	3,450

Of the eight items in this section, Nos. 7 and 8 may be dismissed at once, as they contain little or no coal. Of the remainder of the section, Nos. 2 and 5 are the most prominent in the field and can be used as key rocks by which to recognize and identify the several beds of coal as well as to determine the structure. These sandstones are particularly prominent objects in the landscapes about Twentymile

[2] Op. cit., p. 23.

Park, and for this reason the upper one was named Twentymile sandstone and the lower one Trout Creek sandstone. Fenneman and Gale[3] describe these sandstones as follows:

The prominent ledge-making sandstone found in all parts of the field about midway between the lower and middle coal groups has been called the Trout Creek sandstone member on account of its excellent exposure near Trout Creek, on the northeast side of Twentymile Park. The rock is characteristically massive and white and is frequently more than 100 feet thick. While generally a ridge-maker or ledge-maker, its exposed surfaces readily weather to a friable condition. Its broad exposures are frequently marked by cracks making polygonal figures a foot or more in diameter. [See Pl. IV.] Great concretions and stains due to oxide of iron are also common. * * *

The base of the upper division is marked by a massive sandstone which has been called the Twentymile because of its typical development in and around Twentymile Park. In places it is a single bed of great thickness, but in other places it consists of a series of massive layers aggregating several hundred feet. The description of the Trout Creek sandstone member applies also to the Twentymile. Locally, as in Twentymile Park, this formation weathers into conspicuous pinnacles because of the protection afforded to the friable sandstone beneath by large irregular concretions.

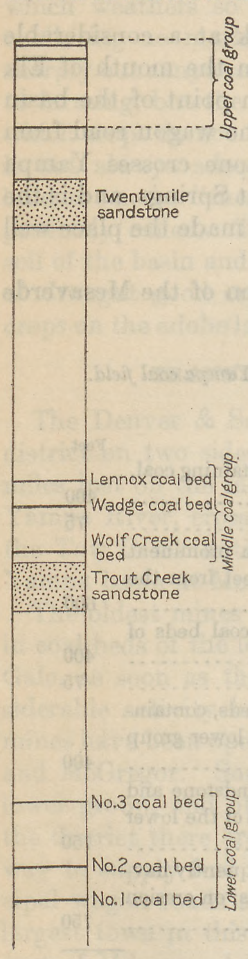


FIGURE 3.—Columnar section of the Twentymile Park district, showing the position of the coal beds with reference to the two key sandstones.

The surface of the Twentymile sandstone weathers into a network of polygons (see Pl. IV), which are separated by cracks an inch or so deep. This feature is characteristic of this sandstone in the Twentymile Park district.

Fenneman and Gale recognized three great groups of coal beds—the lower group, below the Trout Creek sandstone; the middle group, between the Trout Creek and Twentymile sandstones; and the upper group, above the Twentymile sandstone. Their generalized section, slightly modified, showing the key rocks and the groups of coal beds is given in Figure 3.

The upper limit of the Mesaverde formation is somewhat uncertain. The most striking change in the character of the rocks in Twentymile Park occurs about 150 feet above the Twentymile sandstone, for at this horizon practically all white sandstone disappears and the rocks for probably more than 1,000 feet are largely shale. If this section were considered by itself the logical place to divide the measures would be at this uppermost sandstone, but so far as known the rocks

[3] Op. cit., pp. 26, 27.

for a distance of about 400 feet above the Twentymile sandstone are either wholly or in large part of fresh-water origin; hence it seems more logical to include them in the Mesaverde formation than to group them as part of the Lewis shale, which is distinctly a marine shale. The division established at this horizon also fits the facts in the western part of the Yampa field better than one at 150 feet above the Twentymile sandstone, for in the western part of the field that part of the Mesaverde formation above the Twentymile sandstone is less shaly and contains several beds of coal and of massive sandstone. In view of all these facts the writer, following Fenneman and Gale, draws the upper boundary of the Mesaverde formation at the top of the upper coal group, which is here estimated to be 400 feet above the Twentymile sandstone. According to this method of treatment there is little if any Lewis shale in Twentymile Park, and in the field represented by the map this formation appears only in the flat lands between the Tow Creek anticline and Hayden, but the exact boundary between it and the Mesaverde formation below can not be located, as the rocks above and below it seem to be of the same composition.

COAL BEDS.

In the Twentymile Park district most of the rocks above the Twentymile sandstone have been eroded, so that coal must be obtained chiefly from the middle and lower groups. The coal beds of the lower group have been mined extensively on Oak Creek, where they probably are thicker and more numerous than they are at other places in the district, and they are also being mined at several places on Yampa River and Indian Creek. The general impression seems to be that the coal of these beds is the best in the field, but that the beds of the middle group are more regular in thickness and more extensive in geographic distribution.

The writer's examination was confined largely to the beds of the middle group, and particular attention was given to the tracing of their outcrops so as to determine if possible the extent of individual beds and the quality of the coal as compared with that obtained from mines operating on the beds of the lower group.

MOUNT HARRIS AND VICINITY.

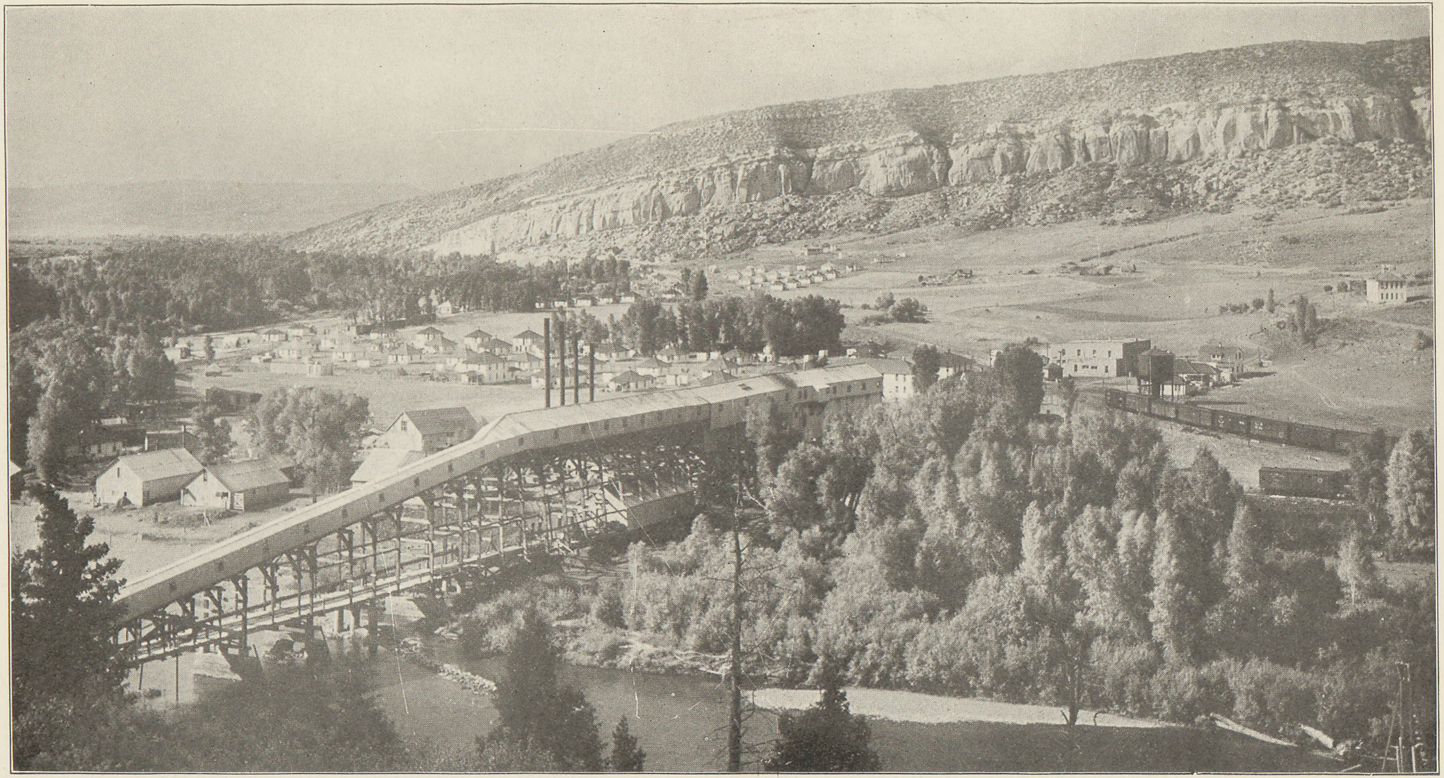
As mines are in operation in most of the beds of both the middle and lower groups in the vicinity of Mount Harris, and as this locality offers exceptional opportunities for determining the stratigraphic relations, work was begun here and the tracing extended from point to point on the rim of Twentymile Park.

Exploitation of the coal beds of the middle group at Mount Harris was begun a few years ago by the Colorado & Utah Coal Co., which opened a mine on a bed originally prospected by an old miner and prospector named Wadge and therefore generally known as the Wadge bed. Fenneman and Gale's measurement of this bed in 1905 gave 8 feet 3 inches of coal without a parting. The main slope of the Colorado & Utah Coal Co.'s mine (No. 1 on the map), in the NE. ¼ SW. ¼ sec. 15, T. 6 N., R. 87 W., is a short distance west of this prospect (see Pls. II and III), and in this mine E. T. Hancock and the writer in 1915 made measurements 1 to 3 in the following list in the course of cutting mine samples for analysis. J. J. Forbes, of the Bureau of Mines, also sampled this mine in 1918 and obtained measurements 4 to 11. The analyses are given on pages 70 and 71.

Thickness of coal bed in Mount Harris mine.

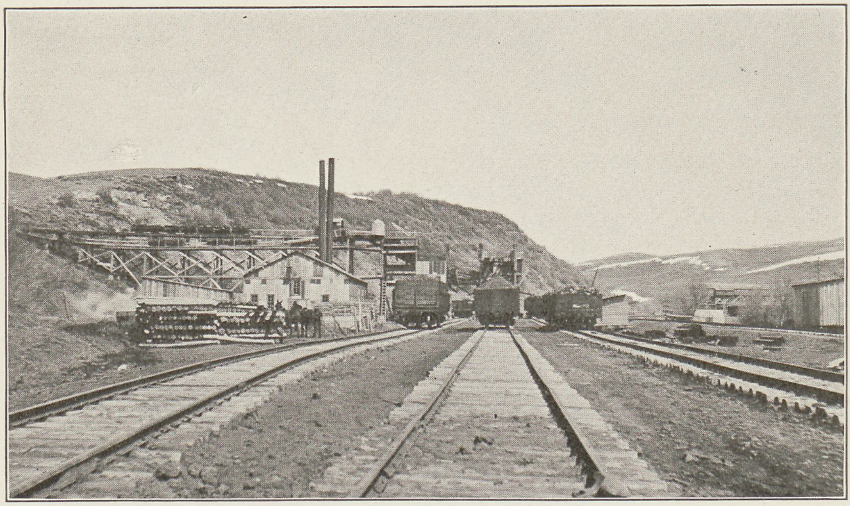
	Ft.	in.
1. Face of main entry, 2,600 feet south of mine mouth (analysis 22737)	9	
2. Main dip entry, 1,700 feet southwest of mine mouth (analysis 22738)	8	5
3. Face of Hill entry, 800 feet southeast of mine mouth (analysis 22739)	7	6
4. Left rib, 20 feet from face of 10 south entry. This thickness, however, is not all coal, as the bed consists of an upper bench of coal 8 feet 1½ inches thick, separated by shale 2½ inches thick from a lower bench of coal 1 foot thick. (Analysis 31199 represents both benches of coal)	9	4
5. Face of 3 east entry, off main south slope (analysis 31200)	9	9
6. 20 feet from face of G slope, off main south entry (analysis 31201)	9	
7. Face of 7 east back entry, off 2 south entry (analysis 31202)	9	5
8. Face of 10 east entry, off main south entry. The bed here is broken by a ¾-inch shale parting into an upper bench of coal 5 feet 6 inches thick and a lower bench 3 feet 3½ inches thick. (Analysis 31203 represents both benches of coal)	8	10¼
9. Left rib in last crosscut in A slope, 40 feet from face (analysis 31204)	8	4
10. 30 feet from face of main south entry (analysis 31205)	9	
11. 5 feet from face of main dip entry (analysis 31206)	8	6

The average of these eleven measurements is 8 feet 10 inches. (For a graphic representation of some of these sections see No. 1, Fig. 4.) The samples taken at the points specified above, as well as all others described in this report, unless otherwise stated, were taken in the manner described below, so that the analyses are strictly comparable. The samples were obtained by making cuts entirely across the bed from roof to floor, except such partings as are discarded by the miner, pulverizing the coal until it passed through a sieve of ½-inch mesh, and quartering down until each sample weighed about 4 pounds. They were then sealed air-tight in completely filled metal containers and sent to the laboratory for analysis.



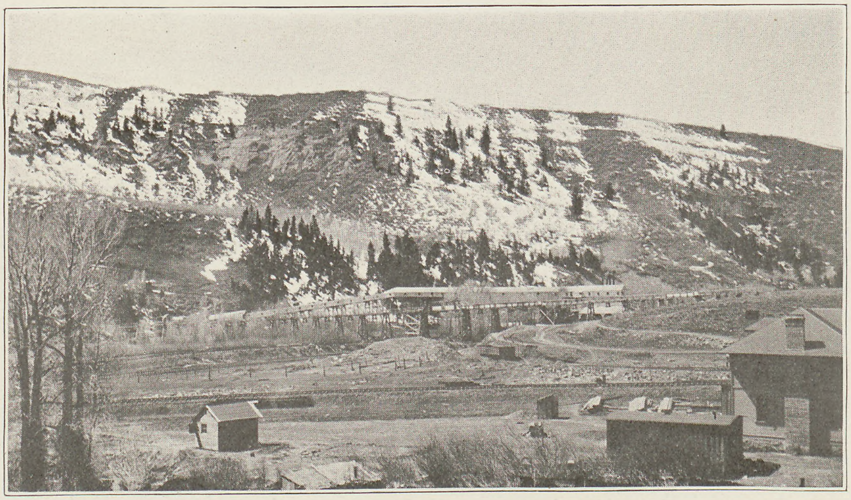
MOUNT HARRIS.

Tipple of the Colorado & Utah Coal Co. and the town of Mount Harris, as seen from the bluff on the south side of the river. Photograph by L. C. McClure, furnished by the Colorado & Utah Coal Co.



A. TIPPLE OF WADGE MINE, MOUNT HARRIS.

Coal from mines on both sides of the river is brought to this tipple, which is on Wolf Creek near the center of sec. 15, T. 6 N., R. 87 W. Photograph furnished by the Victor-American Fuel Co.



B. TRAMROAD OF WADGE MINE, MOUNT HARRIS.

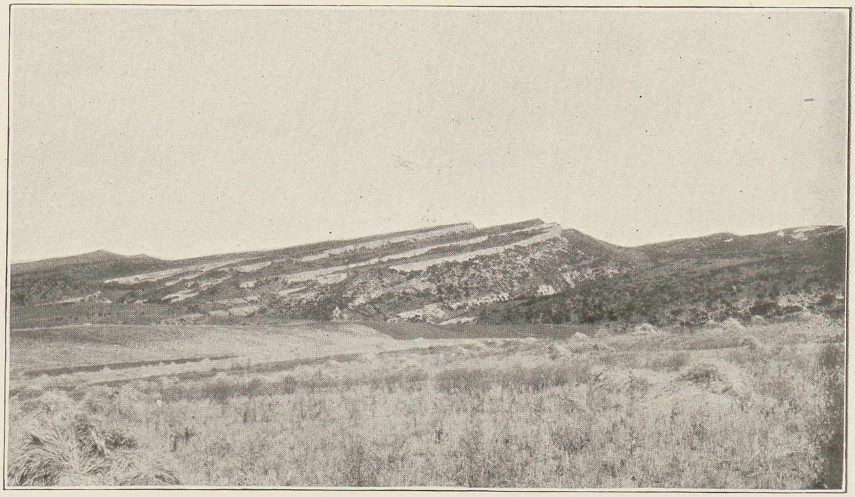
The point of view is near the mouth of Wolf Creek. Escarpment of Twentymile sandstone in the background. Photograph furnished by the Victor-American Fuel Co.

A. POLYGONAL WEATHERING OF TROUT CREEK SANDSTONE IN SEC. 9, T. 6 N., R. 86 W.

Shows edge of bed. Photograph by M. R. Campbell.

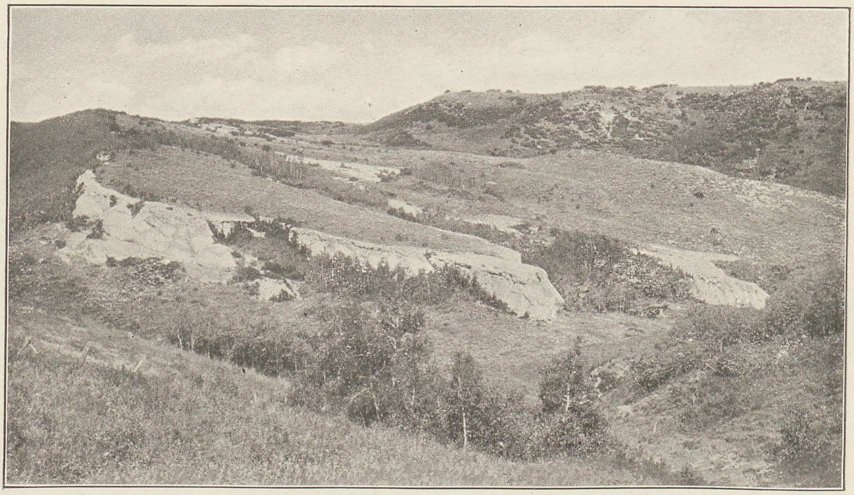
B. POLYGONAL WEATHERING ON A BEDDING PLANE IN TWENTYMILE PARK.

Photograph by M. R. Campbell.



A. DIP SLOPE OF TWENTYMILE SANDSTONE IN SECS. 27 AND 28, T. 6 N., R. 87 W.

Massive white sandstone, as seen from a point near the center of sec. 33. The Grassy Creek fault causes an apparent duplication of the beds. Photograph by M. R. Campbell.



B. DIP SLOPE OF TROUT CREEK SANDSTONE IN SEC. 9, T. 6 N., R. 86 W.

Photograph by M. R. Campbell.

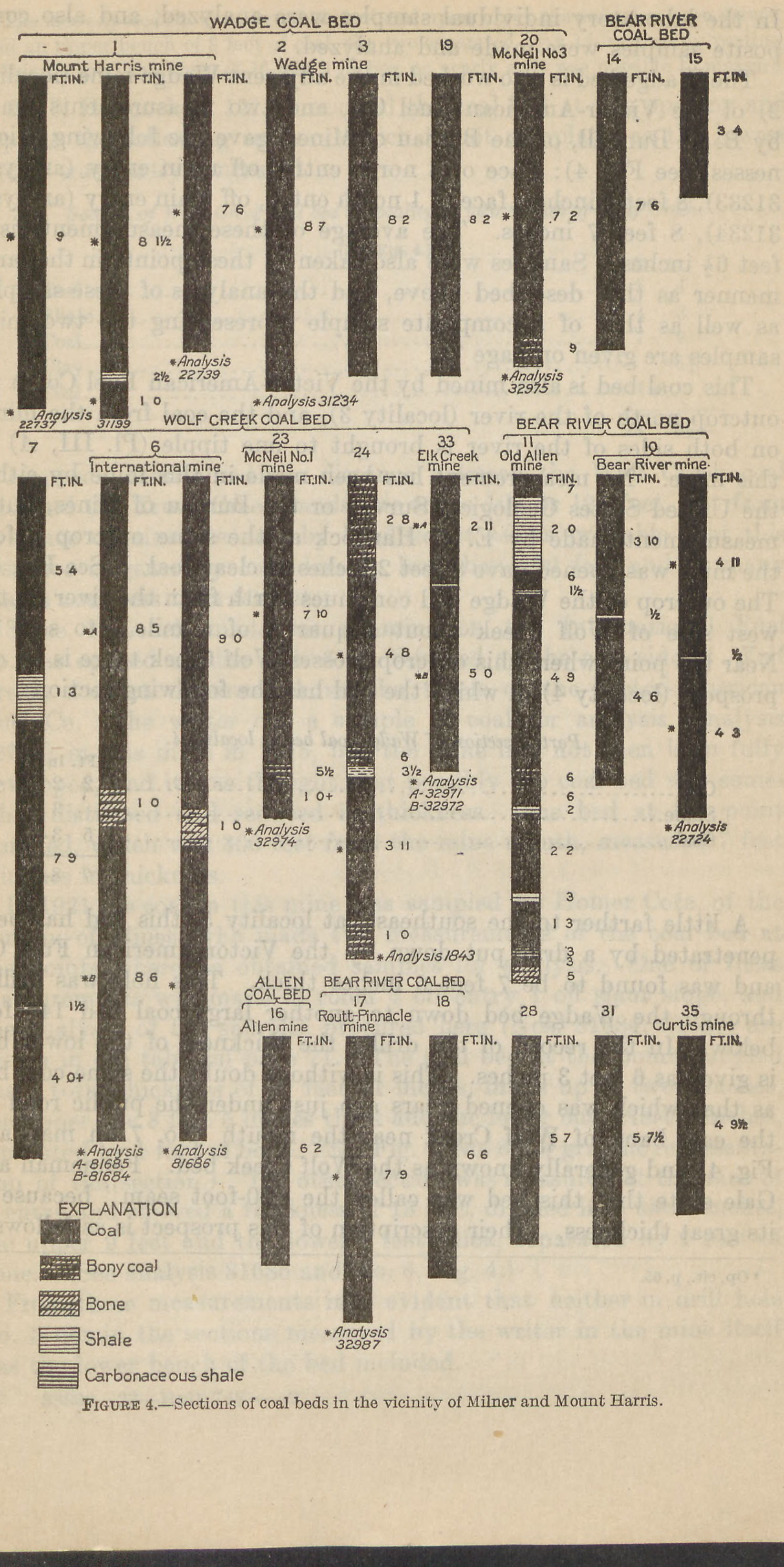


FIGURE 4.—Sections of coal beds in the vicinity of Milner and Mount Harris.

In the laboratory individual samples were analyzed, and also composite samples were made and analyzed.

The Wadge bed is also worked in the adjacent Wadge mine (locality 2) of the Victor-American Fuel Co., and two measurements made by B. F. Bunnell, of the Bureau of Mines, gave the following thicknesses (see Fig. 4): Face of 3 north entry, off main entry (analysis 31233), 8 feet 6 inches; face of 1 north entry, off main entry (analysis 31234), 8 feet 7 inches. The average of these measurements is 8 feet 6½ inches. Samples were also taken at these points in the same manner as that described above, and the analyses of these samples as well as that of a composite sample representing the two mine samples are given on page 71.

This coal bed is also mined by the Victor-American Fuel Co. in its outcrop north of the river (locality 3), and the coal from the mines on both sides of the river is brought to one tipple (Pl. III, *A*) at this mine. No measurement has been made in this mine by either the United States Geological Survey or the Bureau of Mines, but a measurement made by E. T. Hancock at the same outcrop before the mine was opened gave 8 feet 2 inches of clear coal. (See Fig. 4.) The outcrop of the Wadge bed continues north from the river on the west side of Wolf Creek about a quarter of a mile into sec. 10. Near the point where this outcrop crosses Wolf Creek there is an old prospect (locality 4) in which the bed has the following section:

Partial section of Wadge coal bed at locality 4.

	Ft.	in.
Coal	2	2
Shale		3
Coal	5	3+
	7	8+

A little farther to the southeast, at locality 5, this bed has been penetrated by a drill put down by the Victor-American Fuel Co. and was found to be 7 feet 6 inches thick. This hole was drilled through the Wadge bed down to another large coal bed 140 feet below. In the record of the driller the thickness of the lower bed is given as 6 feet 3 inches. This is without doubt the same coal bed as that which was opened years ago just under the public road on the east bank of Wolf Creek near the mouth (No. 7 on map and Fig. 4) and generally known as the Wolf Creek bed. Fenneman and Gale state that this bed was called the "20-foot seam" because of its great thickness. Their description of this prospect is as follows: [4]

[4] Op. cit., p. 65.

The face exposed shows a lower bench of coal upon which the entry has been driven, and an upper bench of 8 feet of coal, the two separated by a 15-inch sandy parting, making a total thickness of 16 feet 3 inches, as nearly as it was possible to measure.

E. T. Hancock in 1915 measured the coal bed at this opening and reports the following section, which is not complete, as the lowest bench was partly concealed:

Section of Wolf Creek coal bed at locality 7, near mouth of Wolf Creek.

[See Fig. 4.]

	Ft.	in.
Coal	5	4
Shale	1	3
Coal	7	9
Clay		1½
Coal	4+	
	18	5½+

Hancock determined the distance between the Wolf Creek coal bed and the Trout Creek sandstone to be 100 or 125 feet, but from evidence obtained in near-by localities it seems probable that this distance is generally considerably less than 100 feet and in many places even less than 50 feet.

Since Hancock made his examination the International Fuel Co. has opened a mine (No. 6) in this bed on the east side of Wolf Creek, a short distance above the tipple of the Victor-American Fuel Co. The writer cut a sample of coal for analysis (analysis 22736) in this mine in 1915, but the mine had not then been fully developed, and it was thought that possibly the coal bed was somewhat disturbed and reduced in thickness. The bed at the point sampled, which was 300 feet from the mine mouth, measured 7 feet 2 inches in thickness.

In 1921 the coal in this mine was sampled by Homer Cote, of the Bureau of Mines, who made two measurements of the coal bed at the points where he obtained samples for analysis. One of these measurements was made in room 4 off entry 1 off slant slope, and the analyses of the samples procured here (Nos. 81684, 81685) are shown in the table on page 71. The coal bed at the point sampled has a total thickness of 17 feet 11 inches, made up of two benches, the upper one 8 feet 5 inches thick and the lower one 8 feet 6 inches, separated by 1 foot of bone. (See Fig. 4, No. 6, for graphic representation of the section.) The other section was measured at the face of A entry and showed a thickness of 18 feet, divided into two benches, the upper 9 feet and the lower 8 feet thick, separated by 1 foot of bone. (See analysis 81686 and No. 6, Fig. 4.)

From these measurements it is evident that neither in drill hole No. 5 nor in the sections measured by the writer in the mine itself was the lower bench of the bed included.

Both the Wolf Creek and the Wadge beds pass under water level of Yampa River in the town of Mount Harris and are not exposed lower down on this stream. They can be traced by old prospects southward from Yampa River almost continuously to a point near the east quarter corner of sec. 22, T. 6 N., R. 87 W., where D. E. Winchester in 1917 reported a prospect (No. 8) on the Wolf Creek bed which measures as follows:

Partial section of Wolf Creek coal bed at locality 8.

	Ft.	in.
Coal	5	
Parting		3
Coal	1	1
Shale		4
Coal	4	10+
	11	6+

The Wadge bed is also opened near by, but the prospect has fallen shut, so that the thickness of the bed could not be determined

Across the divide separating the small creek upon which prospect No. 8 is situated and the eastern branches of Grassy Creek the Wadge bed shows in outcrop (No. 9) in the NE. ¼ sec. 27, T. 6 N., R. 87 W., with a thickness of 6 or 8 feet, but the old pits dug here are in such a condition that it was not possible to measure the full thickness of the bed. South of this point the bed is probably cut by a fault (shown on the map) and dropped about 150 feet, so that this line of outcrop is interrupted and comes in again farther to the east. No coal was seen south of the outcrop noted above, but burned shale marking the position of both beds was seen in a gulch in the northwest corner of sec. 2, T. 5 N., R. 87 W.

The outcrop of the Wolf Creek bed follows closely the top of the Trout Creek sandstone, but nothing is known of it south of the gulch mentioned above. As the land to the south of this gulch is very high, it seems probable that the outcrop swings to the east and then turns north on the east side of the Tow Creek anticline.

Resting on the Trout Creek sandstone is a small coal bed which is exposed on the north bank of Yampa River just east of the mouth of Wolf Creek and which probably does not exceed 18 inches in thickness. This bed and one called by Fenneman and Gale the Lennox bed, 3 feet thick and 70 feet above the Wadge bed, are all the coal beds in the middle group, except the two main beds, that are known in the Twentymile Park district.

In this district the Twentymile sandstone overlies at some distance the middle group of coal beds and makes conspicuous cliffs below Mount Harris, which are well shown in Plate II. The Trout Creek sandstone, which also is very conspicuous, makes a large ridge east of Wolf Creek. This sandstone dips about 10° W., forming a ridge that is unsymmetrical, having a slope on the west side corresponding closely with the dip of the rocks and a very steep front on the east side formed by the cut edges of the massive sandstone. Plate IX, *A*, shows the eastward-facing escarpment of this sandstone as it is seen from the wagon road that follows the river and skirts the bluff formed by this bed near the east line of sec. 15. This unsymmetrical ridge or cuesta,[5] as it may be called, is well developed south of Yampa River, and the back or gentle slope of the cuesta is well shown in Plate XII, *A*, which is a view from a point near the tipple of the Wadge mine, looking southeast.

The coal beds of the lower group have been thoroughly prospected in the northerly bend of the river in the vicinity of the Bear River mine (No. 10). This mine is at the foot of the slope below the escarpment of the Trout Creek sandstone shown in Plate IX, *A*, but as the photograph was taken in 1905 it does not show the mine. The Bear River mine and the prospects in this vicinity have been examined by E. T. Hancock, from whose unpublished report the writer obtains the following facts. The lower coal group in the vicinity of the Bear River mine consists of one principal bed and several smaller beds which are of doubtful commercial value. The principal bed, which was first developed at the Bear River mine (No. 10), lies nearly 600 feet below the top of the Trout Creek sandstone and varies in section from point to point on its outcrop. At the old Allen mine (No. 11), on the south side of the river in the NW. ¼ sec. 14, T. 6 N., R. 87 W., the bed is very much broken by partings, as shown in the following section:

Section of Bear River coal bed in old Allen mine, in the NW. ¼ sec. 14, T. 6 N., R. 87 W.

[See Fig. 4.]

	Ft.	in.
Shale, gray, sandy.		
Coal		7
Shale, brown	2	
Coal		6
Shale, brown, sandy		1½
Coal	4	9
Coal, impure		6
Coal		6
Shale, sandy		2
Coal	2	2
Shale, sandy		3
Coal	1	3
Shale, carbonaceous		3
Coal		3
Bone		5
	13	8½

[5] Cuesta is a Spanish term which means the flank or slope of a hill. It has been introduced into English geographic nomenclature and given a special meaning somewhat different from the original Spanish meaning. As used by many American geographers it means an unsymmetrical ridge with one slope long and gentle and generally agreeing with the dip of the resistant bed or beds that form it and the other slope steep or even precipitous on the cut edges of the beds that form the gentle slope.

This bed is exposed where it crosses the railroad, with a thickness of about 8 feet, but the section is not well shown, and a detailed measurement of it was not made. North of the railroad it has been extensively mined at Bear River station. In this mine (No. 10) the coal bed at a point 30 feet from the mine mouth has, according to Hancock, the following section:

Section of coal bed in Bear River mine.

[See Fig. 4.]

	Ft.	in.
Shale, carbonaceous.		
Coal	3	10
Shale, sandy		½
Coal	4	6
Shale, sandy.	8	4½

In the second drift of the mine, about 300 feet from the main entry, the coal bed is free from partings and has a thickness of 9 feet 4 inches. In the main entry, 375 feet from the mine mouth, the coal bed has the following section:

Section of coal bed in Bear River mine.

[See Fig. 4.]

	Ft.	in.
Coal (sampled)	4	4
Coal, soft (sampled)		7
Parting		½
Coal (sampled)	4	3
	9	2½

The sample obtained at this point was analyzed, with the result shown in No. 22724, page 72. Near the end of the first drift north the coal bed is 8 feet 5 inches thick.

The next exposure of this bed north of the river is at the old James mine (No. 12), in the S. ½ NW. ¼ sec. 1, T. 6 N., R. 87 W., where it consists of a single bench of coal 5 feet 2 inches thick. In an old prospect entry (No. 13) just over the spur that projects from the ridge on the west in the SE. ¼ NW. ¼ sec. 1, the coal bed is much broken by partings, as shown by the following section:

Section of coal beds in SW. ¼ NW. ¼ sec. 1, T. 6 N., R. 87 W.

	Ft.	in.
Shale.		
Coal		6
Coal, shaly		2
Coal	1	2
Shale, carbonaceous		8
Coal	1	2
Coal, sandy		½
Coal	2	3
Interval	20	
Coal [6]	6	4
Shale	2	
Coal	2	6
Total section	36	9½
Total coal	14	1½

[6] Section above interval measured by E. T. Hancock; section below interval measured by N. M. Fenneman and H. S. Gale (U. S. Geol. Survey Bull. 297, p. 67, 1906).

It seems probable that the lower bed in this section corresponds with the Bear River bed at the mine on the river, and that the bed 20 feet higher is the same as the thin coal beds in shale showing in the railroad cut about 40 feet above the big or Bear River bed. This bed, from 20 to 40 feet above the Bear River bed, and a small one not exceeding 3 feet in thickness 85 feet below the Bear River bed are the only ones found by Hancock north of the river.

South of Yampa River Winchester found two thick beds in the lower group, about 125 feet apart, the upper one 425 feet below the top of the Trout Creek sandstone. The lower of these two beds is locally called the "Allen" bed and the upper the "Pinnacle" bed. The use of the latter term doubtless implies that this bed is regarded as the same as the Pinnacle bed on Oak Creek. The evidence for and against such a correlation will be presented on another page, but the writer is certain that in the present state of development it is impossible to make such a correlation with any degree of certainty. In view of this opinion, which is based on careful examination of all available outcrops of the lower coal group between Bear River and Oak Creek, the writer prefers to use a local name, and as Bear River is the place where this bed was first worked he proposes to call it by that name.

From the old Allen mine the outcrop of the lower group of coal beds swings eastward around the point of the ridge and there turns south up Indian Creek on the west flank of the Tow Creek anticline. The coal beds in the valley of Indian Creek, which joins Yampa River half a mile above the Bear River mine, have been prospected and mapped by the Allen Coal Co. In ascending the valley the first prospect (No. 14) is on the Bear River bed on the west side of the valley and just east of the center of sec. 14, T. 6 N., R. 87 W. Here the bed is without a parting and 7 feet 6 inches thick. (See Fig. 4.) As the Bear River bed at the type locality is the uppermost bed of consequence in the lower coal group, and as the tracing has been practically complete from the river, the prospect mentioned above is regarded as unquestionably on the Bear River bed.

South of this prospect the outcrop has been traced almost continuously to the prospect (No. 15) just across the section line in sec. 23, where the Bear River bed is only 3 feet 4 inches thick. Almost directly below this prospect at a distance of about 125 feet is the mine (No. 16) of the Allen Coal Co. on the Allen bed. Two sections measured by Winchester give thicknesses of 8 feet and 6 feet 2 inches of clear coal. (See Fig. 4.) About half a mile up the creek from the Allen mine is the Routt-Pinnacle mine in the Bear River bed. Originally two mines were opened here, the Routt-Pinnacle mine (No. 17) and the Indian Creek mine, but within two years they have been consolidated, and they are now operated by the Routt-Pinnacle Coal Co. Some trouble was experienced with the coal bed in the old Routt-Pinnacle mine, and consequently a gangway was driven through from one mine to the other, and all the coal is now mined from the old Indian Creek mine, but it is lowered over the tramway and loaded into railroad cars from the tipple of the Routt-Pinnacle Coal Co.

The writer cut a sample for analysis in this mine, and at the point of sampling, 1,900 feet south of the mine mouth, the coal bed has a thickness of 7 feet 9 inches of clear coal. (See Fig. 4.) The analysis of the sample is given as No. 32987 on page 72. Winchester gives a measurement in this same mine of 7 feet 7 inches of clear coal. Farther up the valley, near the south line of sec. 24, there is a prospect (No. 18) in the Bear River bed, which, according to Winchester, shows a thickness of 6 feet 6 inches of clear coal. (See Fig. 4.)

The writer has no knowledge of either one of the large beds in the lower group south of the prospect last mentioned, but the Tow Creek anticline, coming into the coal field from the north and pitching toward the south, carries the outcrop of all the beds associated with the lower and middle coal groups far to the south. As shown by the map, the writer has traced the Trout Creek sandstone as far as the SE. ¼ sec. 35, T. 6 N., R. 87 W. South of this locality it seems to cap the arch, and hence its outcrop probably swings to the east and then northeast to the point indicated in the SE. ¼ sec. 30, T. 6 N., R. 86 W. But as the steeper dips are on the east limb of the anticline, it is possible that the Trout Creek sandstone may be exposed in secs. 1 and 12, T. 5 N., R. 87 W., in sec. 6, T. 5 N., R. 86 W., and in sec. 31, T. 6 N., R. 86 W. The surface of the Tow Creek anticline is rough, almost mountainous, and no attempt was made to trace the coal beds beyond the south line of sec. 24, T. 6 N., R. 87 W. It seems probable that they are not exposed in this region, as the writer found no one who knew of any coal showing in this part of the field.

MILNER AND VICINITY.

The outcrops of the coal beds of both the lower and the middle groups swing back northward on the east side of the Tow Creek anticline and cross Yampa River in a synclinal point at McGregor and Milner. The first exposure of the Wadge bed is in the southeast corner of sec. 20, T. 6 N., R. 86 W. This is an old prospect (No. 19), but the coal bed is well shown with a thickness of 8 feet 2 inches without a parting. (See Fig. 4.) The bed here dips slightly toward the southeast, and as the stream flows a little more toward the east than the strike of the rocks the bed descends at about the same rate as the grade of the stream, and as a result the outcrop is but little above stream level from the southeast corner of sec. 20 to McNeil

No. 3 mine. In the intervening distance there are three prospects showing 6 to 8 feet of coal. McNeil mine No. 3 (locality 20) has recently been opened and consists of a main entry driven in on the coal bed about 400 feet. A sample of coal for analysis (No. 32975, p. 71) was cut at the face of this entry, where the bed has the following section:

Section of Wadge coal bed in mine No. 3, McNeil Coal Co.

[See Fig. 4.]

	Ft.	in.
Shale.		
Coal (sampled)	7	2
Coal, bony		9
	7	11

This bed underlies most of sec. 21 and parts of secs. 16, 17, and 20, but throughout these sections there is considerable uncertainty concerning its outcrop. To judge by the position of the outcrop of the Trout Creek sandstone, to which the outcrops of the Wadge and Wolf Creek beds must of necessity be rudely parallel, the outcrops of the coal beds on the west side of the syncline are about as represented on the map. This is confirmed by the finding, about 500 feet east of the west quarter corner of sec. 16, of the outcrop (locality 21) of a large coal bed in the river bluff, dipping about 20° E.

From the position of this outcrop it is necessary to conclude that both the Wolf Creek and the Wadge coal beds underlie the flood plain of Yampa River, unless the original cutting of Yampa River was so deep as to have cut through even the lowest of these coal beds. This does not seem probable, for the greatest known depth of the sand and gravel that form the flood plain is less than 100 feet.

In addition to the Wolf Creek and Wadge beds in the syncline west of McGregor, the Lennox bed is also probably present, as the outcrop of a coal bed 3 feet thick was observed in the bluff at locality 22, about a quarter of a mile east of the quarter-corner post on the west line of sec. 16, T. 6 N., R. 86 W. If this is correctly identified the Wolf Creek bed should be present about 200 feet below the top of the bluff, or about 140 feet below the flood plain of Yampa River.

Owing to the shallowness of the syncline in sec. 16 it is probable that the coal in the Wadge bed is affected by weathering to such an extent that its market value is greatly reduced, and it can with difficulty compete with coal from the same bed in other mines in which the coal is not weathered. The Wolf Creek bed is doubtless similarly affected on the east and west margins of the basin, but the effect of weathering probably does not extend far into the trough, as this coal bed in the middle is under considerable cover and it is largely below the level of the ground water of this part of the field.

So far as the writer is aware this bed has not been prospected on the east flank of the Tow Creek anticline south of Yampa River, but its position can be determined approximately by the outcrop of the Trout Creek sandstone, as shown on the map. This sandstone makes a pronounced ridge across sec. 20 and part way across sec. 17, T. 6 N., R. 86 W. The ridge dies down near the river, but the massive sandstone, dipping 22° E., is well shown in the river bluff a short distance west of the east quarter corner of sec. 17. The Wolf Creek coal bed should normally occur within 100 feet of this sandstone, so its outcrop is due in the bluff a little farther east. North of the east quarter corner of sec. 17 the Wolf Creek bed is not exposed, but as the Trout Creek sandstone is exposed north of the river in the southwest corner of sec. 9, dipping strongly to the east, it is probable that the outcrop of the Wolf Creek coal bed crosses the river bottom and is cut off by the fault that is supposed to pass close to the foot of the bluff and along the county road near the south line of sec. 9. The Wadge coal bed also is probably present beneath the flood plain of Yampa River, but its depth can not be determined without drilling. The next natural exposure of the Wolf Creek bed is on the east side of the rocky point on which stands the town of McGregor. (See Pl. VI, *A*.) Here the river swings strongly against the bluff, exposing the following section:

Section of Wolf Creek coal bed and associated rocks in river bank at McGregor.

	Feet.
Shale.	
Coal, Wolf Creek bed	8+
Shale, sandy, and thin sandstone	35
Sandstone, massive, white, Trout Creek	5+
	48+

The sandstone at water level rises southward and can be followed up the river until at least 50 feet is exposed. It has all the characteristics of the Trout Creek sandstone and is so regarded by the writer, though it is not more than 35 feet below the Wolf Creek coal bed. This exposure of the coal doubtless led to the location of the McNeil mine No. 1 (locality 23) just to the west of this rocky point. In this mine the writer cut a sample for analysis (No. 32974, p. 72) about 1,600 feet south of the mine mouth, where the bed has the following section:

Section of Wolf Creek bed in McNeil No. 1 mine.

[See Fig. 4.]

	Ft.	in.
Coal (sampled)	7	10
Coal, bony		5½
Coal	1+	
	9	3½+

The bed dips southwestward and is about 50 feet below water level in the back end of the mine. As the dips in this mine are all southwestward, toward the deeper part of the basin, and as similar dips can be seen in mine No. 3, the axis of the basin must be west of these mines. However, in mine No. 3 the entry seems to be level for about 250 feet from the mouth and then begins to rise eastward with a perceptible grade; hence it seems possible that the mouth of this mine is about at the axis of the basin. This view is corroborated by the rise of the Wadge bed up the creek from this mine at least as far as locality 19. The eastern outcrops of the Wadge and Wolf Creek coal beds doubtless cross Yampa River to the fault along the county road, but they are concealed by the sand and gravel composing the flood plain. As described on page 31 it is probable that the outcrops of these beds swing eastward in conformity with the eastward swing in the outcrops of the coal beds of the lower group.

North of Yampa River the coal beds of the middle group are both present in some high land north of the main Milner-Mount Harris road and occupy most of sec. 9, T. 7 N., R. 86 W. These beds have been worked extensively in the past, and the coal was hauled as far as Steamboat Springs. The mine most recently in operation is known as the McCrosky mine (No. 24), in the Wolf Creek bed. According to Fenneman and Gale the coal bed in this mine has the following section:

Section of the Wolf Creek coal bed in the old McCroskey mine, north of Yampa River.

[See Fig. 4.]

	Ft.	in.
Coal, bony	2	8
Coal	4	8
Coal, bony		6
Clay		3½
Coal	3	11
Coal, bony	1	
	13	½

At this mine, which is about 80 feet above the flood plain of Yampa River, there is a slight eastward dip. It is so slight as to be scarcely apparent at the mine, but from the bluff on the south side of the river it is plainly apparent that the coal bed dips eastward until it is at flood-plain level at an old prospect (No. 26) by the roadside.

Up the hill directly above prospect 26 the Wadge bed has been opened by a mine (No. 25) in which the writer made the following measurements:

Section of Wadge bed at locality 25.

	Ft.	in.
Coal	2	2½
Shale		9
Coal, bottom not exposed	4	5+
	7	4½+

At the time of measurement the bottom of the coal bed was not exposed, but the figures given above probably represent nearly the entire thickness of the bed. The distance between the Wolf Creek and Wadge beds was determined at this place by hand level to be 175 feet, but as the beds dip southward this apparent distance probably should be reduced to about 150 feet.

The Wadge and Wolf Creek coal beds have not been prospected on the north side of Yampa River, except in the face of the hills fronting the river valley, and hence their positions at other places can be determined only by the outcrop of the Trout Creek sandstone and its relation to the surface.

The Trout Creek sandstone shows clearly beneath the Wolf Creek coal bed at the old McCrosky mine (No. 24), just north of the south quarter corner of sec. 9, T. 6 N., R. 86 W. From this place it can be traced continuously westward and northward around the hill into the NW. ¼ sec. 9. It crosses the creek in the northern part of the section and from this place extends northward into sec. 4 as a great inclined plate of white sandstone (see Pl. V, *B*), with but little cover above its upper surface. It is deeply cut by the next ravine, but its outcrop on the east side of this ravine swings again to the north and terminates about a quarter of a mile northwest of the common corner of secs. 3, 4, 9, and 10. From this northern point the outcrop is not plain, but the bed is more steeply upturned on the east side of the syncline than it is on the west side, and the sandstone does not make outstanding ledges as it does on the west. Its outcrop, however, was seen in the brow of the hill just east of the section corner noted above, and from this point it makes the eastern crest of the ridge nearly to the west quarter corner of sec. 10. Here the sandstone appears to be badly broken, the ridge breaks down, and the outcrop can be followed only by an irregular row of blocks of the harder part of the sandstone as far as the county road. From this disposition of the Trout Creek sandstone it is apparent that the coal beds above the sandstone underlie but a small territory north of the river. The Wadge bed is confined to the hilltops in the S. ½ sec. 9, and the Wolf Creek bed to the southern and eastern parts of this section, but much of this bed is under so thin cover that doubtless it is badly affected by weathering.

The relation of the coal beds of the middle group north of Yampa River to the same beds south of that stream has always been puzzling, as they do not exactly match. For instance, the Trout Creek sandstone that shows so prominently in the river bluff near the east quarter corner of sec. 17, T. 6 N., R. 86 W., shows with equal prominence in the bluff facing Tow Creek a few hundred yards north of the southwest corner of sec. 9 and with the same steep eastward dip. Just across the narrow valley of Tow Creek, however, the same sandstone may be observed dipping very gently eastward under the Wolf Creek coal bed, and this sandstone reaches water level only between the old mine at locality 24 and the prospect at locality 26. If the dip observed south of the river near the west quarter corner of sec. 16 and north of the river in the southwest corner of sec. 9 holds for any great distance the Trout Creek sandstone must pass below water level in the broad flood plain of Yampa River, whereas on the north of the main road it is above water level for a distance of half a mile to the east of Tow Creek. Similarly the Wolf Creek coal bed is below water level in McNeil No. 3 mine, but directly across the valley it is above the flood plain. The only explanation of these apparent anomalous relations is that this part of the basin has been cut directly across by a fault and that the part on the south has been depressed 100 to 150 feet with relation to the part on the north. Further evidence regarding this fault is given on pages 29–31 in the consideration of the coal beds of the lower group on the east side of the syncline.

The coal beds of the lower group are exposed on both sides of Yampa Valley, having been prospected and mined at a number of places on the west limb of the syncline. At locality 27, in the bluff on the south side of the river, several beds are exposed and the presence of others is indicated by red, baked rocks where the coal has burned. A roughly measured section at this place is given below. The beds dip about 30° E.

Section at locality 27, south of Yampa River.

	Ft.	in.
Sandstone, Trout Creek	50+	
Shale	360	
Coal	1	
Shale		½
Coal	2	6½
Interval, mainly sandstone	130	
Coal		9½
Interval, mainly sandstone	110	
Coal	1	6
Shale	3	6
Coal	2	
Interval, mainly sandstone	90	
Coal	1	
Interval, mainly sandstone	100	
Coal	1	3½
Sandstone, massive	90	
Coal, small, burned.		
Interval, mainly sandstone	50	
Coal, big bed, burned.		
Interval	40	
Sandstone, white.		
	1,033	8

At the outcrop of the uppermost coal bed in this section there are traces of an old timbered drift, which is supposed to have been the Chisney mine mentioned by Fenneman and Gale. The section of this bed is not very promising, and it seems probable that there may be another bench of coal which is not exposed. This is probably the same coal bed that has been mined to a considerable extent at locality 28, on the opposite side of the river valley. Below this principal bed there are about six others which are rather poorly exposed in the south bluff of the river, below the Chisney mine, and which are shown in the section given above either as actual outcrops or as burned beds that are marked in outcrop by a deep-red color.

North of Yampa River the principal coal bed is exposed at locality 28, by the side of the main road. This bed was mined long ago, but although the old entries are badly caved a thickness of 5 feet 7 inches of clear coal (Fig. 4) was measured. About 50 feet below this bed is another which has been exposed by a rock slide and which shows a thickness of 3 feet 2 inches. Below this bed there are indications of the outcrop of several others, but they have not been prospected here, and their thickness is unknown.

The last coal outcrop is about 40 feet above a white sandstone that is very conspicuous in the steep hillside bordering the road west of locality 28. This bed and a buff sandstone about 380 feet lower in the geologic column are important markers in that part the coal field which lies north of Yampa River, and their outcrops are shown approximately in Figure 5. As practically all of the known coal beds lie above the white sandstone, its outcrop is taken as marking the limit of the coal field.

The relation of the coals already described seems to be clear, but their relation to beds opened farther north on Tow Creek is not so apparent. On the south side of Tow Creek an old opening (No. 29) exposes a coal bed at least 5 feet thick, and it is probably somewhat thicker, but the condition of the entry did not permit exact measurement. It is probable that this bed is the same as the bed seen near the river road, 5 feet 7 inches thick. The correlation of coal beds on the two sides of Tow Creek is rendered difficult and uncertain by the presence of the fault shown on the map. This fault probably weakened the upturned rocks that formed the rim of the basin and permitted Tow Creek to find a passage across this rim toward the east, rather than through the shale directly to the river along the axis of the anticline. The fault also offsets the coal beds, throwing the outcrop of the beds south of the fault farther west than the outcrop of the same beds north of the fault.

North of sec. 9, T. 6 N., R. 86 W., the coal beds are poorly exposed, and in a reconnaissance examination the writer was not able to trace their outcrops in a satisfactory manner. The syncline that is so

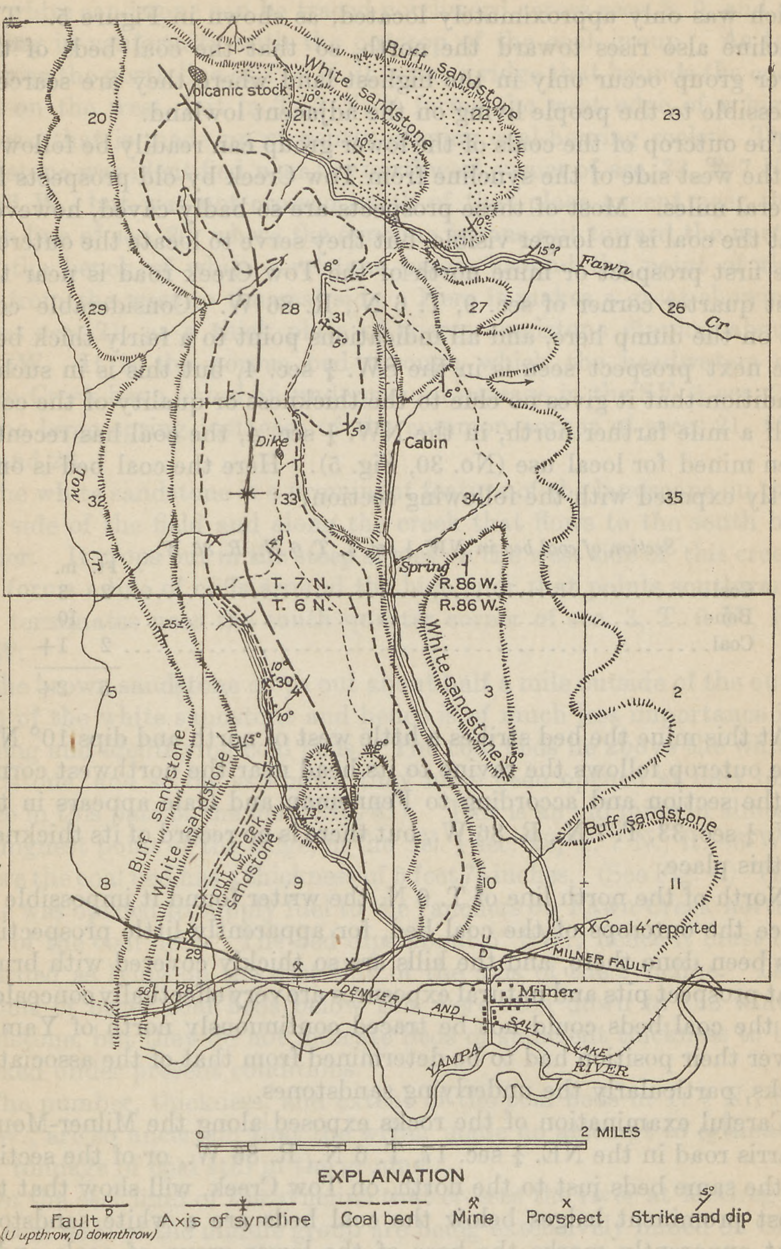


FIGURE 5.—Sketch map showing the extension of the coal field north of Milner.

apparent in sec. 9 rises rapidly northward, and beyond the center of sec. 4 the rocks dip only slightly from both sides toward the axis, which was only approximately located, as shown in Figure 5. The syncline also rises toward the north, so that the coal beds of the lower group occur only in the highest land where they are scarcely accessible to the people living on the adjacent lowland.

The outcrop of the coals of the lower group can readily be followed on the west side of the syncline from Tow Creek by old prospects for several miles. Most of these prospects are so badly caved, however, that the coal is no longer visible, but they serve to locate the outcrop. The first prospect or mine north of the Tow Creek road is near the west quarter corner of sec. 9, T. 6 N., R. 86 W. Considerable coal lies on the dump here, and all indications point to a fairly thick bed. The next prospect seen is in the SW. ¼ sec. 4, but this is in such a condition that it gives no clue to the thickness or quality of the coal. Half a mile farther north, in the NW. ¼ sec. 4, the coal has recently been mined for local use (No. 30, Fig. 5). Here the coal bed is only partly exposed with the following section:

Section of coal bed in NW. ¼ sec. 4, T. 6 N., R. 86 W.

	Ft.	in.
Coal	2	3
Bone		10
Coal	2	1+
	5	2+

At this mine the bed strikes a little west of north and dips 10° NE. The outcrop follows the ravine to its head near the northwest corner of the section and according to Fenneman and Gale appears in the SW. ¼ sec. 33, T. 7 N., R. 86 W., but there is no record of its thickness at this place.

North of the north line of T. 6 N. the writer found it impossible to trace the outcrops of the coal bed, for apparently little prospecting has been done there, and the hills are so thickly covered with brush that prospect pits and natural exposures are very effectually concealed. As the coal beds could not be traced continuously north of Yampa River their position had to be determined from that of the associated rocks, particularly the underlying sandstones.

Careful examination of the rocks exposed along the Milner-Mount Harris road in the NE. ¼ sec. 17, T. 6 N., R. 86 W., or of the section of the same beds just to the north, on Tow Creek, will show that the most prominent ledges below the coal beds are a white sandstone that apparently marks the base of the lower group of coals and a brownish-buff sandstone that occurs about 400 feet lower in the formation. Although these beds were not followed continuously in the region north of the river, they were identified with seemingly but little chance of error at every place upon the rim of the basin that was visited, and their approximate outcrop is shown in Figure 5. The white sandstone can be traced northward across secs. 8, 9, and 4, curving in conformity with the outcrop of the coal group. As far north as the north line of T. 6 N. it forms a ridge that bounds the coal field on the west, but in T. 7 N. it forms the west edge of a high plateau that is made up of gently dipping coal-bearing rocks. The sandstone was identified near the northwest corner of sec. 33, T. 7 N., R. 86 W., but was not crossed north of that place except near the north line of sec. 20, where the syncline spoons out toward the north and the bench of white sandstone passes around the point of the fold from the west to the east side. Here it makes a great showing across sec. 21, as a thick plate of coarse sandstone dipping about 10° SW. It is the porous bed through which the headwaters of Fawn Creek have found an underground passage in the SE. ¼ sec. 21 to the large spring just east of the common corner of secs. 21, 22, 27, and 28.

The white sandstone is a prominent feature of the landscape on the east side of the field and along the creek that flows to the south by Milner. It crops out in the steep slopes on the west side of this creek and forms a line of cliffs around the high spur that points southward and terminates near the south quarter corner of sec. 3, T. 6 N., R. 86 W.

The brown sandstone crops out about half a mile outside of the outcrop of the white sandstone and hence is of much less importance in tracing and identifying coal beds. The coal beds lie above the white sandstone, and so far as known they have been opened at only one place in this part of the field (No. 31). This is an old mine in almost the highest point of the ridge, in the SE. ¼ sec. 28, T. 7 N., R. 86 W., where the coal bed has a thickness of 5 feet 7½ inches. (See Fig. 4.) The mine was opened to supply fuel to the ranchers on Fawn Creek northeast of the coal field. The bed dips about 5° SW.; hence it must be regarded as lying on the east side of the axis of the syncline. The blooms of other coal beds below this were seen down to the white sandstone, but they do not indicate beds of sufficient thickness to be worked under present conditions.

The number, thickness, and extent of the coal beds in T. 7 N., R. 86 W., are so uncertain that the writer made no attempt to estimate the tonnage of coal still in the ground.

On the east limb of the syncline that crosses the river at McGregor the coal beds of the middle group are being extensively mined on Elk Creek. These beds can easily be identified by their physical characteristics as the Wolf Creek and Wadge beds, but their positions with regard to the massive sandstones are not so apparent as they are at Mount Harris, for on Elk Creek the Trout Creek sandstone is friable and makes little showing at the surface and the Twentymile sandstone crops out far away to the southwest, on the divide between Elk Creek and Twentymile Park.

The Wolf Creek coal bed was first opened on the north side of Elk Creek (No. 32) by the Federal Coal Co., but at the time of the writer's visit this mine was idle. The mine is high on the hillside at the site of the old Hitchens mine, as described by Fenneman and Gale, but the coal bed is under slight cover with excellent drainage in both directions, and as a consequence the coal is weathered and the company has had difficulty in disposing of its output. The same thing is true, to a certain extent, of the coal mined by the Elk Creek Mining Co. at locality 33, but as the mine has been driven in thicker cover has been found and correspondingly better coal. The relation of these mines to the surface features is well shown in Plate VII, *A*. The writer sampled this coal for analysis at a point about 1,000 feet from the mine mouth, where the bed has the following section:

Section of Wolf Creek coal bed in mine of Elk Creek Mining Co.

	Ft.	in.
Sandstone.		
"Draw slate"		6
Coal, bony (sample 32971, p. 72)	2	11
Coal (sample 32972, p. 72)	5	
	8	5

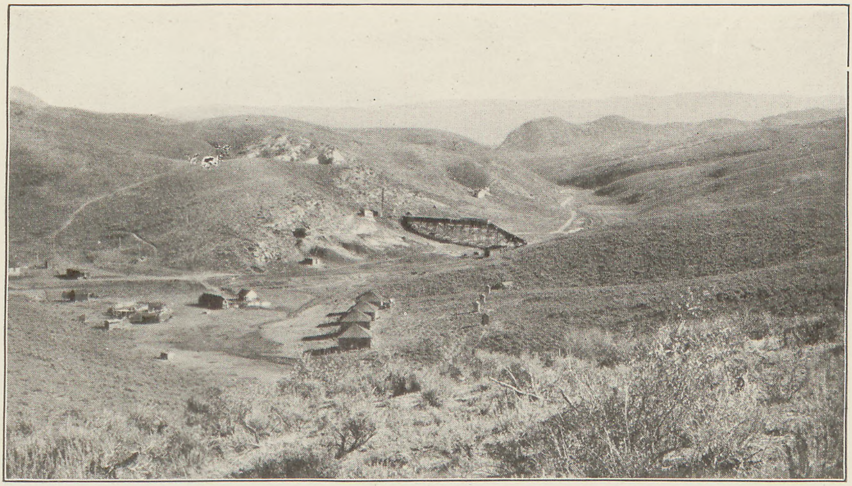
The Wadge coal bed is opened still farther up Elk Creek at locality 34, near the north quarter corner of sec. 28, T. 6 N., R. 86 W. A mine was being developed here at the time of the writer's visit, but it was not examined and the thickness of the coal bed was not determined. According to report the bed is 8 feet thick. As the Wolf Creek and Wadge beds are not opened one above the other, the distance between them could not be measured directly, but the superintendent of the Curtis Coal Co. states that he has measured this distance instrumentally and found it to be 147 feet.

The identity of these coal beds on Elk Creek is beyond question. It is true that owing to its friable character the Trout Creek sandstone is scarcely visible here, but the presence of such a sandstone 35 feet below the Wolf Creek coal bed at McGregor and the exposure of a similar bed in the NE. ¼ sec. 28 make it certain that the lower of these coal beds is the Wolf Creek and the upper the Wadge.

The coal beds of the middle group show remarkable regularity so far in this district, but the same thing can not be said of the beds of the lower group. Persistent efforts have been made by the Curtis Coal Co. to find more than one workable bed in the Elk Creek valley and adjacent regions, but to no avail. The mine of this company (locality 35 on the map; see also Pl. VI, *B*) is on the uppermost or

A. McGREGOR AND YAMPA RIVER VALLEY, AS SEEN FROM THE HILLS NORTH OF MILNER.

The mine is just behind the lower end of the town. Tow Creek anticline on the right. Photograph by M. R. Campbell.

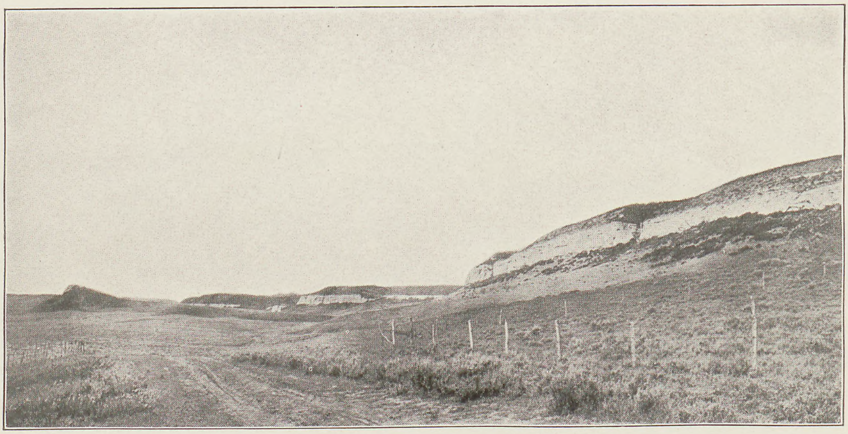


B. MINE OF CURTIS COAL CO. ON ELK CREEK, IN THE SW. ¼ SEC. 22, T. 6 N., R. 86 W.

This mine is No. 35 on the map. View from south line of section, looking northeast. Photograph by M. R. Campbell.

A. MINES IN WOLF CREEK COAL BED ON ELK CREEK.

Mine of Elk Creek Mining Co. at left; mine of Federal Coal Co. at right. Photograph by M. R. Campbell.

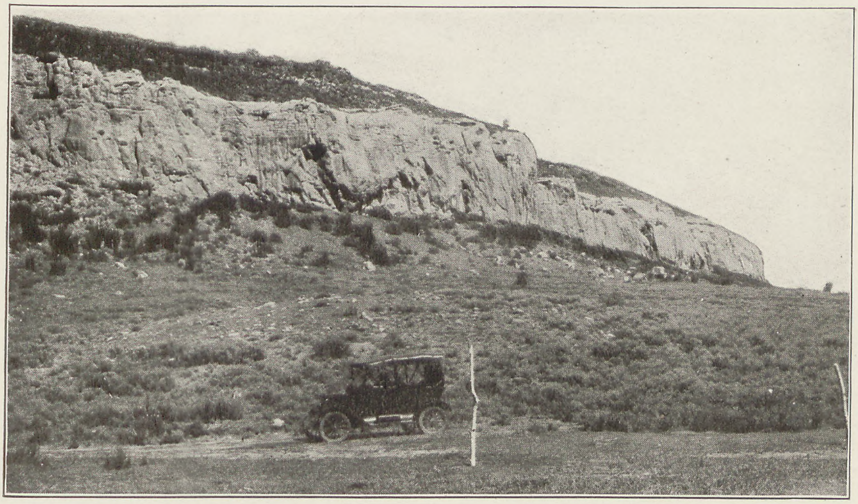


B. CLIFF OF TWENTYMILE SANDSTONE IN FOIDEL CANYON.

Shows fault in the distance and a small remnant of the sandstone on the left, in the middle of the valley. Photograph by M. R. Campbell.

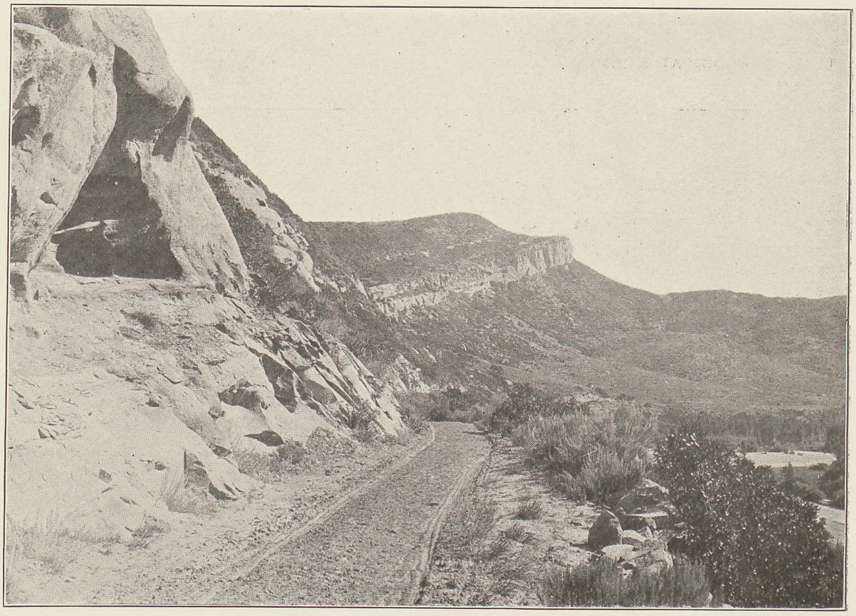
A. UPTURNED TWENTYMILE SANDSTONE AT MOUTH OF SAGE CREEK CANYON.

The massive bed at the left is the Twentymile sandstone; the higher beds belong in the upper coal group. Photograph by M. R. Campbell.



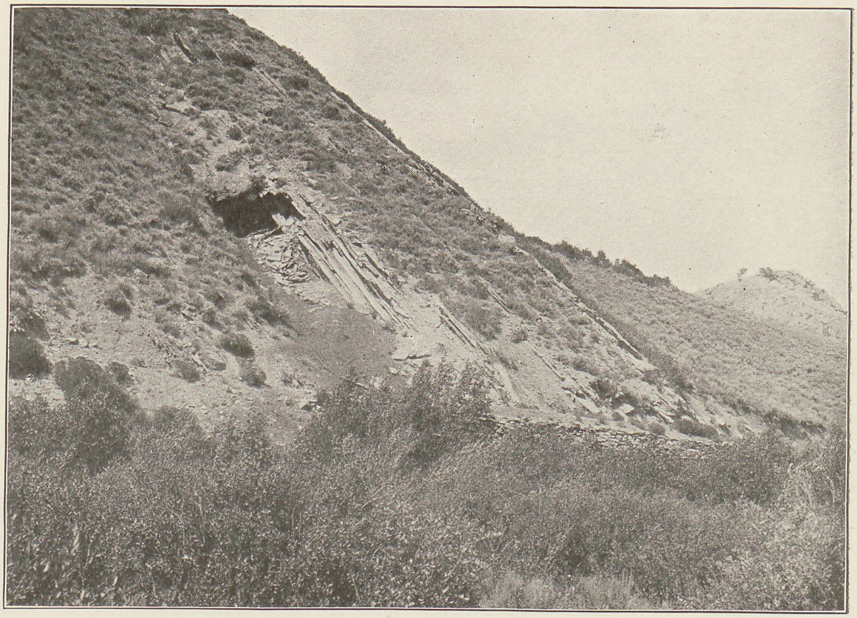
B. CLIFF OF TWENTYMILE SANDSTONE NEAR THE CENTER OF SEC. 31, T. 5 N. R. 86 W.

View from public road. Photograph by M. R. Campbell.



A. ESCARPMENT OF TROUT CREEK SANDSTONE ABOVE BEAR RIVER MINE.

View from wagon road between Mount Harris and Bear River, looking northeast. Photograph by Hoyt S. Gale, 1905.



B. WADGE COAL BED IN NORTH WALL OF DUNKLEY CANYON.

Coal bed 11 feet 9 inches thick. Twentymile sandstone at extreme right. Photograph by Hoyt S. Gale, 1905.

Brooks bed of the group, which according to measurements made by a former superintendent is 600 feet stratigraphically below the Wolf Creek bed. This distance is probably greater than the distance from the Trout Creek sandstone to the uppermost or Bear River bed on Indian Creek but is probably about the same as the distance from the Trout Creek sandstone to the uppermost bed of the lower coal group on Oak Creek. The Brooks bed, 4 feet 9½ inches thick at the Curtis mine (locality 35; see Fig. 4 and Pl. VI, *B*) lies on a massive white sandstone and in turn is overlain by a thinner bed of the same material. This association of massive sandstone and coal bed does not hold far on either side; hence it is practically impossible to correlate the Brooks bed with beds either in Indian Creek valley or in the valley of Oak Creek. Small coal beds are reported below the Brooks bed in this vicinity, but none of them are thick enough to be considered workable under present mining and marketing conditions. Considerable money has been spent here searching for lower beds of workable thickness but without success. Even a drill hole that was put down to a depth of 500 feet somewhere to the southeast of the Curtis mine failed to show beds thick enough to be classed as workable.

Some light on the general structural relations in the Yampa Valley may be obtained by attempting to trace the Brooks bed to the north. The position of the bed on the north side of the upland spur lying between Elk Creek and Yampa River is plainly marked by the massive sandstone that can be traced continuously from the Curtis mine. This shows with a westward dip of 14° near the north quarter corner of sec. 22, T. 6 N., R. 86 W., but there is nothing on the opposite side of the Yampa Valley to suggest a northward continuation of this coal bed and its associated sandstone. The following facts should, however, be noted: (1) An old well drilled for oil (No. 36), which now furnishes a small flow of artesian water for Milner and which is just south of the village, is reported to have penetrated several beds of coal at depths ranging from 480 to 790 feet.[7] (2) Recent water

[7] The partial log of this well as furnished by Mr. J. J. Argo, of Denver, is as follows:

Partial log of the Milner well.

	Thickness.	Depth.
	Feet.	*Feet.*
Coal, poor	3	480
Coal, good	4	560
Coal, good	6	600
Coal, poor	3½	625
Coal, hard	7	670
Coal, anthracite	10	790

wells drilled in the village of Milner even to a depth of more than 400 feet have failed to penetrate coal. (3) An old prospect (No. 37) on a coal bed reported to be 4 feet thick is on the line between secs. 10 and 11, T. 6 N., R. 86 W., about a quarter of a mile north of the section corner. This bed dips slightly toward the west. (4) A number of old coal prospects (No. 38) occur in a cut of the railroad near the north quarter corner of sec. 14. These beds strike northeast and dip 10°–15° NW., and at the quarter-corner post mentioned the coal beds are cut off by a fault and are in contact with the Mancos shale.

When all the facts stated above are considered it seems almost certain that there is some unusual disturbance in the valley of Yampa River, and the fault seen at the north quarter corner of sec. 14 indicates that the entire syncline whose axis is at or near McGregor is cut by an east-west fault, as indicated on the map. The rocks north of this fault have been lifted, with relation to those on the south, about 150 feet. This fault explains the anomalous relation of the coal beds and sandstone about McGregor and also accounts for the peculiar position of coal beds above Milner. It is therefore assumed that the coal beds of the lower group trend northward from the south quarter corner of sec. 15, T. 6 N., R. 86 W., and gradually curve to the east until probably the outcrop of the Brooks bed reaches the vicinity of the northeast corner of sec. 15. This assumption makes the coal beds exposed in the railroad cut at locality 38 lower in the formation than the Brooks bed, which is altogether probable, as at locality 38 there is no indication of a massive sandstone associated with the coal beds. The writer was unable to get measurements of the thickness of the bed that had previously been worked here, but the outcrop indicated a bed not more than 3 or 3½ feet thick.

As the coal beds at locality 38 are cut off by a fault that raises the beds on the north above the same beds on the south, the northward continuation of this line of outcrop should be offset to the west, but as the trace of the fault and all the coal-bearing rocks are covered with gravel along the north line of sec. 14 it is impossible to say how extensive the offset is. It seems probable that the outcrop of the lowermost coal bed north of the fault may even be west of the west line of sec. 11. The basis for this assumption is the fact that at locality 37, on the west line of sec. 11, a few rods north of the county road, a coal bed has been mined in the past, which according to report has a thickness of about 4 feet. From the adjacent outcrops it is apparent that this coal is not closely associated with such a sandstone as that which is so prominent at the Curtis mine, on Elk Creek, but is associated with shale like the coal at locality 38. Altogether the writer is strongly of the opinion that the beds showing at localities 37 and 38 are one and the same and that they do not correspond to the Brooks bed on Elk Creek but lie at a distinctly lower horizon.

This conclusion still leaves the northward continuation of the Brooks bed undetermined, but the writer believes that the Brooks bed overlies the massive white sandstone that crops out on the west side of the creek flowing by Milner and that also caps the mesa in sec. 3, T. 6 N., R. 86 W., as can be seen from the Milner-Steamboat Springs road about half a mile east of Milner. Of course this does not mean that the Brooks coal bed is of workable thickness north of Milner. This point can be determined only by thorough prospecting.

From the well data given above it seems fairly certain that none of the coal beds of the middle group occur beneath Milner but that the lower group is present at a depth of about 500 feet. The log of the Milner well shows at least five beds of coal of workable thickness in an interval of about 230 feet, but it must be remembered that few logs of wells drilled for oil give reliable information concerning coal beds, and the drillers seldom discriminate closely between coal and black shale. The only interpretation of this log that is justified is that there are probably four or five coal beds underlying Milner, but their thickness and quality are entirely problematic.

The log of the Milner well furnishes some interesting data on the probable outcrop of the Wolf Creek coal bed north of Yampa River and south of the Milner fault. If the first coal of value in the well is at a depth of 560 feet and the interval between the lower and middle group of coal beds is 600 feet, as reported on Elk Creek, then it would appear that the original position of the Wolf Creek coal bed was only about 40 feet higher than the present head of the well. As the dip is probably less than 10°, it means that the Wolf Creek coal bed should crop out not more than half a mile west of locality 36, and the Wadge bed probably at twice this distance, or, if allowance is made for flattening in dip toward the axis, about 1¼ miles west of locality 36.

The assumed eastward swing of the outcrops across the flood plain of Yampa River conforms with dips and strikes on Trout Creek in sec. 14, T. 6 N., R. 86 W., also with dips in the high ridge lying between Trout Creek and Yampa River in secs. 13 and 14. The rocks composing this ridge are sandstone and shale of the lower part of the Mesaverde formation, but on the north bank of Yampa River in secs. 11 and 12 all the rocks belong in the Mancos shale, which should underlie those to the south. From this evidence it seems certain that the fault seen at the north quarter corner of sec. 14 continues eastward along Yampa River an undetermined distance, separating Mancos shale on the north from lower Mesaverde sandstone and shale on the south. This hypothesis would mean that the narrowest part of the syncline is at McGregor and that north of this place the basin deepens and broadens, and were it not for the fault a considerable area of the coal beds of the middle group would be preserved north of Yampa River. The movement connected with the faulting, however, has lifted these beds, and now they are largely eroded.

LOWER FISH CREEK AND VICINITY.

South of Elk Creek there are no known exposures of the coal beds of the lower group on the divide between Elk Creek on the north and Fish Creek on the south, but the outcrop of the coal beds of the middle group can be traced almost continuously by the coal itself showing at the surface or by the associated Trout Creek sandstone, which is particularly massive and makes prominent "saw teeth" on the backs of low hills along its outcrop.

The most conspicuous feature of the surface south of Elk Creek is a high hill in the SW. ¼ sec. 27, T. 6 N., R. 86 W. This is held up by the Trout Creek sandstone, which crops out on its east side 100 feet or more below the summit. Both the Wolf Creek and the Wadge coal beds doubtless occur in this hill a short distance above the sandstone, but, so far as the writer is aware, they are not exposed. The Wolf Creek bed caps an isolated but rather high hill in the NW. ¼ sec. 27, as can be seen from the west quarter corner of this same section or from the top of the high hill in the SW. ¼ of this section, but its thickness could not be determined. The Wadge bed does not hold its position on the east side of the large hill but gradually descends to the valley on its west side, and the first exposure known is in the extreme northwest corner of sec. 34. There is no prospect here, the coal showing merely in natural outcrop, which could not be measured. The "blossom" of the Wolf Creek bed about 40 feet above the Trout Creek sandstone was seen near the center of sec. 34, but the exact thickness could not be determined. It is plainly apparent, however, that both beds hold their thickness and relative positions in passing from Elk Creek to Fish Creek.

In the NE. ¼ sec. 3, T. 5 N., R. 86 W., there are some old prospects (No. 39) on the Wadge bed. The most promising of these prospects is at the southeast end of a narrow ridge between two branches of the creek. The prospect was so caved that the writer could not get a full section, but he uncovered 5 feet 6 inches of clear coal without a parting, and still the base was concealed. At this place Winchester reports 8 feet of coal.

In the gap which Fish Creek has cut through the ridge made by the upturned sandstones of the middle coal group the coal beds are not well exposed, but the creek, in cutting against a projecting point of the hill on the west, has partly exposed a coal bed (No. 40) dipping 23° SW. The section measured here is as follows:

Section of part of Wolf Creek coal bed on Fish Creek.

	Ft.	in.
Coal	3	6
Sandstone, thin-bedded	5	
Coal and shale	1	
Coal	4+	
	13	6+

This coal bed can be traced across the creek into the point of the hill on the east, where its relation to the Trout Creek sandstone can be seen. It is estimated to be about 50 feet above that sandstone and consequently is the Wolf Creek bed. The "smut" of the Wadge bed is also visible in this hill, and its outcrop can be traced eastward to the old mine (No. 41) at the road forks, where the road to Steamboat Springs turns to the north through a gap in this ridge and the other road goes southeast to the Chergo (old Hutchinson) mine, on Middle Creek.

The Wadge bed can be traced with little difficulty, even where there are no prospects, for, being generally softer and more easily weathered than the adjacent shale, its outcrop is marked by a decided crease where it crosses hills or along the ridge that commonly marks the upturned rock on the rim of the basin of Twentymile Park. In this crease there are generally fragments of the weathered coal, either showing directly at the surface or where they have been brought up by burrowing animals.

The old mine (No. 41) at the forks of the road previously mentioned is badly caved, but a section measured on the edge of an old opening showed about 11 feet of clear coal. (See Fig. 6.) Fenneman and Gale,[8] who examined the field when this mine was open and the coal was accessible, state that "A measurement of the seam gave 9 feet 10 inches of hard, shiny coal." The place of the Wolf Creek bed is clearly distinguishable in this gap on the north side of the hill, but no actual exposure of coal was seen.

In passing eastward from this old mine Fenneman and Gale thought that the outcrop of the Wadge bed swung southeastward parallel with the highway to the Hutchinson (Chergo) mine (No. 43) on Middle Creek and so show it on their map, but the writer followed the "crease" of the bed and its "smut" along the outcrop direct to the mouth of Middle Creek, and therefore he is satisfied that Fenneman and Gale's map is incorrect. The dips here are light to the southwest, and in the bluff overlooking the mouth of Middle Creek the "crease" of the outcrop can be traced down the bluff until the dip flattens, and thence the outcrop continues up Middle Creek to the Hutchinson (Chergo) mine at nearly the level of the terrace, 60 or 80

[8] Op. cit., p. 50.

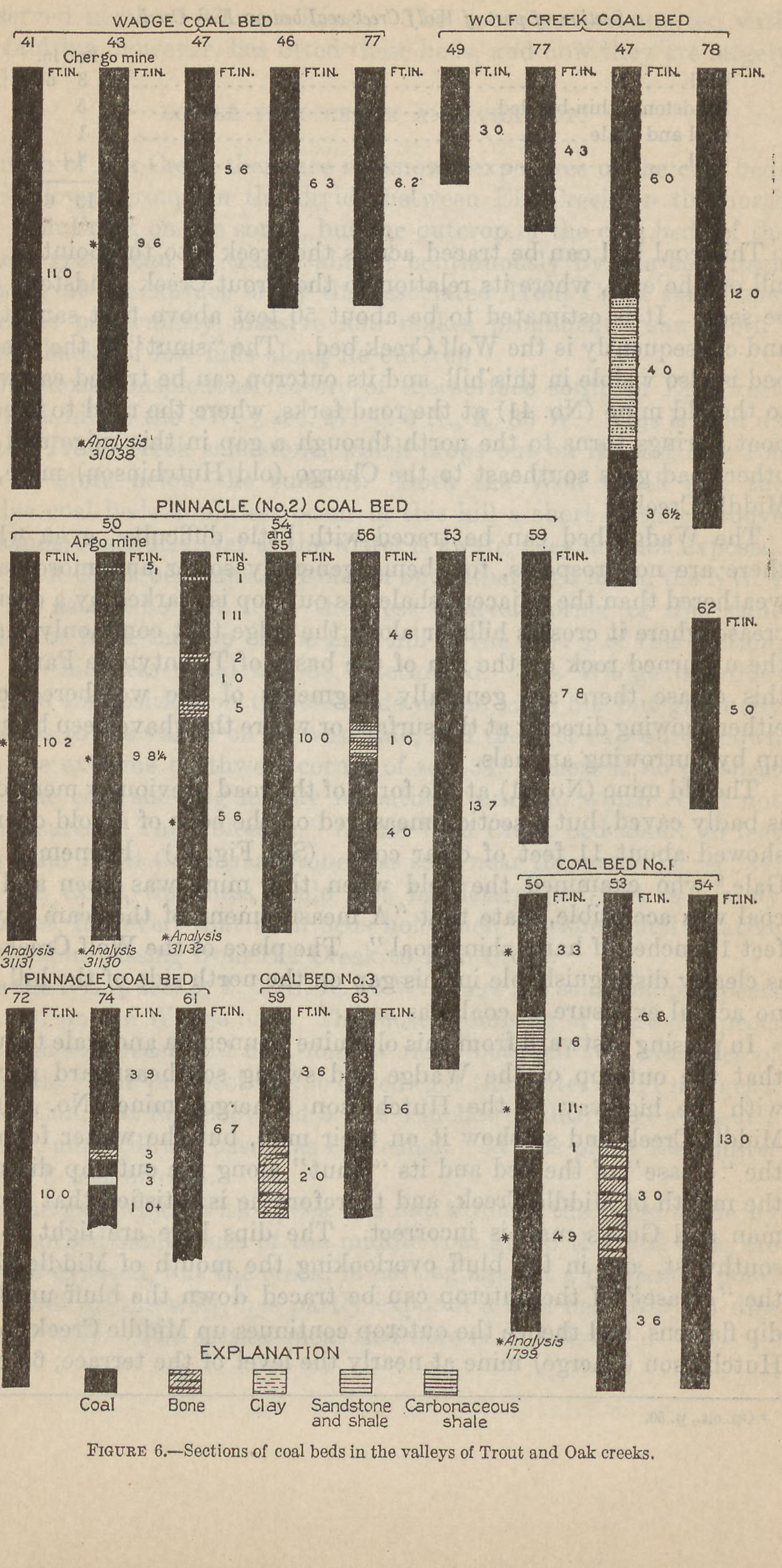


FIGURE 6.—Sections of coal beds in the valleys of Trout and Oak creeks.

feet above the creek. The Wolf Creek bed evidently parallels the outcrop of the Wadge bed as far as Trout Creek in the SE. ¼ sec. 1, T. 5 N., R. 86 W., where it was once mined on the west bank of the creek, but this mine has long since fallen shut, and now little or no coal shows at the surface. The bed evidently crosses Trout Creek here and is the one in which the Jones mine (No. 42) was operated long ago and in which Fenneman and Gale made the following measurement of a part of the coal bed:

Section of coal bed in old Jones mine in the NW. ¼ sec. 7, T. 5 N., R. 85 W.

	Ft.	in.
Coal	1	
Clay		3
Coal	6+	
	7	3+

Regarding this bed they state: "This mine is opened near water level, where the rocks are nearly horizontal, the dip being to the southeast and very light." As Fenneman and Gale traced the group of coal beds into this district from Oak Creek and the head of Trout Creek, they correctly identified the bed at the old Hutchinson (Chergo) mine as belonging to the middle group, and as they found evidence of the presence of faults in some old placer pits just east of Middle Creek, they naturally concluded that the coal bed in which the old Jones mine was opened belonged to the lower group, which is badly covered by gravel east of Trout Creek and can not be traced continuously. In order to harmonize this assumption with certain known facts, it was necessary to assume that this supposed outcrop of the lower group was separated by a fault from the outcrop of the same group that crosses Trout Creek three-quarters of a mile above the mouth of Fish Creek and that for a short distance these outcrops occur in duplicate.

The writer is now thoroughly satisfied that the coal bed at the old Jones mine (No. 42) is the Wolf Creek bed. This conclusion is based on the fact that in the vicinity of this mine the beds dip lightly to the southwest, as they should if the coal were a member of the middle group, instead of to the southeast, and the southeastward dip observed by Fenneman and Gale is probably only local. Moreover, the coal bed is in direct strike with the old mine on the west bank of Middle Creek, which is also tied to the outcrop of the Trout Creek sandstone about 50 feet below. This conclusion makes the structure and outcrop of the coal beds in this district perfectly normal, but with a flatter dip than is known at any other point on the margin of the basin.

As stated before, the bed at the old Hutchinson (Chergo) mine (No 43) is undoubtedly the Wadge bed, and Fenneman and Gale's statement regarding a bed of coal 50 feet below this bed is probably in error, owing to their mistaking coal taken out of the Hutchinson mine and dumped near the creek for a dump pile of a mine at that place, or else the coal may have come from an old shaft down to the Wolf Creek bed.

The Wadge bed is now being mined extensively (for a local mine) by Tom Chergo at the site (No. 43) of the old Hutchinson mine. The writer sampled this bed for analysis at the face of the main slope, 200 feet from the mine mouth. The bed at this point has a thickness of 9 feet 6 inches of clear coal, and the sample represented the entire bed. The analysis of this sample is shown as No. 31038 in the table on page 71. The bed dips about 15° W., and the coal is drawn to the surface by horsepower.

The coal beds of the lower group are well exposed in the wagon road along Fish Creek (No. 44), about half a mile above its mouth. Little additional information regarding these coals can be given beyond that presented by Fenneman and Gale, except that the uppermost bed, of which they could get no measurement, is now opened and shows a thickness of 3 feet 4 inches. Fenneman and Gale's section,[9] somewhat generalized, is as follows:

Generalized section of lower coal group on lower Fish Creek.

	Ft.	in.
Coal	3	4
Shale	8	
Coal	5	
Shale	20	
Coal	7+	
Shale and sandstone	98	
Coal	1	
Shale and sandstone	42	
Coal	3	
Total section	187	4+
Total coal	19	4+

Coals of this group also show at the place where they cross Trout Creek, three-quarters of a mile above the mouth of Fish Creek, but no measurements at this place were obtained. Gale's notes state that one of these exposures appears to be on a bed of considerable thickness. The lower group of coal beds, on crossing Trout Creek, is immediately concealed by a thick mantle of gravel and boulders, which covers the upland east of Trout Creek and completely conceals the underlying rocks for a distance of 3 or 4 miles. The extension of the outcrop of these beds is described in connection with the coals of Oak Creek on page 44.

[9] Op. cit., p. 49.

South of the Chergo mine (No. 43), in the SE. ¼ sec. 12, T. 5 N., R. 86 W., the writer traced the outcrop of the Wadge coal bed southeastward into sec. 18, as shown on the map. It doubtless swings well up on the back of the high knob near the center of sec. 18, where it dips about 8° SW. From this point the outcrop of the Wadge bed extends up the valley to the point (No. 45) in the SE. ¼ sec. 36 where it passes beneath water level. A prospect entry at this point reveals a thickness of about 6 feet of coal. A core-drill hole (No. 47) [9a] put down by the Moffat Coal Co. about half a mile south of the last-mentioned locality shows a thickness of 5 feet 6 inches for the Wadge bed. (See Fig. 6.) The outcrop returns on the east side of the creek on the dip slope, forming the west side of the ridge lying between Trout Creek and Oak Creek to a point near the center of sec. 19. From this point the outcrop follows closely the summit of the ridge southward as far as the ridge holds its full height in the SW. ¼ sec. 30, T. 4 N., R. 85 W., or just above the mine of the Moffat Coal Co. The writer has no exact measurements of the thickness of the bed in this territory, but at the old mine of Hayden Bros. (No. 46), now abandoned, in the NE. ¼ SE. ¼ sec. 18, the bed, according to Mr. L. A. Hayden, averages 6 or 6½ feet in thickness. (See Fig. 6.) From the data at hand it seems probable that throughout the dip slope of this ridge the Wadge coal bed is generally 5 or 6 feet thick. It is evidently thinning in a northeasterly direction and therefore may be even thinner than 6 feet in secs. 19, 30, and 31, T. 5 N., R. 85 W., and also in sec. 7, T. 4 N., R. 85 W. In passing westward from Hayden Bros.' mine (No. 46) the bed evidently thickens, for at the old Male ranch on Trout Creek (No. 77) there is a mine in which the coal bed now shows a thickness of 6 feet 2 inches. (See Fig. 6.) Fenneman and Gale state that the bed is 8 feet thick but that only the lower 5 feet was mined.

Although the Wadge coal bed is apparently 5 to 6 feet thick in most of the territory east of Trout Creek, it lies so near the surface in this long dip slope that it is of questionable value, at least when compared with the wholly unweathered coals of the lower group.

The Wolf Creek bed appears to be more seriously diminished in thickness in this region than the Wadge bed, as it is not known to be much more than 3 feet thick east of Trout Creek and south of the old Jones mine (No. 42). The bed has not been definitely traced from this mine, but it probably dips to the southwest at about the same rate as the surface descends, and as a consequence its outcrop swings to the east, crossing the Steamboat Springs road near the volcanic neck that is so prominent in the E. ½ sec. 7, T. 5 N., R. 85 W. Also there are many exposures of coal on Trout Creek south of this point, which seem to indicate that the bed is much broken up by shale part-

[9a] The location of drill hole 47 is in the SE. ¼ sec. 12, T. 4 N., R. 86 W., instead of in the NE. ¼ sec. 36, T. 5 N., R. 86 W., as shown on Plate I

ings and that its outcrop parallels that of the Wadge bed but lies nearer creek level. It crosses Trout Creek near the schoolhouse (No. 48), near the common corner of secs. 24 and 25, T. 5 N., R. 86 W., and secs. 19 and 30, T. 5 N., R. 85 W. The writer has not seen this exposure, but it is reported to be 5 feet thick. From this point the outcrop swings back to the north around the point of the ridge a little north of the center of sec. 19 and there turns south along the eastern front of the ridge lying between Trout and Oak creeks about 150 feet below the crest. The writer in 1905 found an opening on this outcrop (No. 49) in the northeast corner of sec. 30, T. 5 N., R. 85 W., where the bed measures 3 feet in thickness. (See Fig. 6.) It has not been mined in this ridge but has been opened at many places, and the writer understands that everywhere it is about 3 feet thick. This agrees with his observation at the Male ranch on Trout Creek (No. 77), where a bed about 140 feet below the Wadge bed is 4 feet 3 inches thick. (See Fig. 6.) From the evidence available it is probable that throughout most of the territory east of Trout Creek the Wolf Creek bed or one of its benches is 3 feet thick, but as it approaches the creek it probably thickens to 4 or 5 feet.

OAK CREEK AND VICINITY.

The coals of the lower group in the Oak Creek valley are the best-known beds in the field, not because they are more regular and reliable than the beds of other groups, but because they are of better quality and have been mined on a larger scale. In every coal basin in Colorado the coal improves in quality toward the surrounding mountains, and the Yampa field is no exception. The coals improve irregularly in quality from west to east and reach their best condition (except the anthracite in the northern part of the field, which is due to local metamorphism by sills of lava) at the extreme eastern edge of the field, in the valley of Oak Creek. In this valley the coal beds have been extensively developed and prospected. Although thick in places, they are very irregular in thickness, seemingly even more irregular than in other parts of the field.

The writer, owing to lack of time, made no pretense of gathering sufficient data to show fully the condition of the coal beds on Oak Creek but had to content himself with a few facts which will give a general idea of the condition of the lower group in this part of the field.

Fenneman and Gale in 1905 recognized in Oak Creek valley the three principal coal beds of this group, as shown by their generalized section [10] measured at the old Shuster mine, where the plant of the Moffat Coal Co. is now located. This section is as follows:

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[10] Op. cit., p. 42.

Generalized section of coal beds on Oak Creek.

	Ft.	in.
Coal [No. 3]	5	
Interval	75	
Coal	2	3
Interval	75	
Coal, base not exposed	2+	
Interval	23	
Coal, with shale [No. 2]	4	6
Coal	2	6
Interval	51	
Coal (Shuster bed) [No. 1]	11	6
Sandstone, massive or thick-bedded	22	
Shale and thin sandstone	22	
Sandstone	3	
Shale and thin sandstone	72	
Sandstone	3	
	373	9+

The three important coal beds are now known as Nos. 1, 2, and 3, and the distances between them at the Moffat mine (No. 50) are about as follows:

Generalized section of principal coal beds on Oak Creek.

	Feet.
Coal No. 3	5
Interval	200
Coal No. 2	8–9
Interval	80
Coal No. 1	8–11

Coal bed No. 2 is now generally known as the Pinnacle or Argo bed, from the Pinnacle mine of the Victor-American Fuel Co. and the Argo mine of the Moffat Coal Co.

The lower or No. 1 coal bed is apparently very irregular in this part of the district. At the time of Fenneman and Gale's examination it was visible at only a few places. At the best exposure, known as the Shuster mine (No. 50, Fig. 6), the bed has the following section:

Section of coal bed No. 1 in Shuster mine.

	Ft.	in.
Coal, sampled	3	3
Shale, carbonaceous	1	6
Coal, sampled	1	11
Clay		1
Coal, sampled	4	9
	11	6

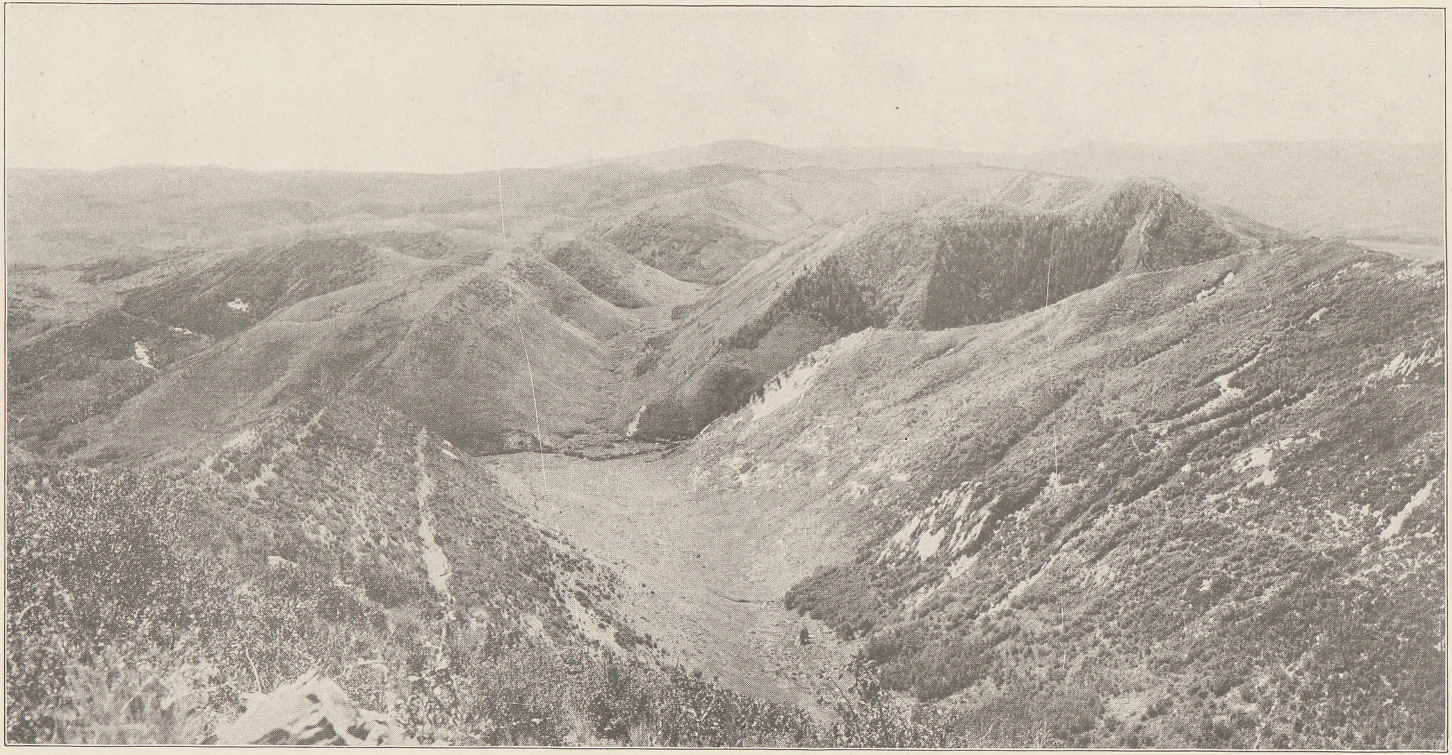
The analysis of the sample from this mine will be found under No. 1799, page 73.

On the strength of the showing made at this old mine the original (No. 1) mine of the Moffat Coal Co. was opened at this place (see Pl. XII, *B*), and the first commercial mining in this part of the State was begun in this bed. At first the bed was very promising, but within a short distance one of the partings in it began to increase, eventually resulting in the separation of the two benches by as much as 40 feet. At the point in the mine where the bed was so broken that mining became unprofitable, a rock tunnel was driven through to No. 2 bed, about 80 feet higher in the section, and work in the lower bed was stopped.

The lower coal bed (No. 1) was also opened several years ago by the Juniper Coal Co. just north of the mine of the Moffat Coal Co., but on account of litigation the mine was abandoned, and the coal is now inaccessible. It is reported, however, that considerable trouble was experienced with the same split in the coal bed that was encountered by the Moffat Coal Co. As all mining on this bed has been abandoned the only sections of it now available are those obtained in drill holes put down back of the line of outcrop. Drill hole 54, put down by the Moffat Coal Co., showed an excellent section of this bed 13 feet thick without a parting, but in a near-by hole (No. 53) the bed, although showing a total thickness of 13 feet 2 inches, is broken by a bone parting 3 feet thick into two benches, the upper one 6 feet 8 inches and the lower one 3 feet 6 inches thick. These sections are shown graphically in Figure 6. In the southeastern part of sec. 19, T. 3 N., R. 86 W., the outcrop of this coal bed crosses Oak Creek, and the writer could not learn of any prospect openings between this place and the point where Oak Creek leaves the north-south valley and turns to the east.

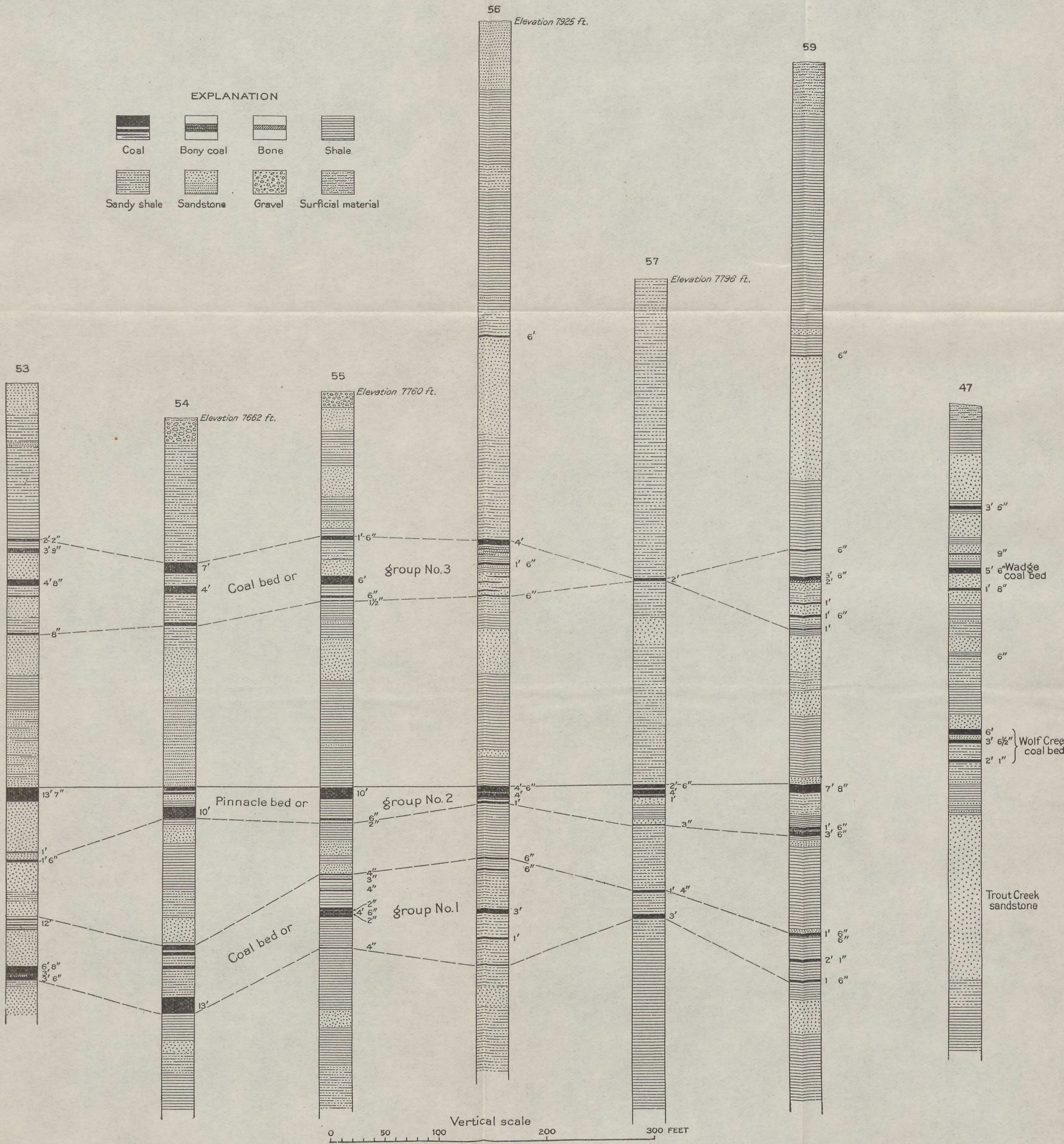
When the Moffat Coal Co. decided that bed No. 1 had become too much broken by the sandstone partings to make mining profitable it developed a mine in the No. 2 or Pinnacle bed. This new mine is known as the Argo mine, from the fact that the mouth of the slope is in Argo Gulch and the coal is either taken out through the old mine or lowered over an outside inclined tramroad down Argo Gulch. In advance of this change of base, however, several drill holes were put down to determine the character of bed No. 2 as well as all other beds in the lower group, and the bed sections noted in the logs of these holes are shown graphically in Figures 6 and 8 and Plate XI.

The Pinnacle (Argo) bed in the Argo mine is 8 to 9 feet thick without a parting. The writer made no measurements in this mine, but the following sections were measured on October 6 and 7, 1918, by J. J. Forbes, of the Bureau of Mines, in sampling the coal:

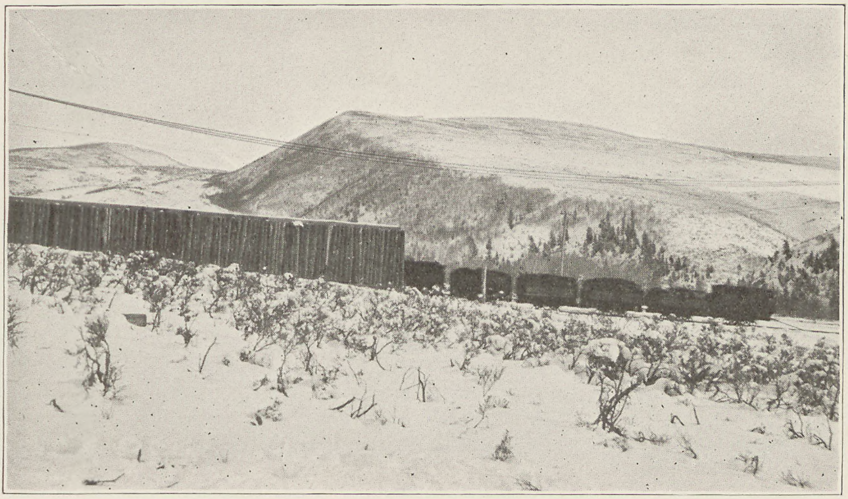


RIM OF TWENTYMILE PARK AT DUNKLEY CANYON.

View from top of ridge north of the canyon, looking south. Camera is on the outcrop of the Wadge coal bed. Lower coal group in the ridge on the right. Trout Creek sandstone crops out in bare space in middle. Photograph by Hoyt S. Gale, 1905.

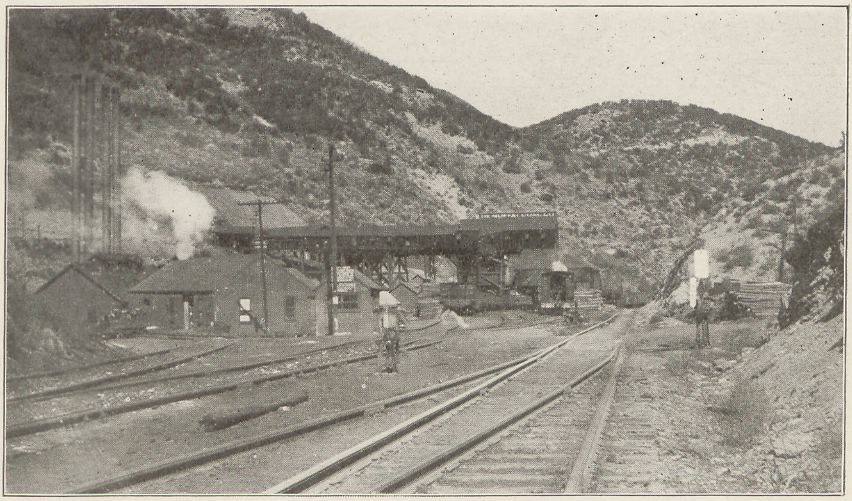


CORE-DRILL SECTIONS ON OAK AND TROUT CREEKS.



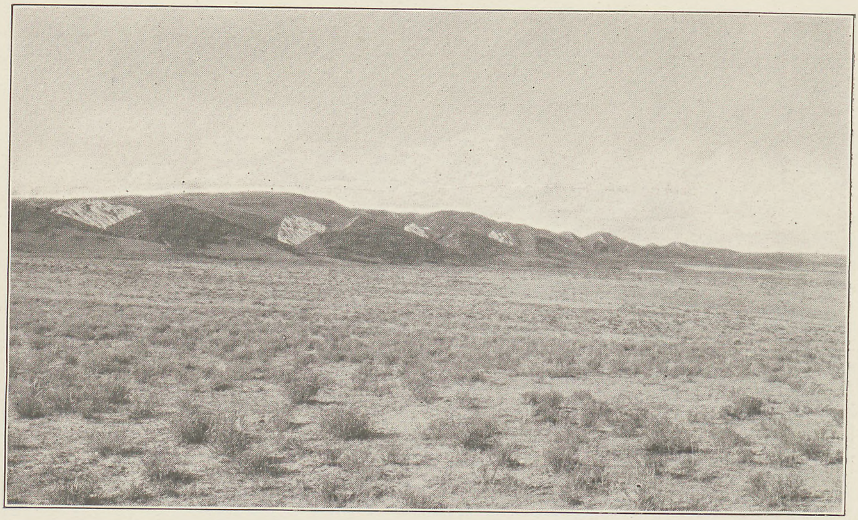
A. CUESTA OF THE TROUT CREEK SANDSTONE EAST OF MOUNT HARRIS.

Back slope of the cuesta as seen from point near tipple of Wadge mine. Photograph furnished by Victor-American Fuel Co.



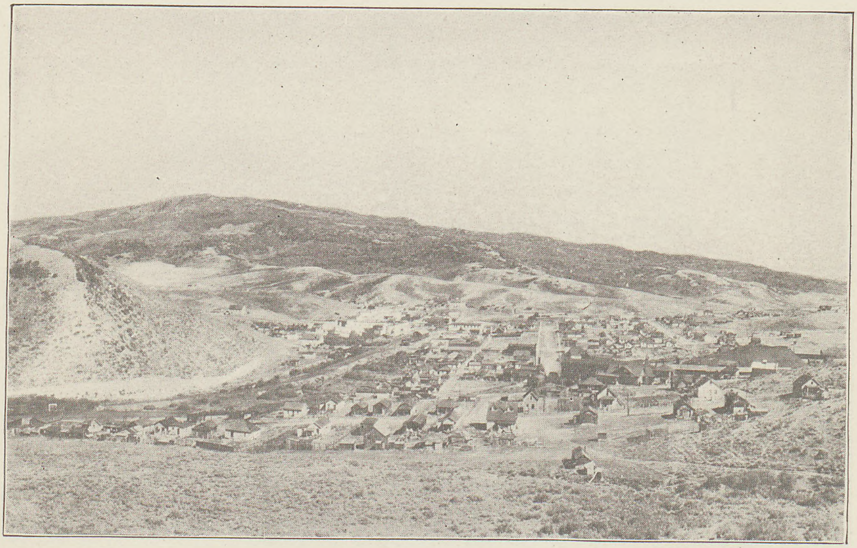
B. TIPPLE OF MOFFAT COAL CO. AT OAK HILL.

Mine is 1 mile below the town of Oak Creek. Photograph by M. R. Campbell.



A. EAST SIDE OF THE TOW CREEK ANTICLINE, FROM THE SW. ¼ SEC. 18, T. 5 N., R. 86 W.

Front row of knobs represents the Twentymile sandstone; behind may be seen great faces of the Trout Creek sandstone. Photograph by M. R. Campbell.



B. TOWN OF OAK CREEK AND TIPPLE OF THE PINNACLE COAL MINE

Photograph by M. R. Campbell.

Sections of Pinnacle coal bed in Argo mine of Moffat Coal Co.

[See Fig. 6.]

31130. Face of south entry, 5,000 feet southwest of mine mouth.

	Ft.	in.
Coal (sampled)		5
Sandstone		¾
Coal (sampled)	9	8¼
	10	2

31131. Left rib of slope 9,120 feet below south entry and 1,500 feet from face of slope.

	Ft.	in.
Coal (sampled)	10	2

31132. Face of south slope, 375 feet below fourth level.

	Ft.	in.
Coal (sampled)		8
Sandstone		1
Coal (sampled)	1	11
Bone		2
Coal (sampled)	1	
Bone		5
Coal (sampled)	5	6
	9	9

31133. Face of third level, 2,100 feet from south slope.

	Ft.	in.
Coal (sampled)		10
Bone		3
Coal (sampled)	8	8
	9	9

The samples obtained here were analyzed by the Bureau of Mines, and the results are given on pages 72–73. A composite sample made by combining the mine samples gave analysis No. 31134.

This bed of coal is also worked in the Pinnacle mine (No. 52) of the Victor-American Fuel Co., in the SE. ¼ sec. 36, T. 4 N., R. 86 W., and because of the excellency of the coal it has become widely known as the Pinnacle bed. As this name is almost universally used in the district, it will be adopted here as the name of No. 2 coal bed, but the writer does not believe that in the present state of knowledge regarding the lower group of coal beds it is safe to extend this name beyond the area already developed in the valley of Oak Creek and possibly in prospected territory in the Trout Creek canyon. The writer made no examination of the Pinnacle mine, but it is reported that the coal bed generally ranges from 8 to 9 feet in thickness and is in places as much as 14 feet thick. The tipple of this mine in the town of Oak Creek is shown in Plate XIII, *B*.

The Argo and Pinnacle mines are both in the southern point of the Argo syncline, and the strike of the bed and the lateral entries follow approximately the arc of a circle. Near the Moffat tipple the direction of dip is about N. 45° W., a little west of the township line it is nearly due north, and in the western part of sec. 25, T. 4 N., R. 86 W. it is about N. 45° E. The dip of the coal bed ranges from 6° to 17°.

The Pinnacle coal bed was tested by the Moffat Coal Co. in advance of the development of the Argo mine, and its thickness was found to be as follows (see Fig. 6): In holes 54 and 55 the bed is 10 feet thick without a parting; in hole 56 it consists of two benches of coal, the upper bench 4 feet 6 inches and the lower bench 4 feet thick, separated by 1 foot of bone and shale; and in hole 53 the coal bed is exceptionally thick, measuring 13 feet 7 inches without a parting.

Coal bed No. 3, or rather group No. 3, as there is in most places more than one coal bed at this horizon, as shown by the sections on Plate XI, lies about 200 feet above the Pinnacle bed and in the vicinity of the Moffat mine overlies very closely a sandstone that is conspicuous on the hillsides. This coal bed has not been mined here, but its character and thickness are well known from prospect pits that have been opened in it and from core-drill holes that have penetrated it. The bed is generally considered too thin and too irregular in thickness to be mined, especially while thicker and more regular coal beds still remain untouched. Its thickness and irregularity are well shown in the drill holes put down by the Moffat Coal Co. (Figs. 6 and 8). Thus in hole 57 the coal bed is 2 feet thick; in hole 56, 4 feet; in hole 53, 4 feet 8 inches; in hole 55, 6 feet; in hole 54, 7 feet with possibly a lower bench 43 feet below the main bench; and in hole 59, 3 feet 6 inches of coal overlying 2 feet of bone.

North of the Moffat mine there is some uncertainty regarding the coal beds that have been mined and prospected. The old Juniper mine, next adjoining the Moffat mine on the north, opened both bed No. 1 and the Pinnacle bed (No. 2), but owing to litigation the mine has been abandoned. According to report, the same difficulty was experienced in attempting to mine bed No. 1 here as in the Moffat mine. The next mine to the north is that of Hayden Bros. at Haybro (No. 58). The proprietors of this mine feel sure that they are working the Pinnacle bed, and this belief seemed to be substantiated by a hasty examination of the valley by the writer, but the available evidence is somewhat conflicting. The best evidence is that afforded by the section representing drill hole No. 59. (See Pl. XI.) This hole is a short distance west of the forks of the road in the NW. ¼ sec. 8, T. 4 N., R. 85 W., as shown on the map. The best coal bed penetrated by the drill has a thickness of 7 feet 8 inches of clear coal (see Fig. 6), and 33 feet below it is another bed which has the following section:

Section of coal bed in drill hole 59, in the NW. ¼ sec. 8, T. 4 N., R. 85 W.

	Ft.	in.
Coal, bony	1	6
Shale, carbonaceous	1	
Coal, streaked with bone	3	6
	6	

Two coal beds of this size and at this distance apart are not known in the valley of Oak Creek, except where one of the large beds "splits," and, as beds are known to split as much as 40 feet in this field, it seems probable that these two beds really represent one of the main beds of the section. As they are about 200 feet below a group of coal beds and about 90 feet above another group it seems probable that they represent the Pinnacle (No. 2) bed. If this assumption is correct bed No. 1 is badly broken up and is represented by three thin beds, as shown by the following detailed section:

Section of No. 1 (?) coal bed in drill hole 59.

	Ft.	in.
Coal, impure	1	6
Bone		6
Shale	18	
Coal	1	6
Shale	17	
Coal	1	6
	40	

At 190 feet above the principal bed (Pinnacle?) is a coal bed 3 feet 6 inches thick (see Fig. 6), which lies in the midst of a group of four thin beds. This has much the appearance of coal bed No. 3 and is generally so regarded. This interpretation appears also to agree with the following evidence furnished by L. A. Hayden.

Only a small amount of drilling has been done at Haybro (locality 58), but, as reported by Mr. Hayden, one well put down here reached the bed now being worked, 7 feet 2 inches thick (Fig. 8), at a depth of 82 feet and reached a bed 5 feet 5 inches thick at a depth of 294 feet, or, with allowance for the dip, about 200 feet stratigraphically lower. As there is no coal bed known at Haybro above the one being mined and as the interval between this bed and the next one below, according to this drill record, is about 200 feet, the evidence indicates that the bed mined is No. 3 and that the one struck at a depth of 294 feet is the Pinnacle bed. This is hearsay evidence, however, as the well log was not seen. It is obvious that additional data are necessary to determine whether or not the conclusion stated is correct. In the meantime the bed mined at Haybro is tentatively regarded as bed No. 3.

All the coal beds in this group are exposed in natural outcrop or have been mined at locality 60, where Oak Creek leaves the north-south valley and turns east toward Yampa River, but they are exposed in such a way that it is very difficult to measure a section. The section measured by Fenneman and Gale in 1905 agrees pretty closely with the log of the drill hole referred to above and makes it seem probable that the same beds are here exposed as were penetrated by the drill.

According to the tentative conclusion reached above there are only two coal beds of prominence in this section, and this agrees with the evidence farther north. The lower bed (Pinnacle?) has been opened at locality 61, high on the ridge near the center of sec. 32, T. 5 N., R. 85 W., where 6 feet 7 inches of coal is exposed, but the section is not complete, and the bed is probably somewhat thicker. North of this point the writer knows of no prospects or exposures of coal for 3 miles. In the E. ½ sec. 17 there are two old prospects on coal beds nearly 200 feet apart. The lower bed was mined at locality 62, high on the ridge beneath or within a massive sandstone. At this place it dips 10° W. and is 5 feet thick. The upper bed lies in a great mass of shale, and as the old prospect entry is badly caved only the top of the coal bed is visible. If the coal extends to the bottom of the old entry, which seems probable, there must be 6 or 7 feet of coal, but the writer does not know whether it is broken by partings or is clear coal.

North of these prospects the beds are concealed by gravel that mantles all of the upland, and this condition holds to the vicinity of the point where this group of beds crosses Trout Creek, in the NW. ¼ sec. 6, T. 5 N., R. 85 W.

SOUTH RIM OF TWENTYMILE PARK.

South of the Pinnacle mine the coal beds of the lower group extend for about 3 miles into T. 3 N., R. 86 W. (See Fig. 7.) Although the rocks rise somewhat toward the south, the hills also are higher, and consequently the same geologic horizons are represented, but some of the coal beds apparently disappear and others become more prominent.

The Pinnacle coal is the lowest coal bed known in T. 3 N., R. 86 W., and it seems to break up and be valueless a short distance up Oak Creek. On the other hand, bed No. 3, as shown in the well logs in Plate XI, consists really of a group of beds, one or more of which are locally of workable thickness. This group has been prospected in a ravine that drains nearly due east in the middle of sec. 1. At locality 63 (Fig. 7) the lowest bed of this group has been mined to some extent in the past, but all the operations have been abandoned. Near the outcrop the bed has a thickness of 5 feet 6 inches (see Fig. 6), and it lies only a short distance above a thick coarse sandstone. About 100 feet higher in the section another coal bed has been opened, but the drift was in such a condition that the coal bed could not be seen. It appears, however, to be 4 or 5 feet thick.

The best geologic section showing the relation of these coal beds is at locality 64, on Oak Creek, a little north of the south quarter corner of sec. 1. An attempt was made during the World War to develop a mine here, and three coal beds were prospected, one above the other. A hand-leveled section at this locality is as follows:

Section at locality 64, sec. 1, T. 3 N., R. 86 W.

	Feet.
Coal bed, possibly	5
Interval	110
Coal bed (Fig. 8)	5½
Interval	187
Coal, Pinnacle.	
Interval to bottom of valley	200

According to report, the Pinnacle coal bed is too badly broken by partings to be of value here, and consequently the inclined tramway was carried to No. 3 bed. So far as the writer is aware the Pinnacle

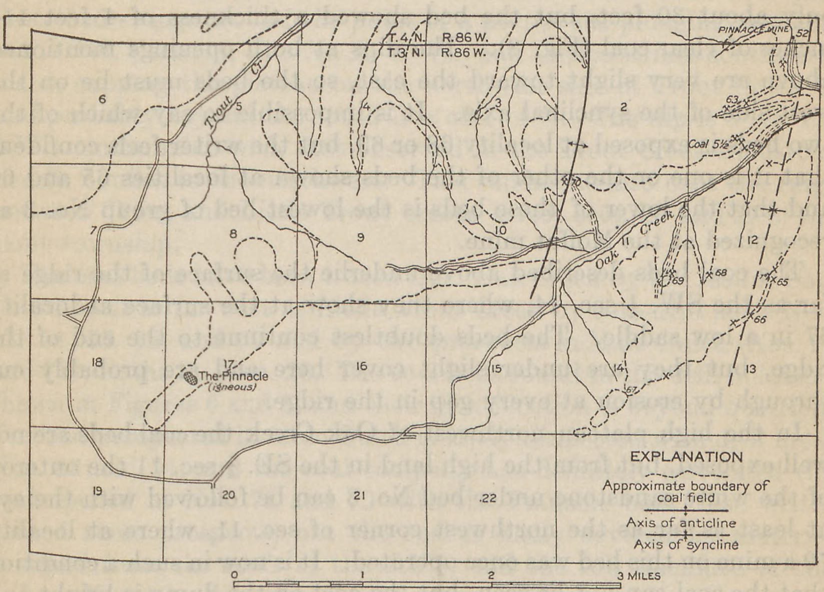


FIGURE. 7.—Sketch map showing approximate boundaries of the coal field in T. 3 N., R. 86 W.

bed is not known south of this place. In 1913 E. T. Hancock, of the Geological Survey, made an examination of coal beds in secs. 12 and 13, T. 3 N., R. 86 W. At locality 65 he found two beds of coal separated by an interval of 75 or 80 feet. The upper of these beds has a thickness of 11 feet of clear coal and the lower bed 5 feet 5 inches, overlain by 22 inches of shaly coal (Fig. 8). As these beds overlie a massive white sandstone, and as they are supposed to be the only beds of workable thickness in this part of the field, they are correlated with coal group No. 3 and the overlying beds in the vicinity of the Pinnacle mine. At locality 66 two beds of coal that appear to be the same as those just described have been prospected. Here the upper bed has a thickness of 5 feet of clear coal (Fig. 8), and the lower bed, some 80 feet lower, has at least 3 feet of good coal overlain by 14 inches of shaly coal, but as the base of the coal was not exposed the full thickness is unknown. These beds dip 6°–12° NW., so they apparently lie east of the synclinal axis, as shown in Figure 7.

One of these beds was opened and mined many years ago at locality 68, in the SW ¼ sec. 12. A large amount of good coal is on the dump, but the drift is caved so that the coal bed could not be measured. The appearance of the cave, however, indicates a fairly thick bed, possibly 6 or 7 feet. Recently a local mine has been opened at locality 69, on the next ridge to the west, in the SE. ¼ sec. 11. At the time this drift was visited by the writer it had been driven in on the bed only about 30 feet, but the bed showed a thickness of 4 feet 11½ inches of clear coal (Fig. 8). The dips at both openings mentioned above are very slight toward the east, so the beds must lie on the west side of the synclinal axis. It is impossible to say which of the two beds is exposed at locality 68 or 69, but the writer feels confident that it is one or the other of the beds shown at localities 65 and 66 and that the lower of these beds is the lowest bed of group No. 3 as recognized at the Moffat mine.

The coal beds described above underlie the surface of the ridge as far as the SW. ¼ sec. 14, where they show at the surface at locality 67 in a low saddle. The beds doubtless continue to the end of the ridge, but they are under slight cover here and are probably cut through by erosion at every gap in the ridge.

In the high plateau northwest of Oak Creek the coal beds are not well exposed, but from the high land in the SE. ¼ sec. 11 the outcrop of the white sandstone under bed No. 3 can be followed with the eye at least as far as the northwest corner of sec. 11, where at locality 70 a mine on this bed was once operated. It is now in such a condition that the coal can not be seen, but the coal on the dump is bright and of good quality.

As stated above, the coal beds and associated rocks rise gently up Oak Creek on the northwest side to a point near the northwest corner of sec. 11, and from about that point westward they dip gently at least as far as Trout Creek.

The tracing of coal beds and key rocks from Oak Creek to Trout Creek can best be done along the Oak Creek-Hayden road, which climbs the dividing ridge just above and west of the Moffat mine. From the summit this road follows down Egeria Gulch and crosses Trout Creek at the old Male ranch. The road passes just above the Argo mine of the Moffat Coal Co., and a short distance to the west, at locality 51, just across the creek from the southwest corner of sec. 30, T. 4 N., R. 85 W., No. 3 coal bed has been opened. Its thickness in this locality was not determined, but as shown in Figure 8 by the record of core-drill hole No. 55, put down by the Moffat Coal Co., the bed has a thickness of 6 feet of clear coal. A little more than 100 feet above coal No. 3 is a massive sandstone well exposed in the road, which appears to be the best key rock in the region for carrying the correlation to Trout Creek. This sandstone forms the ridge on the southwest side of Egeria Gulch from the summit to Trout Creek, and in places the creek cuts into it and exposes its typical character. This sandstone is well exposed on Little Trout Creek, where it dips 20° NE. It is also the first prominent sandstone observed on ascending Trout Creek above the mouth of Egeria Gulch, where it dips 27° NE.

On the northwest side of Trout Creek the thick sandstone just described swings around the point of a northward-plunging anticline in the SW. ¼ sec. 14, T. 4 N., R. 86 W., and thence strikes southwestward, capping the plateau on the northwest side of Trout Creek to and probably beyond the south line of T. 4 N. The dip is 8° or 10° NW., conformable with that observed in the Trout Creek sandstone nearly 2 miles to the northwest. This sandstone also caps the ridge between Trout and Little Trout creeks across secs. 23 and 27 of the same township.

The coal beds have been traced from Oak Creek by the Moffat Coal Co. at least as far west as Little Trout Creek by core-drill holes Nos. 53, 54, 55, 56, and 57 and by two prospects in Mule Gulch (Nos. 71 and 72), in the S. ½ sec. 26. The coal beds found in the drill holes are shown in Figures 6 and 8, and their identification is beyond question. The bed prospected in Mule Gulch is easily connected with drill holes Nos. 53 and 54, and the coal company has definitely correlated the coal opened in Nos. 71 and 72 with the Pinnacle bed. The writer visited these prospects, but the coal is badly covered by material slumped from the roofs of the drifts, and the full thickness of the bed could not be determined. At prospect 71 the bed appears to be at least 7 or 8 feet thick, and at prospect 72 the Moffat Coal Co. reports its thickness as 10 feet. The bed dips lightly down the gulch, in conformity with the plunging axis of the anticline.

The writer made a section of the slope opposite the mouth of Mule Gulch and found indications of the several coal beds in their appropriate positions, but as no prospecting had been done here, the thickness of the beds could not be obtained. A small coal bloom 340 feet above the creek appears to represent bed No. 1; about 100 feet higher is burned rock which is taken to represent No. 2 or the Pinnacle bed; 220 feet higher are slight indications of another bed, which doubtless represents bed No. 3. The entire height of the hill or plateau is 800 feet.

In the valley of Trout Creek above the old Male ranch, in sec. 14, T. 4 N., R. 86 W., the writer found very little evidence of coal beds other than that reported by Fenneman and Gale.[11] Their statement is as follows:

As the sandstone beds follow down Trout Creek in approximately horizontal position from near Pinnacle post office, it is thought that the coal beds would be found outcropping along the summits of the ridges adjacent to the canyon. About 1 mile above Male's ranch, however, the beds suddenly dip to the northeast, and the coal beds of the lower and middle groups are brought down and pass beneath the level of the stream. Several openings have been made on these beds as they approach water level.

About 1 mile above the mouth of the canyon [locality 74] a 40-foot entry on the west side of the creek has been opened on a seam of about 6½ feet of coal [Pinnacle bed]. This coal is without constant character near the entrance, containing lenses of sandstone up to 8 inches in thickness, which vary markedly from point to point. At the breast of the drift the following measurement was made:

Measurement at breast of upper opening on Trout Creek canyon.

	Ft.	in.
Coal (under shale roof)	3	9
Bone		3
Coal		5
Bone		3
Coal (base not reached)	1+	
	5	8+

* * * * * * *

About three-quarters of a mile downstream from the opening just described, also on the west side of the creek, is an entry driven in about 100 feet [locality 73] on a seam [No. 3] also belonging to the lower group and apparently about 200 feet higher stratigraphically than the seam last named. It dips due northeast at an angle of 32°. The following measurements were taken in the entry:

Section measured at entry one-fourth mile above mouth of Trout Creek canyon.

	Ft.	in.
Sandstone, slabby.		
Coal		6–8
Clay, blue	2±	
Coal	1	8
Clay, hard, blue		9
Coal	3	
"Slate" parting		½–1
Coal	2±	

On the east side of the canyon, nearly opposite the tunnel, is an exposure of at least 2 feet of coal, but the entire thickness of the seam could not be ascertained. Stratigraphically it is intermediate between the two seams which have been opened on the west side of the canyon.

The writer observed a small coal bed in shale about 20 feet above creek level at locality 75, and the same bed was seen in an old prospect about 100 feet above creek level at locality 76, where it has a thickness of about 4 feet but includes shale partings near the top and bottom. This bed is without much doubt one of the beds belonging to group No. 1 on Oak Creek, which appears to be without value in the country to the west.

[11] Op. cit., p. 45.

The only other occurrences of coal known to the writer in this part of the Trout Creek valley are at two pits noted on the plats of the General Land Office, one in the extreme southwest corner of sec. 28, T. 4 N., R. 86 W., and the other in the northwest corner of sec. 33. These pits were not visited by the writer, but it seems probable that they are on the Pinnacle bed. From the top of the high ridge in sec. 34 the writer could see plainly two small faults cutting the edge of the plateau on the northwest side of Trout Creek.

On the south rim of Twentymile Park the coal beds of the middle group are exposed at only two localities—the crossing of Trout Creek and the crossing of Middle Creek.

At the crossing of Trout Creek (locality 77) both the Wadge and the Wolf Creek coal beds are exposed. The Wadge bed has been mined for a great many years to supply the local needs of ranchmen in this part of the district, and the Wolf Creek bed has been opened by a prospect entry to find out its thickness and character. The mine in the Wadge bed has long been known as the Male mine, because it is on the Male ranch. It was opened in the hillside on the east side of Trout Creek about 100 yards from the place where the public road crosses the creek. At the time of the writer's visit the full thickness of the bed did not show, the bottom being concealed; the part worked is 6 feet 2 inches thick (Fig. 6). The roof of the mine is composed of weak shale 8 feet thick, which is overlain by thin-bedded sandstone. Fenneman and Gale report that the bed is 8 feet thick, but at the time of their visit only the lowermost 5 feet was being mined. From their report it seems probable that this bed is 8 feet thick and composed of clear coal.

The distance between the Wadge bed and the Wolf Creek bed was not accurately measured, but a determination based on a measurement of the horizontal distance between the two openings by pacing and the observed dip of the beds, which is here about 10°, makes it about 150 feet. The prospect entry shows that the Wolf Creek bed is 4 feet 3 inches thick (Fig. 6). This agrees with the general impression of the thinness of the Wolf Creek bed in the tract east of Trout Creek, but it seems probable that Trout Creek marks about the western limit of the thin coal in this bed, and west of the creek it is generally as thick as the Wadge bed, if not thicker.

This transition from a thin bed on the east to a thick bed on the west is shown in the log of a well (No. 47) drilled by the Moffat Coal Co. in the SE. ¼ sec. 12, T. 4 N., R. 86 W., about half a mile south of the point where the Wadge bed crosses Trout Creek. (See map, Pl. I.)[11a] The log is shown graphically in Plate XI. In this log the Wolf Creek coal shows as a double bed consisting of an upper bench 6 feet thick and a lower bench 3 feet 6½ inches thick, separated by sandstone and shale 4 feet thick (Fig. 6). The base of this bed is 67

[11a] See footnote on page 37 concerning the location of drill hole 47.

feet above the Trout Creek sandstone, which, according to the log, has a thickness of 155 feet. The Wolf Creek bed is underlain at a distance of 16 feet by another bed of coal 2 feet 1 inch thick, and a thin layer of coal rests nearly on top of the Trout Creek sandstone. The distance between the two main coal beds according to this well log is 145 feet, and the Wadge bed is here underlain at a distance of 15 feet by a small bed 20 inches thick and overlain at a distance of 55 feet by a coal bed, the Lennox of Fenneman and Gale, 3 feet 6 inches thick. The Wadge bed in this locality is unusually thin, being only 5 feet 6 inches thick.

The next exposure of the middle coal group that was visited (No. 78) is in the gap which Middle Creek has cut through the Trout Creek sandstone ridge near the north quarter corner of sec. 10, T. 4 N., R. 86 W., 2 miles northwest of Male's ranch and just to the left of the road from the ranch toward Hayden. At this place a large coal bed (Wolf Creek) has been prospected on the point of the ridge on the west side of the creek. This bed is about 25 feet above the massive Trout Creek sandstone and, as measured by the writer, has a thickness of 12 feet of clear coal (Fig. 6). The old prospect had fallen shut, so the writer was compelled to measure the bed on a sloping surface by the side of the prospect. About 150 feet higher in the formation and near the Hayden road are traces of another coal bed (Wadge) that has been burned. To judge from the width of the burned material, the bed probably had a thickness of 10 or 12 feet.

On the north slope of this ridge, probably 50 feet higher than the Wadge bed, which is burned, a coal bed 3 feet thick crops out by the side of the road. This undoubtedly corresponds with the coal bed in the drill hole on Trout Creek 55 feet above the Wadge bed and also probably with the Lennox bed as described by Fenneman and Gale. This bed is also visible on the side of the ridge on the left in passing from Male's to Middle Creek on the Hayden road. The outcrop is probably in the SE. ¼ sec. 10, T. 4 N., R. 86 W., and the bed dips about 25° NE. The Lennox bed is also exposed in the road between Middle Creek and Foidel Canyon, but in this place its dip corresponds closely with the northwestward slope of the surface, and its thickness could not be determined.

DUNKLEY CANYON AND VICINITY.

From the last-mentioned exposure on Middle Creek near the Oak Creek-Hayden road the outcrops of both groups of coal beds swing far to the south in the southern projection of the synclinal basin of Twentymile Park. On the west side of this syncline the beds are sharply upturned, and as a consequence both groups crop out close together in Dunkley Canyon (see Pl. X), a canyon cut by Fish Creek where it enters Twentymile Park from Williams Park. As stated before, the beds are sharply upturned, dipping 54° E., and most of the coal beds and key rocks are exposed in the walls of the canyon.

The most prominent exposure in this canyon, to a person approaching from the east, is the massive white Twentymile sandstone, which shows on both sides of the creek. It is about 100 feet thick and is particularly prominent by the side of the public road, where it stands up in an enormous plate of sandstone several hundred feet high. The principal beds of sandstone and the ridges formed by them are well shown in Plate X.

The section of the middle coal group measured by the writer in the irrigation ditch that has been cut largely in solid rock along the north wall of Dunkley Canyon (locality 79) is as follows:

Section of middle coal group in Dunkley Canyon.

	Ft.	in.
Coal ("smut").		
Shale, generally sandy, but with thin beds of sandstone near base.	86	
Coal, Wadge bed (No. 79)	11	9
Shale, sandy, with thin beds of sandstone	87	
Coal	1	
Sandstone	13	
Shale	97	
Coal, Wolf Creek bed represented by burned rock and ashes.	11	
Shale	32	
Sandstone, white, massive, Trout Creek.		
	338	9

According to Fenneman and Gale the distance from the Trout Creek to the Twentymile sandstone is 1,170 feet. The Wadge bed is now mined from a drift on the north side just above the public road. A photograph of this drift taken by H. S. Gale in 1905 is shown in Plate IX, *B*. It appears nearly the same to-day, the only difference being the regrading of the public road. In this drift there is 11 feet 9 inches of clear coal (Fig. 8), but mining is rather difficult, as the bed dips 54° E. A sample taken in this mine for analysis (No. 30862, p. 71), shows the coal to be of good quality. The Wolf Creek bed is burned so extensively that no reliable measurement could be made, but to judge by the width of the burned zone, it seems probable that the bed is of about the same thickness as the Wadge bed. It is interesting here to note the fact that this bed lies only about 32 feet above the Trout Creek sandstone. As a similar interval was observed on Middle Creek (No. 78) and in bore hole No. 47, it may be assumed that on the south side of Twentymile Park the distance of the Wolf Creek coal bed above the Trout Creek sandstone ranges from 25 to 50 feet.

The coal beds of the lower group are fairly well exposed in Dunkley Canyon (locality 80), but most of them are so thin as to be of little value. Two, however, would be considered of workable thickness according to present standards. The upper bed of these two has been opened by an old entry on the north side of the road, where it shows a thickness of 5 feet 6 inches (Fig. 8). About 45 feet lower in the formation is another bed 4 feet thick (Fig. 8), showing in the irrigation ditch. So far as known, these are the only beds of importance in the lower group. According to Fenneman and Gale's section the bed 5 feet 6 inches thick is somewhat more than 800 feet below the Trout Creek sandstone, and the interval is occupied largely by shale, which makes the longitudinal valley shown in Plate X. According to calculation based on a foot traverse made by the writer, the distance from the top of the Trout Creek sandstone down to the principal coal bed in the lower group in Dunkley Canyon is 700 feet. As the Trout Creek sandstone ranges in thickness from 50 to 100 feet the interval between the base of this sandstone and the uppermost coal bed in Dunkley Canyon is about 600 feet. This agrees closely with 650 feet, the distance on Trout Creek from the base of the Trout Creek sandstone to the uppermost coal of the lower group.

As the uppermost coal of the lower group lies close below a thick, coarse sandstone near the Argo mine on Oak Creek, in the Trout Creek canyon above the Male ranch, and in Dunkley Canyon, and as the distance between this coal bed and the Trout Creek sandstone at the two places last mentioned is essentially the same, it seems safe to correlate the two coal beds noted in Dunkley Canyon with the No. 3 bed or group on Oak Creek and to regard them as possibly equivalent to the two beds of this group that have been prospected southwest of the Pinnacle mine. If this correlation is correct both the Pinnacle bed and coal bed No. 1 on Oak Creek have degenerated so toward the west that they are no longer recognizable as beds of workable thickness but may be represented by some of the thin layers of coal to be seen in Dunkley Canyon below the principal beds.

From Dunkley Canyon the ridge that forms the bounding wall of Twentymile Park is made up of the sandstones associated with the coal beds of the middle and lower groups of coal beds and trends about N. 20° W. for a distance of nearly 5 miles. Winchester made an examination of this ridge in secs. 27 and 28, T. 5 N., R. 87 W., and at locality 81 found an old prospect on a bed of the lower coal group. This bed is 9 feet thick (Fig. 8) and is probably the same as the bed at locality 80, in Dunkley Canyon. The coal at locality 81 is only a short distance beneath a massive white sandstone, which is without much doubt the same stratum as that which overlies the bed at locality 80. In Dunkley Canyon it is more resistant than the Trout Creek sandstone and forms the east slope of the westernmost ridge, as shown in Plate X. Winchester reports much red, baked rock east of locality 81, and it is probable that both the Wolf Creek and Wadge beds are burned out at the surface there.

In secs. 16 and 21, T. 5 N., R. 87 W., the sandstone ridge is cut by Grassy Creek, and the coal beds are well exposed in the gap. At locality 82 both the Wadge and the Wolf Creek beds show in the banks of the creek near the line between secs. 16 and 21. At this place the Wadge bed, striking N. 60° W. and dipping 56° NE., has been opened on both sides of the creek. The coal is badly weathered in the old prospects, but in the one on the east side it shows a thickness of about 12 feet (Fig. 8). The coal is considerably crushed in the upturned rocks, however, and possibly the thickness of the bed is exaggerated in the slipping and bunching that has taken place on the bedding planes. The Wolf Creek bed is not so well exposed, but a landslide on the east side of the creek has revealed at least 9 feet of coal with probably a bony parting down 6 feet from the top. The bottom of the bed is not visible, but the exposure is so large as to suggest that this bed is fully as thick as the Wadge bed near by. About a quarter of a mile above these exposures the rocks near the creek are much baked and reddened by heat, and it seems probable that the red color is due to the burning of a large coal bed of the lower group.

From the Grassy Creek gap the height of the ridge gradually decreases northwestward until it dies out in an anticlinal point in the W. ½ sec. 8. At this point the ridge is cut deeply by a small tributary of Grassy Creek, revealing the Twentymile sandstone, which here forms the outer rim of the ridge. It seems probable that the stream has cut deeply enough to reach both the Wadge and the Wolf Creek beds, but no prospecting has been done, and the writer saw no positive indications of coal.

SAGE CREEK ANTICLINE.

In the Sage Creek valley the coal beds are exposed at a number of places between the head of the creek and the point where the creek leaves the canyon, in the southwest corner of sec. 36, T. 6 N., R. 88 W. In passing toward Hayden from Dunkley the first indication of coal or key rocks is seen in the northwest corner of sec. 30, T. 5 N., R. 87 W., where the Trout Creek sandstone crosses the road, showing on the west an enormous expanse of bare rock. At this place it strikes N. 45° W. and dips 55° NE. It apparently extends about three-quarters of a mile southeast of the road, to the extreme point of a syncline, and there the outcrop turns back toward the northeast, joining the exposure of the same rock seen at locality 82, on the north line of sec. 21. The writer looked in vain near the point where the sandstone crosses the public road for signs of the Wolf Creek coal bed. A mine has been opened, however, at locality

83 near the north line of sec. 30, and coal has been mined there for many years to supply the local demand. The coal bed strikes N. 40° E. and dips 8° NW.; the difference in the dips on the two sides of this synclinal point is striking. The coal bed near the mouth of this mine measures 6 feet (Fig. 8), but the writer is not sure that his measurement includes the entire bed, as he was not equipped with a light and could not examine the mine far back from the mouth. From the relation of this bed to the Trout Creek sandstone the writer is strongly of the opinion that it is the Wadge bed that has been mined here and that the Wolf Creek bed could be found farther up the ravine. The coal beds of the lower group undoubtedly crop out in the southeast corner of the section, but the local people seem to have no knowledge of their positions or even of their existence.

In passing northward along the Hayden road from the vicinity of locality 83, the synclinal point of the Twentymile sandstone is crossed at the line between sec. 18, T. 5 N., R. 87 W., and sec. 13, T. 5 N., R. 88 W. Before this line is reached the great cliff of sandstone on the right is a conspicuous object as it dips at a low angle toward the axis of the basin, and the other limb, sharply upturned, is crossed near the upper end of the reservoir made by damming Sage Creek.

The next place at which beds of the middle coal group were observed by the writer is in the canyon which Sage Creek has cut through the upturned rocks that form the rim of the basin at locality 84, in sec. 13, T. 5 N., R. 88 W. Here a coal bed lying about 50 feet above the Trout Creek sandstone and dipping 56° E. shows 7 feet 7 inches of clear coal (Fig. 8). At 93 feet above this bed are indications of a large coal bed having been burned; hence it is assumed that the bed prospected is the Wolf Creek bed and the burned bed is the Wadge, and that the Wadge bed probably has a thickness at least as great as that of the Wolf Creek bed.

About a quarter of a mile beyond locality 84 Sage Creek turns to the north and follows the axis of the anticlinal fold for more than 3 miles. No coal beds crop out near the road, as the creek has cut considerably below even the horizon of the lowest beds, but there are many indications of burned shale on the east, which probably mark the positions of the several beds. At locality 85 the writer made a side excursion to a point near the center of sec. 12, T. 5 N., R. 88 W., but saw no coal prospects. Burned rock, however, marks the positions of both coal groups.

The writer found no outcrop of the beds of the lower group in Sage Creek canyon, but Fenneman and Gale [12] evidently found some indications of the presence of coal beds in this group, for they make the following statement:

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[12] Op. cit., pp. 55-56.

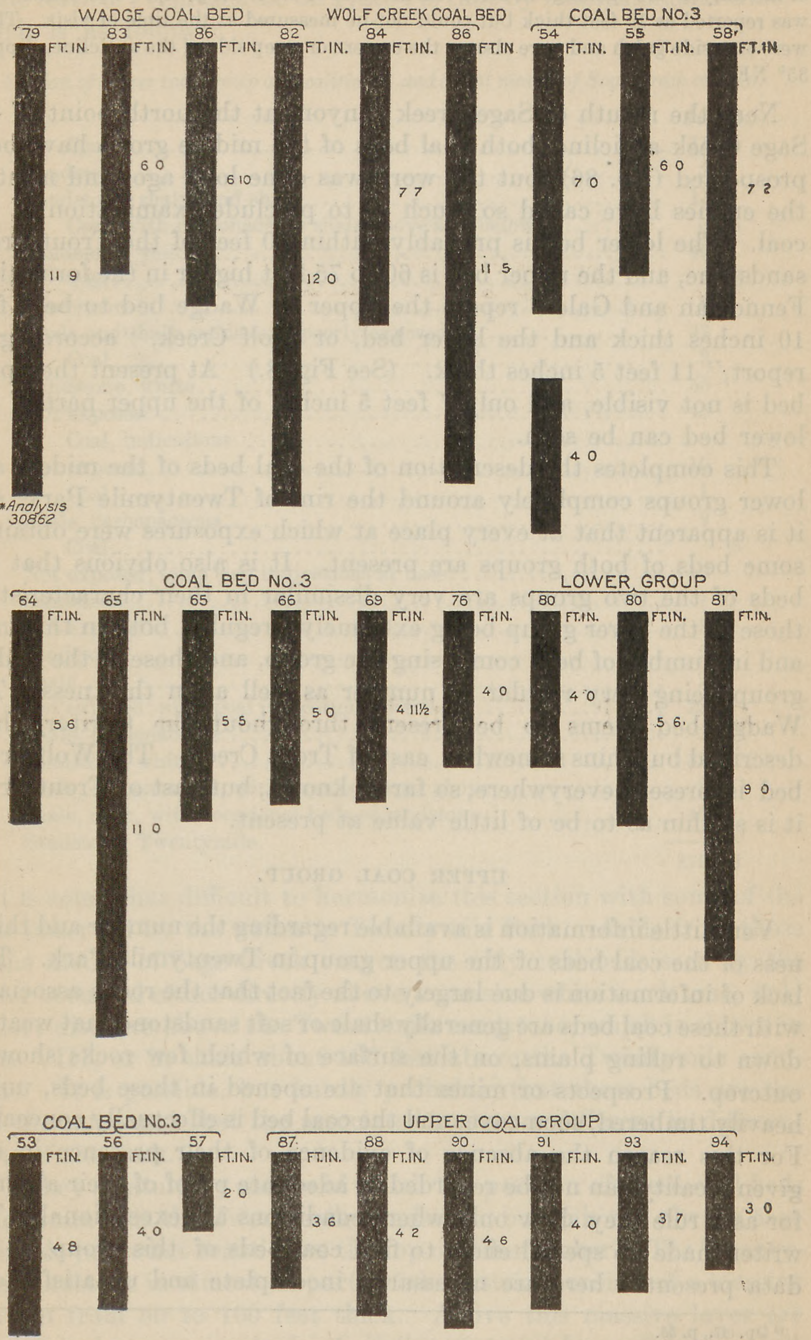

FIGURE 8.—Sections of coal beds in the vicinity of Oak Creek, Dunkley Canyon, and Sage Creek canyon.

A mile or more south of the prospects last mentioned [locality 86, near the mouth of the canyon] are openings on three or four seams of the lower group. One of the seams was reported as 10 feet thick but could not be measured at the time of visit. These were on a side gulch and were also on the eastern or steep side of the anticline, dipping 35° NE.

Near the mouth of Sage Creek canyon, at the north point of the Sage Creek anticline, both coal beds of the middle group have been prospected (No. 86), but the work was done long ago, and most of the entries have caved so much as to preclude examination of the coal. The lower bed is probably within 50 feet of the Trout Creek sandstone, and the upper bed is 60 to 75 feet higher in the formation. Fenneman and Gale [13] report the upper or Wadge bed to be 6 feet 10 inches thick and the lower bed, or Wolf Creek, "according to report," 11 feet 5 inches thick. (See Fig. 8.) At present the upper bed is not visible, and only 7 feet 5 inches of the upper part of the lower bed can be seen.

This completes the description of the coal beds of the middle and lower groups completely around the rim of Twentymile Park, and it is apparent that at every place at which exposures were obtained some beds of both groups are present. It is also obvious that the beds of the two groups are very dissimilar in their characteristics, those of the lower group being extremely irregular, both in thickness and in number of beds composing the group, and those of the middle group being very regular in number as well as in thickness. The Wadge bed seems to be present throughout the territory here described but thins somewhat east of Trout Creek. The Wolf Creek bed is present everywhere, so far as known, but east of Trout Creek it is so thin as to be of little value at present.

UPPER COAL GROUP.

Very little information is available regarding the number and thickness of the coal beds of the upper group in Twentymile Park. This lack of information is due largely to the fact that the rocks associated with these coal beds are generally shale or soft sandstone that weather down to rolling plains, on the surface of which few rocks show in outcrop. Prospects or mines that are opened in these beds, unless heavily timbered, soon cave, and the coal bed is effectually concealed. For this reason the absence of evidence of their presence in any given locality can not be regarded as adequate proof of their absence, for as a rule they show only where conditions are exceptional. The writer made no special effort to find coal beds of this group, so the data presented here are necessarily incomplete and unsatisfactory.

[13] Op. cit., p. 55.

The most complete section of this group that has been measured in the territory represented on Plate I is that by Fenneman and Gale,[14] which is as follows:

Section of upper coal group at localities 81 and 82, at mouth of Sage Creek canyon.

	Ft.	in.
Coal	11	
Sandstone	2	
Sandstone, shaly, and shale	11	
Coal, with carbonaceous shale above and below	5	6
Sandstone, yellow	46	
Coal	4	8
Sandstone	2	
Shale and shaly sandstone, poorly exposed	43	
Coal	3	
Sandstone, white	55	
Not exposed	45	
Coal, indications		
Not exposed	10	
Coal	1	
Shale, carbonaceous	9	
Coal		6
Not exposed; some coal indications at base	10	
Sandstone	1	
Not exposed	6	
Sandstone	2	
Shale	2	
Not exposed; some coal indications at top	23	
Shale, carbonaceous	2	
Sandstone, white	38	
Shale, carbonaceous, with streaks of coal above	2	
Shale, dark, with occasional beds of sandstone	45	
Sandstone, Twentymile.		
	379	8

It is somewhat difficult to harmonize this section with some of the facts observed by the writer in Twentymile Park. Aside from those at the mouth of Sage Creek canyon the only coal beds seen by the writer occurred either directly above a massive white sandstone, only a short distance above the Twentymile sandstone, which is shown in Plate VIII, or in shale about 160 feet above the Twentymile sandstone. It is possible, but hardly probable, that these beds are one and the same and that the associated rocks are different in different parts of the park.

The key stratum by means of which the position of these coal beds is determined is the Twentymile sandstone, but it is not always easy to decide just what constitutes the top of this member. The Twentymile sandstone in almost all parts of the district consists of a massive stratum from 50 to 100 feet thick. Above this massive layer are other thin but massive beds of similar material for a distance of at

[14] Op. cit., p. 28.

least 100 feet, and still higher are layers of sandstone, thinner bedded and not so characteristically white, up to about 150 feet above the massive layer. The relation of the upper layer of white sandstone to the main bed of the Twentymile sandstone is well shown in Plate VIII, *B*, which was taken in Foidel Canyon. Shall the Twentymile sandstone be considered as embracing only the lower massive layer, or shall it include all the layers of similar rock and be considered as 150 to 250 feet thick? From the descriptions given by Fenneman and Gale it seems probable that they intended the name to apply only to the lowermost massive bed, and the writer has followed their usage. This involves some difficulties, especially in passing down to the sandstone from some higher parts of the formation. Under such circumstances it is difficult if not impossible when a massive bed of white sandstone is encountered to say whether it is the uppermost part of the real Twentymile sandstone or merely one of the strata of white sandstone that overlie that bed.

The most persistent coal bed of this group in the Twentymile Park district is one that lies about 160 feet above the Twentymile sandstone. This bed is well shown by the roadside in the bank of Yampa River at locality 87, in the NW. ¼ sec. 9, T. 6 N., R. 87 W.

According to Fenneman and Gale the coal bed at this prospect is 3 feet thick but includes a parting three-quarters of an inch thick. By uncovering the coal bed at the side of the old prospect, the writer got a measurement of 3 feet 6 inches (Fig. 8) of apparently clear coal. He also determined its stratigraphic position, with considerable care, as 165 feet above the Twentymile sandstone. It is not possible to identify this bed in the section measured by Fenneman and Gale at the mouth of Sage Creek canyon, but to judge alone by its distance above the Twentymile sandstone, as determined by the writer on Yampa River, it would be equivalent to coal No. 5 of their section.

This probably agrees well with a coal bed first reported by Fenneman and Gale at locality 88, in the NW. ¼ sec. 28, T. 5 N., R. 86 W. They give the thickness of this bed as 3 feet and its position as 215 feet above the Twentymile sandstone. The writer also visited this prospect and found a thickness of 4 feet 2 inches of coal (Fig. 8), and a hand-leveled section showed it to be about 160 feet above the Twentymile sandstone. As the two measurements given above are almost the same it seems safe to conclude that there is a coal bed about 160 feet above the Twentymile sandstone, which is present in all parts of Twentymile Park where its horizon is under cover, and that it ranges from 3 to 4 feet in thickness. It is also interesting to note that in both localities the coal bed is overlain by a great mass of shale, but in the Foidel Canyon locality it rests upon a massive layer of white sandstone nearly 20 feet thick. This association of shale, sandstone, and coal makes it possible to identify the bed at other places with considerable certainty.

A coal bed having similar relations is exposed on Fish Creek across sec. 25, T. 5 N., R. 87 W., and also across most of sec. 19, T. 5 N., R. 86 W. On account of this extended outcrop along the creek it will be referred to here as the Fish Creek bed. This coal bed is also exposed in the NW. ¼ sec. 36, T. 5 N., R. 87 W., in many places by the side of the road leading from Oak Creek to Hayden. It lies on a bed of white sandstone. It was once opened at locality 89, 500 feet south of the northwest corner of this section, but the prospect pit has fallen shut, and the thickness of the bed could not be seen. It undoubtedly goes under Fish Creek a short distance west of the section corner, but in the other direction it continues at or near water level more than a mile. At locality 90, in the NW. ¼ sec. 25, according to Winchester, it shows in an old mine a thickness of 4 feet 6 inches (Fig. 8). Somewhere in sec. 24 it goes below creek level, but it rises again as the creek turns eastward near the east line of the section. At locality 91, near the center of sec. 19, the bed is exposed on the north side of Fish Creek, about 30 feet above water level, and has a thickness of 4 feet (Fig. 8). This bed crops out on the north bank of the creek at locality 92, near the east line of the section, and there disappears beneath creek level. Its disappearance at this point is due to the northeastward dip of the rocks into the subordinate basin of the Argo syncline, the axis of which probably passes near the northeast corner of sec. 20.

As the rocks on the southeast side of Fish Creek rise steadily to the top of the Twentymile sandstone facing Foidel Canyon, it is uncertain whether the Fish Creek coal bed will be found in the territory between the creek and the sandstone cliff. If it is present in part or all of this territory it is probably so near the surface as to be greatly weathered and hence of little value.

Northeast of locality 92 the bed dips below the surface, but along Foidel Creek it probably does not descend more than 100 feet, as it reappears at creek level at a point west of locality 93, near the center of sec. 22, T. 5 N., R. 86 W. At locality 93 the Fish Creek coal bed rises northeastward at nearly the same rate (10°) as the surface, and as a result it is very near or at the surface throughout a considerable tract. It has been stripped here in a number of places and shows a thickness of 3 feet 7 inches (Fig. 8).

The next place at which the Fish Creek bed is known is locality 94, in the southeast corner of sec. 33, T. 6 N., R. 86 W. Although this bed does not rest on sandstone, it is correlated with the Fish Creek bed by means of its distance above the Twentymile sandstone, which, though not accurately measured, is about 160 feet. The coal bed at locality 94 is 3 feet thick (Fig. 8), strikes N. 42° W., and dips 23° SW. The Fish Creek bed so far as known is not exposed at any other place in Twentymile Park.

West of the Tow Creek anticline this bed is exposed at a number of places at and near locality 95, in the NW. ¼ sec. 28, T. 6 N., R. 87 W., but the writer saw no opening on the bed and hence was unable to obtain an accurate measurement of its thickness. It is probably, however, about 3 feet thick.

At several places in Twentymile Park there is a small coal bed that appears to lie directly upon the massive layer of the Twentymile sandstone. It is possible that this sandstone is the bed which underlies the Fish Creek coal bed and which in places has thickened and practically become a part of the Twentymile sandstone. The writer is inclined to the belief, however, that this is a lower coal bed which rests directly on the massive layer of the Twentymile sandstone. This bed was seen in its best development at localities 96, 97, and 98, at the south end of the Tow Creek anticline. As the anticline plunges toward the south the last bed of rock to make a showing in the surface features is the Twentymile sandstone, which forms the surface of the arch in most of secs. 14 and 15, T. 5 N., R. 87 W. At locality 96 the coal bed directly above it is 14 inches thick; at locality 97, 18 inches thick; and at locality 98, 20 inches thick. A coal bed that appears to have the same stratigraphic position as that just described was noted at locality 99, in the SE. ¼ sec. 10, T. 5 N., R. 86 W. This bed dips 8° W. and has a thickness of 2 feet 4 inches. It does not rest directly on the Twentymile sandstone but lies not more than 20 feet above that bed.

No other coal beds of the upper group were seen in Twentymile Park, and the writer can add no information to that contained in Fenneman and Gale's report regarding the higher beds. He made an effort to enter the mine at locality 100, in the NE. ¼ sec. 35, T. 6 N., R. 88 W., but the mine had been idle so long that it was full of carbon dioxide, and the lights would burn for only a distance of about 200 feet in the rock tunnel which leads back to the coal bed that was mined. Although the mine has not been operated for a number of years, the coal on the dump is bright, and its manner of breaking down indicates that it is of good quality, probably to be classed as bituminous coal of about the same rank as that mined at Mount Harris.

STRUCTURE.

A brief description of the structure has already been given, but there are certain features of it that have a direct bearing on the exploration for and mining of coal and hence they deserve more careful attention. These are the great westward-facing dip slopes, the depth of the basin of Twentymile Park, and the faults, or breaks in the rocks.

The great sandstone dip slopes have been described as the most pronounced feature of the park, especially those in which one or the other of the great sandstone key rocks, the Trout Creek or the Twentymile, forms the surface from the foot to the summit of the ridge that makes the park boundary. Where the sandstone forms the surface such coal beds as are present must have a considerable cover, and therefore they are not likely to be deeply affected by weathering and consequent deterioration of the coal, but in many places, particularly where the ridge is due to the Trout Creek sandstone dipping at a low angle, rocks containing the coal beds of the middle group may form the surface throughout the dip slope, and they may be under such slight cover that they are more or less weathered. If the drainage is good and the coal beds are liable to be alternately soaked with water and then dried out oxidation will take place, and the coal may be so greatly deteriorated as to make the marketing of it a difficult task, but if the beds are so situated that the coal remains wet, then it will be affected slightly if at all and the decomposition will proceed so slowly as to be negligible. The dip slopes in which the coal is most liable to be affected are described below.

In the great dip slope on the west side of the ridge between Oak Creek and Trout Creek the Wadge bed may in places be very seriously affected. The Wolf Creek bed is generally so thin that it will not be mined for a long time to come, and as it lies about 150 feet below the Wadge it is not liable to be affected by weathering, but where the drainage is such that the coal may be dry during a part of the year even this bed may be affected to a slight extent.

The dip slope of the Trout Creek sandstone which extends northwestward to Foidel Canyon from the top of the great cliff that runs southwestward from the northeast corner of sec. 9, T. 4 N., R. 86 W., to about the southwest corner of sec. 25 of the next township is also liable to carry coal that is considerably weathered, particularly in the Wadge bed and near the summit of the ridge.

In the shallow part of the synclinal basin north of Elk Creek in secs. 16 and 21, T. 6 N., R. 86 W., described on pages 19–20 and 28, the Wadge bed and in places the Wolf Creek bed have apparently such slight cover that they may be very seriously affected.

In other places in Twentymile Park the dip slopes are either short and of only local effect or the dip of the sandstone is so steep as to carry the coal beds under thick cover within a short distance and thus expose only a small amount of coal to the influence of the weather.

The depth of the synclinal basin of Twentymile Park is one of the troublesome questions in the geology of this district, and the writer has few definite data upon which to base an answer. That part of the basin southeast of Fish Creek need not be considered here, because all the evidence points to that part being very shallow, and probably at no point in it is the Twentymile sandstone more than 250 feet below the surface. Northwest of Fish Creek and extending from Dunkley Canyon to the north line of secs. 32 and 33, T. 6 N., R. 86 W., the depth of the basin is very uncertain; the Twentymile sandstone on the west side of this area dips into it from the Tow Creek anticline at an average angle of about 20°, and the same bed dips into the southern part of the basin at an angle of about 54°. It is obvious that if these dips hold downward for any great distance they carry the Twentymile sandstone to a considerable depth below the surface. So few data regarding the altitude of the surface are available that it is impossible to construct accurate sections in order to determine this point.

In the northern part of Twentymile Park the great dip slope of the Twentymile sandstone down the west face of the ridge east of Fish Creek in sec. 11, T. 5 N., R. 86 W., probably continues at about the same rate of dip to the axis of the syncline, which is assumed to be, as represented on the map, near the west line of sec. 5, T. 5 N., R. 86 W. At this point the top of the Twentymile sandstone is probably about 700 feet below the surface. As the Wadge coal is about 600 feet lower down, its depth is about 1,300 feet. West of the axis the beds rise steeply in the great Tow Creek anticline and descend gradually on the west to Grassy Creek, where both the Twentymile and the Trout Creek sandstones are exposed, as shown on the map.

In the southern part of the park the large syncline of Twentymile Park is interrupted near the middle by the northward-plunging anticline whose axis at this place corresponds closely with Foidel Canyon. The eastern part of the major basin is so shallow that the Twentymile sandstone is at or near the surface in the western part of the subordinate basin or Argo syncline and the Trout Creek sandstone in the eastern part. West of Foidel Canyon the Twentymile sandstone dips gently but steadily to the deepest part of the major basin, which probably is near the line between secs. 26 and 27, T. 5 N., R. 87 W. At this point the Twentymile sandstone is probably 600 feet below the surface. A short distance west of this point the sandstone makes its appearance in the east limb of the Williams Park anticline, rises steeply toward the west and then descends gently into the subordinate basin whose axis is near the north quarter corner of sec. 30, T. 5 N., R. 87 W. West of this is the great Sage Creek anticline, which would carry these beds, were they not eroded, high above the present surface.

Very few data are available regarding the depth of the Twentymile sandstone northwest of Grassy Gap, but it seems probable that in the deepest part here considered this sandstone may be 500 or 600 feet below the surface.

So far as known at the present time, there are only three faults in this district that are of any considerable extent either longitudinally or in the amount of displacement they have produced in the strata. These are the Milner fault and the Grassy Creek fault, previously mentioned, and the Foidel Canyon fault and other minor faults in the same general zone.

Fenneman and Gale did not recognize any of these faults except the Foidel Canyon fault (see Pl. VII, *B*), but they postulated a fault near the mouth of Middle Creek, which, as shown on page 35, probably does not exist, at least to the extent assumed by them. The Foidel Canyon fault was noted by Fenneman and Gale where it cuts the Trout Creek sandstone and also where it cuts the Twentymile sandstone, but they did not realize, owing to their poor base map, that these two faults are in a direct line and are one and the same fault.

The displacement was not detected at any other places than on the escarpments formed by these massive beds, but here it is unmistakable. The break in the cliff of the Twentymile sandstone in the SE. ¼ sec. 36, T. 5 N., R. 87 W., is shown in Plate VII, *B*, as seen from the public road in sec. 31, T. 5 N., R. 86 W. In this view the break in the cliff is plainly visible, the farther part of the cliff having been dropped down about 150 feet. As the coal beds in this part of the district are cut by this fault it may cause considerable difficulty and expense in mining.

The Grassy Creek fault may offset the outcrop of both the Trout Creek and Twentymile sandstones, but it was not traced as far east as the outcrop of the Trout Creek bed, and so its effect on that bed is not known. It has a profound effect on the Twentymile sandstone, which it cuts near the gap eroded by Grassy Creek through that massive bed. As the downthrow is on the south side of the fault, the two layers of the Twentymile sandstone are apparently duplicated, and the ridge north of the gap appears to carry more beds of sandstone than is normal for this region. This fault also affects the beds of the middle coal group, causing a drop toward the south of 100 to 150 feet.

DEVELOPMENT OF MINES.

As the coal beds in the Yampa field lie in a great irregular basin or syncline, and as mining has been undertaken only on the rim of this basin, it naturally follows that most of the mining has been done by drift where the tipple could be located in a valley with the coal bed lying in higher land, or by slope leading down toward the bottom of the syncline. Naturally the easiest and least expensive methods will be used as long as favorable locations for mines can be procured, but ultimately the more easily mined coal will have been exhausted, and then shaft mining in the interior of the basin will become necessary. The data are not at hand for making an accurate statement regarding the points at which such shafts could be most advantageously located so as to draw the coal by gravity to the foot of the shaft, but some suggestions will be made that may be of some assistance in planning future developments.

The location of large mines depends chiefly upon the ease with which railroad connection can be effected and upon the "lay" of the coal bed. As all of Twentymile Park is drained by Trout Creek and its tributaries, the natural outlet for much of the coal of this district is down that stream to Milner or direct to Oak Creek through the northward extension of the Oak Creek valley in secs. 20, 29, and 32, T. 5 N., R. 85 W. A connection could also be made by a tunnel from Oak Creek through the ridge on the west to Trout Creek. This line would have the better grade but would require a tunnel about 1½ miles in length. From a main line of railroad down Trout Creek all parts of Twentymile Park could be reached by branch lines up the tributary streams.

So far as the dip of the coal beds is concerned, shafts on any of the synclinal axes shown on the map would have a greater or less extent of coal beds to draw from, but good locations could also be found elsewhere provided there is a sufficiently large area of the coal bed to be mined on the side of the shaft away from the axial line. Thus a shaft on Fish Creek near the west line of sec. 11, T. 5 N., R. 86 W., could draw from the entire area of the coal bed between the shaft and the outcrop on the east and north, and all this coal could be brought to the bottom of the shaft by gravity.

In the deeper parts of the syncline the beds of the middle group could probably be reached only by a shaft 1,000 to 1,200 feet deep, and the beds of the lower group at depths of 1,700 to 1,900 feet. Such depths are not practicable at the present time, but they will be in the future, as soon as the more easily accessible coal is exhausted.

ESTIMATE OF ORIGINAL TONNAGE OF COAL.

Although in a district in which so little prospecting and mining has been done as in the Twentymile Park district of the Yampa field there are scarcely data enough upon which to base an estimate of the original tonnage of coal in the ground, still it is extremely important to take stock of our resources in the matter of a fuel supply; and an estimate, although confessedly inaccurate, is much better than no estimate at all upon which to base conclusions.

In view of this fact the writer has attempted to estimate the original tonnage of coal in such parts of the Twentymile Park district as he has examined. In studying the district from this point of view it is at once apparent that, although little deep drilling has been done, the coal beds are so well exposed in the rim surrounding the park that a study of their outcrops affords very good data upon which to base an estimate, for both the middle and the lower groups show a workable thickness of coal in every section examined, and hence it is reasonable to assume that this condition holds throughout the deeper parts of the basin, where measurements of thickness are not obtainable. The available data as to thickness may be summarized as follows:

Aggregate thickness of coal in the different groups at different places in the field.

Group.	Mount Harris.	Milner district.	Lower Fish Creek.	Mouth of Middle Creek.	Male mine, Trout Creek.	Upper Middle Creek.	Dunkley Canyon.	Sage Creek.	Average.
	Ft. in.	*Feet.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Upper group	3 6	....	3	....	....	7	....	23 6	9 3
Middle group	16 3	20	16 10	16 9	12 3	22+	22+	18 3	18
Lower group	13 4	13+	18 4	11+	15 2+	(?)	9 6	10	13
	33 1	33+	38 2	27 9+	27 5+	29+	31 6+	51 9	40 3

In making the estimate the writer first noted on a map the aggregate thickness of all coal beds above a minimum thickness of 2 feet in the middle and lower groups at various places on the rim at which such data were available. When this was completed for the middle group, the thickness in the basin was graded between points where it was known, and in this way an estimate of the available thickness of coal in the middle group was made for every section of land or part of section under consideration. From the thickness of coal thus estimated and the area of the section the tonnage was computed on the assumption that the specific weight of the coal is 1.3. On this assumption there would be 1,132,000 short tons in a bed 1 square mile in extent and 1 foot thick. By multiplying this figure by the area of the section and the thickness in feet, the total tonnage of coal for that group and that section was obtained. This process was repeated for the upper and lower groups, and then the amounts were added in order to get the total for each township or fraction. The results are as follows:

Estimated original amount of coal in the Twentymile Park district of the Yampa coal field, in short tons.

T. 6 N., R. 86 W.

[Secs. 3, 4, 8 to 11, 14 to 17, 20 to 22, 27 to 35.]

Upper coal group	1,900,000
Middle coal group	143,100,000
Lower coal group	106,700,000
	251,700,000

T. 6 N., R. 87 W.

[Secs. 8 to 11, 14 to 17, 21 to 23, 25 to 36.]

Upper coal group	32,200,000
Middle coal group	282,800,000
Lower coal group	195,500,000
	510,500,000

T. 5 N., R. 85 W.

[Secs. 6 to 8, 17 to 20, 29 to 32.]

Middle coal group	24,800,000
Lower coal group	101,800,000
	126,600,000

T. 5 N., R. 86 W.

[Secs. 1 to 36.]

Upper coal group	44,100,000
Middle coal group	765,400,000
Lower coal group	465,900,000
	1,275,400,000

T. 5 N., R. 87 W.

[Secs. 1 to 28, 34 to 36.]

Upper coal group	40,700,000
Middle coal group	638,500,000
Lower coal group	300,600,000
	979,800,000

T. 5 N., R. 88 W.

[Secs. 1, 2, 12, and 13.]

Upper coal group	1,700,000
Middle coal group	50,000,000
Lower coal group	24,000,000
	75,700,000

T. 4 N., R. 85 W.

[Secs. 6, 7, 18, 19, 30, and 31.

Middle coal group	27,200,000
Lower coal group	76,200,000
	103,400,000

T. 4 N., R. 86 W.

[Secs. 7 to 18, 22, 24 to 27, 34 to 36.]

Middle coal group	213,800,000
Lower coal group	348,300,000
	562,100,000

T. 4 N., R. 87 W.

[Secs. 2, 3, 13, and 14.]

Middle coal group	71,700,000
Lower coal group	47,600,000
	119,300,000

T. 3 N., R. 86 W.

[Secs. 1 to 3, 10, 11, 13, and 14.]

Lower coal group	46,000,000

These figures gave a grand total for all groups of 4,050,500,000 short tons.

As more detailed prospecting would doubtless reveal many thin beds not now known, it is probable that the figures given above in reality express minimum quantities and that when the field is fully developed a greater tonnage will be revealed.

The total original tonnage of coal in the district is of itself of little interest to the commercial man, for what he wants to know is not how much coal was here once, but how much still remains at any given date. With the total original tonnage known, however, the amount remaining at any date is easily ascertained by deducting from the original tonnage that which has been mined and wasted. The amount produced is easily ascertained from the Mineral Resources reports of the United States Geological Survey, but the amount wasted in mining will always have to be estimated. The waste is different in different fields, but for the Twentymile Park district it will probably amount to about 30 per cent of that which has been mined. The quantity still in the ground at the end of 1918, the latest year for which reliable figures of production are available, would then be determined as follows:

	Short tons.
Quantity mined to end of 1918	5, 941, 805
Wasted in mining and left in mine (estimated)	1, 782, 540
Total exhaustion	7, 724, 345

This in round numbers is 7,700,000 short tons. As the estimated original amount in this district is 4,050,500,000 short tons, the amount remaining in the ground at the end of 1918 would be 4,050,500,000 – 7,700,000 = 4,042,800,000 short tons.

QUALITY OF THE COAL.

IMPORTANCE OF KNOWING QUALITY.

As the use of fuel becomes more and more specialized there is an increased demand for fuller information regarding the quality of coal available, so that where the consumer has a choice of two or more varieties, the one which is most economical may be selected. The highest-grade coal is not always the most economical, for quality of coal must be balanced against needs for certain grades in manufacturing processes and against cost of transportation and delivery. In the past the most easily available coal has too generally been accepted without question as the one to use, but with the more scientific study of the problem there is a growing tendency to seek the coal best adapted to the particular needs of the consumer, and this scientific selection is doubtless destined to be greatly extended in the future.

The production in the Twentymile Park district at the present time is not great, and the increase will doubtless be slow until railroad connection with the outside world that will not involve steep mountain grades and other handicaps such as now prevail becomes available. If these difficulties can be removed or lessened, there seems to be no reason why this field should not become a prominent producer of coal, and then its coal will have to compete with that from fields in adjacent regions on the north, south, east, and west. An adequate railroad outlet will not only aid this coal in finding a wider market but will at once bring it squarely into competition with other coals. It is therefore but just to the operators here as well as to the consumers—the public at large—that they should have all the information available regarding this coal and coal from prospective competing fields.

PHYSICAL PROPERTIES.

The coal of the Twentymile district will slack to a certain extent on long-continued exposure to the weather, but not nearly so readily or completely as that from many fields with which it will come into competition. It is an extremely hard coal, and, as the joints that cut the beds are rather far apart, it mines in large lumps or blocks, which break up with difficulty. On account of its blocky character and hardness it will stand transportation to distant markets with but little breaking up into fine particles, and also, unless shot with too heavy a charge in mining, it will produce a relatively large percentage of lump coal. Like most of the other low-rank bituminous and subbituminous coals of the West, the Twentymile district coal is clean to handle, scarcely soiling the hands.

On account of the properties enumerated above this coal makes an excellent domestic fuel and should be able to hold its own for this use in almost any market. It is well adapted for general manufacturing purposes, but for producing steam the value of a coal depends upon the amount of heat it will yield, and, as shown later, in this respect the Twentymile coal is inferior to many with which it will have to compete.

CHEMICAL PROPERTIES.

The following table of analyses will afford the reader some idea of this coal, both in a qualitative and quantitative way. It includes not only analyses of coal from the principal mines of the district, which will show the relative value of the coal in different parts of the district, but analyses from other fields with which this coal may have to compete.

Each analysis is given in three forms, marked A, B, and C. Form A is the analysis of the sample of coal as it came from the mine in sealed containers, with the same amount of moisture that is in the coal as it is being mined. The coal when sent to market may change somewhat in transit before it reaches the consumer. If the weather is dry it may lose an appreciable percentage of its moisture; on the other hand, if the weather is damp it may absorb an appreciable amount. Analysis A is generally the one considered when coals are bought on specification, but it should be clearly understood that the coal as burned may be of quite different composition.

Form B is a recalculated form which represents the coal as it would be were all the moisture removed. Coal is never in that condition, and hence this form is of service and value only to the mechanical engineer.

Form C is also a theoretical condition, but as it is the analysis of the coal substance free from most of the impurities it is of value for comparing the real coal substance of one sample with that of another, as shown later in this paper.

As proximate analyses do not deal with chemical elements it is impossible to make them strictly accurate, hence the results have been generalized to the nearest tenth of 1 per cent. The ultimate analyses, however, are much more accurate and are given to the nearest hundredth of 1 per cent. The British thermal units are given to the nearest 10 units.

Analyses of coal samples from the Twentymile Park district, Yampa coal field, Colo.

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

Laboratory No.	No. in Fig. 9.	Description.	Location. Quarter.	Location. Sec.	Location. T. N.	Location. R. W.	Coal bed.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heating value (British thermal units).
22737	....	Mine of Colorado & Utah Coal Co., Mount Harris. Mine sample.	SW.	15	6	87	Wadge	2.7	A	10.6	38.4	45.9	5.1	0.43					11,620
									B		43.0	51.3	5.7	.48					13,010
									C		45.6	54.4		.51					13,790
22738	....	do	SW.	15	6	37	do	2.5	A	10.3	37.7	45.7	6.3	.42					11,520
									B		42.1	50.9	7.0	.47					12,850
									C		45.3	54.7		.51					13,920
22739	....	do	SW.	15	6	87	do	2.9	A	10.4	38.5	43.8	7.3	.46					11,310
									B		43.0	48.9	8.1	.51					12,630
									C		46.8	53.2		.56					13,750
22740	1	Composite of Nos. 22737, 22738, and 22739.	SW.	15	6	87	do	2.7	A	10.4	37.9	45.5	6.22	.42	5.85	64.87	1.59	21.05	11,470
									B		42.3	50.8	6.94	.47	5.24	72.39	1.77	13.19	12,800
									C		45.4	54.6		.51	5.63	77.79	1.90	14.17	13,750
31199	....	Mine of Colorado & Utah Coal Co., Mount Harris. Mine sample.	SW.	15	6	87	do	5.5	A	10.4	38.2	46.5	4.9	.42					11,660
									B		42.6	51.9	5.5	.47					13,010
									C		45.1	54.9		.50					13,770
31200	....	do	SW.	15	6	87	do	7.1	A	12.4	37.6	44.2	5.8	.42					11,180
									B		42.9	50.5	6.6	.48					12,780
									C		46.0	54.0		.51					13,670
31201	....	do	SW.	15	6	87	do	5.8	A	10.6	37.6	46.2	5.6	.40					11,550
									B		42.0	51.7	6.3	.45					12,920
									C		44.8	55.2		.48					13,790
31202	....	do	SW.	15	6	87	do	6.4	A	11.4	37.2	45.4	6.0	.40					11,300
									B		42.0	51.3	6.7	.45					12,760
									C		45.0	55.0		.48					13,680
31203	....	do	SW.	15	6	87	do	5.4	A	10.8	37.2	45.3	6.7	.40					11,260
									B		41.7	50.8	7.5	.45					12,620
									C		45.0	55.0		.49					13,640
31204	....	do	SW.	15	6	87	do	5.0	A	9.9	38.0	46.3	5.8	.40					11,600
									B		42.2	51.4	6.4	.44					12,870
									C		45.1	54.9		.47					13,760
31205	....	do	SW.	15	6	87	do	6.0	A	11.3	38.3	46.4	4.0	.39					11,640
									B		43.2	52.3	4.5	.44					13,120
									C		45.2	54.8		.46					13,730
31206	....	do	SW.	15	6	87	do	5.8	A	10.8	37.8	45.3	6.1	.42					11,440
									B		42.4	50.8	6.8	.47					12,820
									C		45.5	54.5		.50					13,770
31207	2	Composite of Nos. 31199-31206.	SW.	15	6	87	do	5.9	A	11.0	37.7	45.7	5.63	.41	5.76	65.31	1.63	21.26	11,460
									B		42.3	51.4	6.32	.46	5.10	73.36	1.83	12.93	12,870
									C		45.2	54.8		.49	5.44	78.31	1.95	13.81	13,730
31233	....	Wadge mine of Victor-American Fuel Co., Mount Harris. Mine sample.	SW.	15	6	87	do	6.9	A	11.5	37.7	46.0	4.8	.41					11,500
									B		42.7	51.9	5.4	.46					12,990
									C		45.1	54.9		.49					13,740
31234	....	do	SW.	15	6	87	do	6.3	A	11.0	37.9	45.4	5.7	.46					11,430
									B		42.5	51.0	6.5	.52					12,840
									C		45.5	54.5		.56					13,730
31235	3	Composite of Nos. 31233 and 31234.	SW.	15	6	87	do	6.6	A	11.3	37.6	45.8	5.32	.45	5.75	64.99	1.54	21.95	11,460
									B		42.4	51.6	6.00	.51	5.07	73.24	1.74	13.44	12,920
									C		45.1	54.9		.54	5.39	77.91	1.85	14.31	13,740
32975	4	Mine No. 3 of McNeil Coal Co., McGregor. Mine sample.	SE.	16	6	86	do	4.3	A	13.8	36.3	43.5	6.43	.63	5.68	61.06	1.53	24.67	10,110
									B		42.1	50.4	7.46	.73	4.81	70.83	1.77	14.40	11,730
									C		45.5	54.5		.79	5.20	76.54	1.91	15.56	12,670
31038	5	Mine of Tom Chergo. Mine sample.	NW.	13	5	86	do	4.0	A	12.8	37.2	44.4	5.59	.43	5.77	63.26	1.49	23.46	11,030
									B		42.6	51.0	6.41	.49	4.99	72.57	1.71	13.83	12,660
									C		45.5	54.5		.52	5.33	77.54	1.83	14.78	13,530
30862	6	Mine of Casper Webber, in Dunkley Canyon. Mine sample.	NW.	2	4	87	do	3.3	A	13.2	35.8	44.9	6.11	.53	5.68	62.75	1.44	23.49	10,970
									B		41.3	51.7	7.04	.61	4.85	72.29	1.66	13.55	12,640
									C		44.4	55.6		.66	5.22	77.76	1.79	14.57	13,600
22736	....	Mine No. 1 of International Fuel Co., Mount Harris. Mine sample.	NE.	15	6	87	Wolf Creek	2.6	A	9.8	36.8	40.8	12.6	.44					10,700
									B		40.8	45.2	14.0	.49					11,870
									C		47.5	52.5		.57					13,800
81684	....	do	NE.	15	6	87	do	......	A	10.1	36.6	44.7	8.6	.59					11,150
									B		40.7	49.7	9.6	.66					12,400
									C		45.0	55.0		.73					13,720
81685	....	do	NE.	15	6	87	do	......	A	9.7	35.1	40.5	14.7	.53					10,240
									B		38.9	44.8	16.3	.59					11,330
									C		46.5	53.5		.70					13,530
81686	....	do	NE.	15	6	87	do	......	A	9.9	35.6	43.5	11.0	.50					10,850
									B		39.5	48.3	12.2	.56					12,050
									C		45.0	55.0		.64					13,720

Analyses of coal samples from the Twentymile Park district, Yampa coal field, Colo.—Continued.

Laboratory No.	No. in Fig. 9.	Description.	Location: Quarter.	Location: Sec.	Location: T. N.	Location: R. W.	Coal bed.	Air-drying loss.	Form of analysis.	Proximate: Moisture.	Proximate: Volatile matter.	Proximate: Fixed carbon.	Proximate: Ash.	Ultimate: Sulphur.	Ultimate: Hydrogen.	Ultimate: Carbon.	Ultimate: Nitrogen.	Ultimate: Oxygen.	Heating value (British thermal units).
81687	7	Composite of Nos. 81684, 81685, and 81686.	NE.	15	6	87	Wolf Creek	......	A	9.8	36.4	42.2	11.56	0.54	5.46	60.99	1.14	20.31	10,760
									B	......	40.4	46.8	12.82	.60	4.85	67.63	1.26	12.84	11,930
									C	......	46.3	53.7	......	.69	5.56	77.57	1.45	14.73	13,680
32974	8	Mine No. 1 of McNeil Coal Co., McGregor. Mine sample.	SE.	16	6	86	do	3.0	A	11.8	35.7	41.8	10.65	.47	5.39	59.37	1.28	22.84	10,210
									B	......	40.5	47.4	12.07	.53	4.63	67.31	1.45	14.01	11,580
									C	......	46.1	53.9	......	.60	5.27	76.55	1.65	15.93	13,170
32971	....	Mine of Elk Creek Mining Co., 1½ miles south of Milner. Mine sample, upper part of coal bed.	SE.	21	6	86	do	3.4	A	12.1	34.6	41.9	11.4	.46	......	......	......	......	10,200
									B	......	39.4	47.6	13.0	.52	......	......	......	......	11,610
									C	......	45.3	54.7	......	.60	......	......	......	......	13,340
32972	....	Same: Lower part of coal bed.	SE.	21	6	86	do	3.4	A	12.5	36.7	43.4	7.4	.42	......	......	......	......	10,800
									B	......	41.9	49.7	8.4	.48	......	......	......	......	12,340
									C	......	45.8	54.2	......	.52	......	......	......	......	13,480
32973	9	Composite of Nos. 32971 and 32972.	SE.	21	6	86	do	3.4	A	12.2	35.5	42.9	9.42	.42	5.42	60.02	1.34	23.38	10,520
									B	......	40.4	48.9	10.74	.48	4.63	68.40	1.53	14.22	11,990
									C	......	45.3	54.7	......	.54	5.19	76.63	1.71	15.93	13,430
1843	....	Old McCroskey mine	SE.	9	6	86	do	4.4	A	12.0	34.5	42.8	10.7	.47	......	......	......	......	......
									B	......	39.2	48.7	12.1	.53	......	......	......	......	......
									C	......	44.6	55.4	......	.60	......	......	......	......	......
22724	10	Mine of Bear River Coal Co., Bear River. Mine sample.	S. ½	11	6	87	Bear River	3.3	A	10.5	37.4	47.1	5.0	.51	......	......	......	......	11,730
									B	......	41.8	52.6	5.6	.57	......	......	......	......	13,100
									C	......	44.3	55.7	......	.60	......	......	......	......	13,880
32987	11	Mine of Routt-Pinnacle Coal Co., Coalview. Mine sample.	NE.	23	6	87	do	3.9	A	9.3	38.0	45.6	7.11	.49	5.46	65.13	1.30	20.51	11,550
									B	......	41.9	50.3	7.84	.54	4.88	71.81	1.43	13.50	12,740
									C	......	45.5	54.5	......	.59	5.30	77.92	1.55	14.64	13,820
31130	....	Argo mine of Moffat Coal Co., Oak Creek. Mine sample.	NW.	31	4	85	Pinnacle	3.5	A	8.5	39.1	49.2	3.2	.47	......	......	......	......	12,410
									B	......	42.7	53.8	3.5	.51	......	......	......	......	13,550
									C	......	44.2	55.8	......	.53	......	......	......	......	14,030
31131	....	do	NW.	31	4	85	do	3.8	A	9.3	39.3	48.2	3.2	.48	......	......	......	......	12,250
									B	......	43.3	53.2	3.5	.53	......	......	......	......	13,500
									C	......	44.9	55.1	......	.55	......	......	......	......	14,000
31132	....	do	NW.	31	4	85	do	3.4	A	8.0	39.0	46.6	6.4	.44	......	......	......	......	12,020
									B	......	42.4	50.6	7.0	.48	......	......	......	......	13,050
									C	......	45.6	54.4	......	.52	......	......	......	......	14,040
31133	....	do	NW.	31	4	85	do	3.4	A	8.9	38.8	48.3	4.0	.46	......	......	......	......	12,220
									B	......	42.6	53.0	4.4	.49	......	......	......	......	13,410
									C	......	44.5	55.5	......	.51	......	......	......	......	14,030
31134	12	Composite of Nos. 31130–31133.	NW.	31	4	85	do	3.5	A	8.6	39.1	48.0	4.25	.41	5.75	69.41	1.50	18.68	12,220
									B	......	42.8	52.5	4.65	.45	5.24	75.96	1.64	12.06	13,370
									C	......	44.9	55.1	......	.47	5.50	79.67	1.72	12.64	14,020
115	13	Pinnacle mine of Victor-American Fuel Co., Oak Creek. Commercial sample, average of 41 car samples.	SE.	36	4	86	do	......	A	8.1	36.8	50.0	5.1	.65	......	......	......	......	12,200
									B	......	40.1	54.4	5.5	.71	......	......	......	......	13,270
									C	......	42.4	57.6	......	.75	......	......	......	......	14,050
116	....	Same: Average of 19 car samples.	SE.	36	4	86	do	......	A	8.1	38.0	47.9	6.0	.67	......	......	......	......	12,060
									B	......	41.3	52.2	6.5	.73	......	......	......	......	13,120
									C	......	44.2	55.8	......	.78	......	......	......	......	14,040
1799	14	Old Shuster mine, Oak Creek. Mine sample.	S. ½	30	4	85	No. 1	2.3	A	8.8	36.1	50.2	4.90	1.51	5.69	68.59	1.54	17.77	12,160
									B	......	39.6	55.0	5.38	1.66	5.17	75.25	1.69	10.85	13,340
									C	......	41.8	58.2	......	1.75	5.46	79.52	1.79	11.48	14,100

Analyses of coals from other fields with which the coals from the Twentymile Park district may have to compete.

Laboratory No.	Letter in Fig. 10.		Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heating value (British thermal units.)
25203	F	Sheridan, Wyo. Composite of 8 mine samples.	12.6	A	24.4	31.1	39.7	4.76	.48	6.34	52.59	1.05	34.78	9,000
				B		41.2	52.5	6.29	.63	4.80	69.53	1.39	17.36	11,890
				C		43.9	56.1		.67	5.12	74.20	1.48	18.53	12,690
3605	G	Hanna, Wyo. Mine sample	2.2	A	10.1	41.0	41.9	6.99	.49	5.53	62.66	1.26	23.07	11,300
				B		45.6	46.6	7.77	.54	4.90	69.70	1.40	15.69	12,570
				C		49.5	50.5		.59	5.32	75.57	1.52	17.00	13,630
5358	H	Rock Springs, Wyo. Mine sample	2.3	A	8.5	35.6	50.4	5.48	.78	5.36	66.15	1.19	21.04	11,830
				B		38.9	55.1	5.99	.85	4.82	72.32	1.30	14.72	12,940
				C		41.4	58.6		.90	5.13	76.93	1.38	15.66	13,760
18783	I	Kemmerer, Wyo. Composite of 4 mine samples.	1.8	A	3.9	40.3	48.4	7.40	.72	5.50	71.87	1.31	13.20	12,840
				B		42.0	50.3	7.70	.75	5.27	71.80	1.36	10.12	13,360
				C		45.5	54.5		.81	5.71	81.04	1.47	10.97	14,480
19847	J	Castlegate, Utah. Mine sample	1.9	A	4.6	42.3	46.9	6.16	.49	5.72	71.80	1.37	14.46	12,870
				B		44.3	49.2	6.46	.51	5.46	75.24	1.44	10.89	13,490
				C		47.4	52.6		.55	5.84	80.44	1.54	11.63	14,420
28919	K	Cameo, Colo. Composite of 2 mine samples.	1.9	A	7.1	36.8	47.2	8.89	.57	5.42	67.64	1.40	16.08	11,890
				B		39.6	50.8	9.57	.61	4.99	72.85	1.51	10.47	12,810
				C		43.8	56.2		.67	5.52	80.56	1.67	11.58	14,160
12327	L	Newcastle, Colo. Composite of 2 mine samples.	3.6	A	7.1	40.8	46.9	5.19	.45	5.65	70.77	1.56	16.38	12,620
				B		43.9	50.5	5.59	.48	5.23	76.20	1.68	10.82	13,590
				C		46.5	53.5		.51	5.54	80.71	1.78	11.46	14,400
13395	M	Canon City, Colo. Composite of 2 mine samples.	5.8	A	10.3	38.2	45.0	6.49	.42	5.38	65.45	1.08	21.18	11,420
				B		42.6	50.2	7.23	.47	4.74	72.94	1.20	13.42	12,720
				C		46.0	54.0		.51	5.11	78.62	1.29	14.47	13,710
31316	N	Louisville, Colo. Composite of 2 mine samples.	11.2	A	19.1	33.4	42.1	5.35	.27	5.97	57.68	1.21	29.52	10,020
				B		41.3	52.1	6.62	.33	4.75	71.33	1.50	15.47	12,390
				C		44.3	55.7		.35	5.09	76.39	1.61	16.56	13,370
11184	O	Kansas coal	3.4	A	4.9	33.5	52.5	9.10	4.95	5.08	71.20	1.24	8.43	12,940
				B		35.2	55.2	9.56	5.20	4.77	74.83	1.30	4.34	13,600
				C		39.0	61.0		5.75	5.27	82.74	1.44	4.80	15,040
10201	P	Northern Missouri coal	8.7	A	13.8	34.7	41.8	9.71	3.32	5.71	59.84	1.06	20.36	10,960
				B		40.2	48.5	11.27	3.85	4.85	69.43	1.23	9.37	12,720
				C		45.4	54.6		4.34	5.47	78.25	1.39	10.55	14,340

The coals of the western fields of the United States are somewhat different from those of the eastern fields in that they show greater variation in rank within a single field. By rank is meant the particular stage which a coal has reached in its change from lignite to anthracite. Rank, then, has reference to the relative value of the coal substance itself, without any consideration of the impurities, such as water, ash, and sulphur, which so commonly occur in coals and detract from their effectiveness and value.

The explanation of the great variation in the rank of coal in western fields is to be found in the facts that they are relatively young, at least as compared with the coals of the East, and that they occur generally in or adjacent to mountainous regions in which the earth's crust has been greatly deformed by movements of various sorts, and the pressure that produced such movements has locally affected the coal, driving off its more volatile constituents and leaving it of higher rank. As these movements may be very local in their effect, so the resulting high-rank coal may be and generally is found in close proximity to the mountains, and lower-rank coal occurs at a distance from them. This fact was early recognized in the great Yampa field, of which the Twentymile Park district is only a small part, and development was begun at the extreme east end, where the coals had evidently been affected by the uplift of the Park Range. It was recognized that farther west the coal is somewhat inferior in quality, but it is still a question whether this change in rank or quality is regular from east to west or whether it may not have been affected by local conditions and hence show irregularity and apparent inconsistencies. As this question can not be answered at the present time, it is generally assumed that the change is gradual and regular.

COMPARATIVE HEATING VALUE OF THE COAL.

In a general way the real test of the value of a coal is the amount of heat it will produce. This is shown in the analyses under the heading "Heating value (British thermal units)." A British thermal unit is the amount of heat required to raise the temperature of 1 pound of water 1° Fahrenheit at the point of maximum density. Thus 1 pound of the coal of this district is sufficient to raise the temperature of 11,000 to 14,000 pounds of water 1° Fahrenheit, the quantity depending upon the efficiency of the coal. In using the table of analyses the heating value in the two forms A and C should be considered. The British thermal units in the C form show the heating power of the coal itself, free from all impurities, such as water and ash, whereas the British thermal units in the A form show the heating power of the coal as it comes out of the mine and approximately as it reaches the consumer.

Figure 9 shows graphically the heating value of the Twentymile Park coals in the two forms. From this diagram it is apparent that there is less variation in the heating values in the pure-coal form than in the other. This means that the coals are intrinsically much alike, but that as they are mined certain coals have a greater percentage of moisture or ash than other coals.

Intrinsically the best coal is the No. 1 bed, first worked by the Moffat Coal Co. at Oak Hill, and the poorest coal is from the Wadge bed in mine No. 3 at McGregor, where the poor showing of the coal may be due to weathering, as the coal is under very slight cover. The best coal is from beds of the lower group, represented by Nos. 12, 13, 14, 10, and 11, Figure 9, and becoming slightly poorer in quality from Oak Creek westward. The Wolf Creek and Wadge beds make the best showing at Mount Harris and become poorer to the south

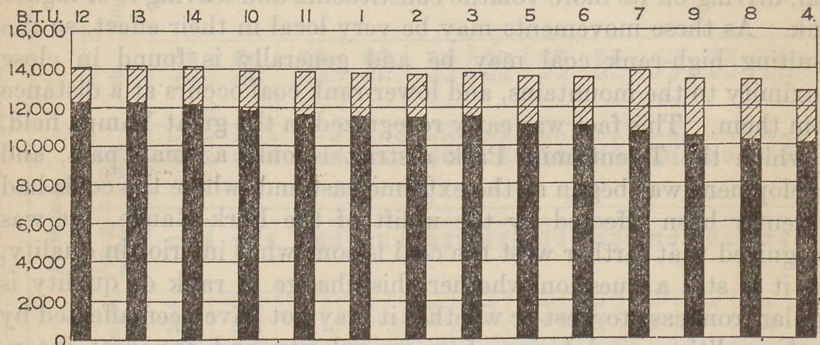

FIGURE 9.—Graph showing the comparative heating values of the Twentymile Park coals. The ruled part of the diagram shows the heating value in the pure-coal form, and the solid black that of the coal in the mine. Figures at the top refer to corresponding numbers in the table of analyses.

and east, with the poorest showing at McGregor, which may be largely due to the slight cover overlying each bed.

In the coal "as mined" that from the lower beds takes the lead, the better quality being found on Oak Creek and the poorer at the Bear River mine and on Indian Creek. The coal beds of the middle group make the best showing at Mount Harris, where the Wadge bed, on account of its relative freedom from ash, is superior to the Wolf Creek bed. The coal in these beds becomes poorer from Mount Harris toward the south and east, and the Wolf Creek is decidedly inferior to the Wadge except in mine No. 3 at McGregor, where, as previously stated, the coal is probably weathered.

The difference in heating value between the best coal (No. 12, 12,220 British thermal units) and the poorest (No. 4, 10,110 British thermal units) is 2,110 British thermal units. In other words, if Oak Creek coal is selling for $5 a ton, coal from mine No. 3 at McGregor would be worth only $4.14 a ton.

The diagram is interesting also in showing the extent to which the moisture and ash reduce the heating value of each coal. If the pure coal is considered 100 per cent efficient, the coal as mined has the following percentages: Oak Creek coals (Nos. 12, 13, and 14), 87 per cent; Bear River and Routt-Pinnacle coal (Nos. 10 and 11), 83 per cent; coal from the Wadge bed at Mount Harris (Nos. 1, 2, and 3), 83½ per cent; Wadge coal bed at Chergo mine (No. 5), 81½ per cent; Wadge coal in Dunkley Canyon (No. 6), 80⅗ per cent; Wadge coal in mine No. 3 at McGregor (No. 4), 80 per cent; coal from Wolf Creek bed at McGregor (No. 8), 80 per cent; Wolf Creek coal at Mount

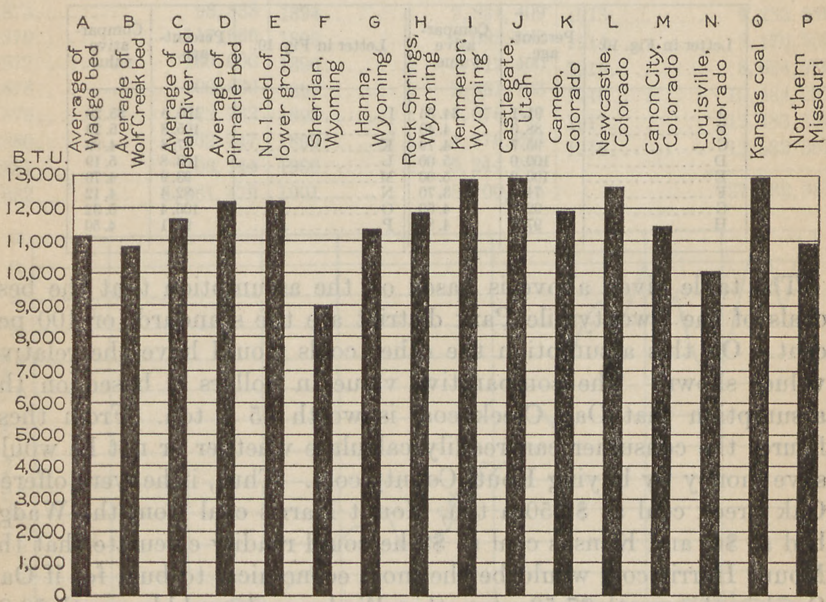

FIGURE 10.—Heating value of Twentymile Park coal "as received," in British thermal units, compared with that of adjacent fields with which this coal may come into competition. (See table of analyses.)

Harris (No. 7), 78⅗ per cent; and Wolf Creek coal on Elk Creek (No. 9), 78⅓ per cent.

As the table of analyses gives the composition and heating value of typical coals of districts or fields in adjacent States with which Routt County coal may have to compete, it is possible to determine their comparative values so far as these values are dependent upon chemical composition. As most coals are used for the generation of heat, a comparison of their heating value expressed in British thermal units will be most helpful. This is given in the table of analyses, but it is expressed graphically in Figure 10, in which the height of the block represents the heating value. This diagram shows four coals that are superior to any coal in Routt County so far mined. These are coals from Kemmerer, Wyo., Castlegate, Utah, and southeastern

Kansas, which are so nearly the same in heating value, approaching 13,000 British thermal units in the coal as it comes from the mine, that they may be considered equivalent, and the Newcastle coal of Colorado, which is better than Routt County coal but yet not equal to the coals just mentioned. The coals from Hanna, Wyo., Rock Springs, Wyo., Cameo, Colo., Canon City, Colo., and northern Missouri are about equal in heating value to the Routt County coals, and those from Louisville, Colo., and Sheridan, Wyo., are distinctly inferior.

Comparative value of Routt County coals and coals of other fields with which Routt County coals may have to compete.

Letter in Fig. 10.	Percentage.	Comparative value.	Letter in Fig. 10.	Percentage.	Comparative value.
A	91.1	$4.56	I	105.6	$5.28
B	88.0	4.40	J	105.8	5.29
C	95.7	4.79	K	97.8	4.89
D	100.0	5.00	L	103.8	5.19
E	100.0	5.00	M	93.9	4.70
F	74.0	3.70	N	82.4	4.12
G	92.1	4.60	O	106.4	5.32
H	97.3	4.86	P	90.1	4.50

The table given above is based on the assumption that the best coals of the Twentymile Park district are the standard, or 100 per cent. On this assumption the other coals would have the relative values shown. The comparative value in dollars is based on the assumption that Oak Creek coal is worth $5 a ton. From these figures the consumer can readily calculate whether or not he would save money by buying Routt County coal. Thus, if he were offered Oak Creek coal at $7.50 a ton, Mount Harris coal from the Wadge bed at $6, and Kansas coal at $8 he could readily calculate that the Mount Harris coal would be the most economical to buy, for if Oak Creek coal is worth $7.50 a ton, then Wadge coal would be worth $6.84 and Kansas coal $7.98. If he could buy Wadge coal for $6 when it is worth $6.84 it surely would be economy to do so, unless some factor other than heating value entered into his problem. The sooty character of some coals is a great detriment to them for domestic use, for they not only soil the hands, but all cooking utensils that come into direct contact with the flame are coated with an oily soot that is very objectionable. The Routt County coals, although not able to produce as much heat as some other coals, are very well adapted, on account of their blocky character and their freedom from soot, to domestic use.

PRODUCTION OF COAL.

Coal has been mined in Colorado for at least three-quarters of a century, the records of production reaching back to 1864, or 12 years before Colorado became a State. The production for the State as given in Mineral Resources of the United States for 1918 is as follows:

Coal produced in Colorado, 1864–1918.

	Short tons.		Short tons.		Short tons.
1864	500	1883	1, 229, 593	1902	7, 401, 343
1865	1, 200	1884	1, 130, 024	1903	7, 423, 602
1866	6, 400	1885	1, 356, 062	1904	6, 656, 355
1867	17, 000	1886	1, 368, 338	1905	8, 826, 429
1868	10, 500	1887	1, 791, 735	1906	10, 111, 218
1869	8, 000	1888	2, 185, 477	1907	10, 790, 236
1870	4, 500	1889	2, 597, 181	1908	9, 634, 973
1871	15, 600	1890	3, 077, 003	1909	10, 716, 936
1872	68, 540	1891	3, 512, 632	1910	11, 973, 736
1873	69, 997	1892	3, 510, 830	1911	10, 157, 383
1874	77, 372	1893	4, 102, 389	1912	10, 977, 824
1875	98, 838	1894	2, 831, 409	1913	9, 232, 510
1876	117, 666	1895	3, 082, 982	1914	8, 170, 559
1877	160, 000	1896	3, 112, 400	1915	8, 624, 980
1878	200, 630	1897	3, 361, 703	1916	10, 484, 237
1879	322, 732	1898	4, 076, 347	1917	12, 483, 336
1880	462, 747	1899	4, 776, 224	1918	12, 532, 381
1881	706, 744	1900	5, 244, 264		
1882	1, 061, 479	1901	5, 700, 015		227, 532, 381

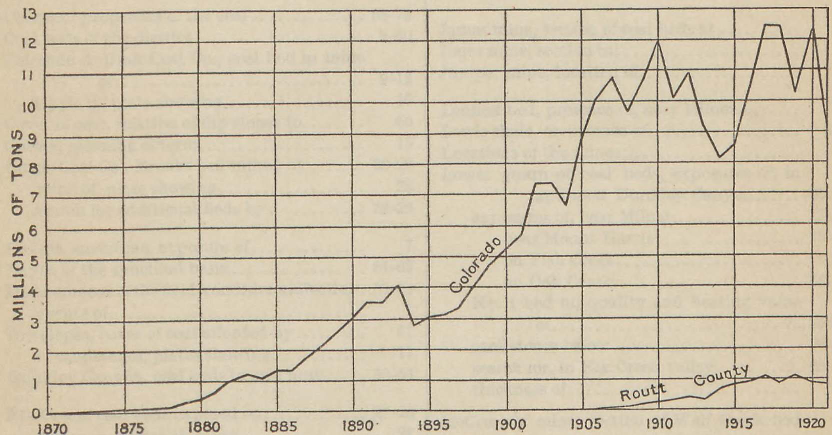

FIGURE 11.—Graph showing production of coal in Colorado, 1870-1918, and in Routt County, 1906-1918.

The production of Routt County, as compared with the total production of the State, is small indeed. Routt County is the latest county to become a commercial producer, as mining dates back only to the completion of the "Moffat road." Its record is as follows:

Coal produced in Routt County, Colo., 1906–1918, in short tons.

1906	5, 297	1911	317, 719	1916	915, 028
1907	5, 690	1912	448, 261	1917	1, 074, 103
1908	13, 005	1913	334, 961	1918	687, 609
1909	92, 439	1914	666, 384		
1910	258, 452	1915	862, 315		5, 681, 335

The production of Routt County, as compared with that of the entire State, is shown graphically in Figure 11. In 1918 Routt County was fourth in the list of coal-producing counties, being exceeded only by Las Animas, Huerfano, and Boulder counties.

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Note.–Outcrops of coal beds shown by solid lines where well determined; by broken lines where uncertain. Sandstone cliffs indicated by hachures; outcrops not characterized by cliffs are indicated by dotted lines; and broad expanses of sandstone at the surface by stippled pattern. Geologic structure is indicated by anticlinal and synclinal axes and faults: *U*, upthrow side of fault; *D*, downthrow. Numbers indicate localities at which coal beds are exposed

MAP OF TWENTYMILE PARK DISTRICT, ROUTT COUNTY, COLO., SHOWING OUTCROPS OF COAL, PRINCIPAL SANDSTONE BEDS, AND GEOLOGIC STRUCTURE

By Marius R. Campbell

Scale $\frac{1}{62{,}500}$

1 ½ 0 1 2 3 4 Miles

1923