THE POWDER RIVER COAL FIELD, WYOMING, ADJACENT TO THE BURLINGTON RAILROAD.

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INTRODUCTION.

The present report is a preliminary statement prepared at the close of the field season, to give advance information concerning the coal resources of a portion of the Powder River coal field, in northeastern Wyoming, adjacent to the Chicago, Burlington and Quincy Railroad.

The Powder River coal field is a small part of a large area of coal-bearing rocks, known as the Northern Great Plains Province. Beginning at Casper and Douglas, on North Platte River, in Wyoming, this province extends northward between the Black Hills and Bighorn Mountains, occupies the eastern part of Montana and all the western half of North Dakota, and reaches into Canada. The examination of that part of the province which lies in Wyoming alone is a matter of several years' work. In 1907 a Geological Survey party under J. A. Taff surveyed the Sheridan district, and another under E. W. Shaw examined the south end of the province between Douglas and Casper. In 1908 H. S. Gale surveyed a field in the vicinity of Buffalo and Trabing and the writers examined a block of townships along the Burlington Railroad, adjoining the areas covered by Taff and Gale, and extending to the eastern limit of the coal field.

The area described in this paper lies between Clearmont and Rozet. It has an east-west length of 60 miles and an average width of over 20 miles. It includes practically 1,400 square miles, or 39 townships.

The primary purpose of the investigation was to determine the amount of land underlain by workable coal beds and to locate the eastern limit of the coal field. The writers were assisted by F. D. Morrison and C. M. Holmes, jr., who, in addition to their duties as camp hands, rendered considerable service in making compass traverses, collecting fossils and coal samples, and assisting in the topographic work.

The region under discussion was surveyed by the General Land Office in 1883, but practically no section corners bearing evidence of having been set during the original survey could be found. Under these conditions it was useless to follow section lines, and on account of the rough character of the country it was impossible to travel in straight courses and to measure distances by pacing; therefore a 2½-mile base line was measured on the Powder River flat, 6 miles north of Arvada, a system of triangulation on prominent buttes was developed, and a topographic map of a part of the area, on a scale of a mile to the inch, was made by the use of 15-inch plane tables and open-sight alidades. A little less than half of the total area, or between 600 and 700 square miles, was mapped in this way. The meandering course of Powder River above Arvada was mapped by a foot and compass traverse. The outcrops of the principal coal beds were sketched with the topography. A profile of the Burlington Railroad, Geological Survey bench marks along Clear Creek, and aneroid-barometer readings were used for vertical control.

LOCATION AND COMMERCIAL RELATION.

The geographic position and outline of the district are shown on the index map (Pl. VIII), which also shows its more general geographic relations.

The Burlington Railroad is the only line at present crossing the Powder River coal field in northeastern Wyoming. The construction of a railroad down Powder River to the Yellowstone is feasible, and such a road would make a much larger part of the coal field readily accessible. Thirty-nine townships lying along or close to the railroad, and therefore more readily accessible and open to development whenever a demand arises for this coal, were selected for examination by the writers in 1908 and constitute the area described in this paper.

Settlers are few in this country because of the scarcity of water. The principal occupation is cattle and sheep raising. Gillette, Arvada, and Clearmont, the only villages, have a total population of about 500. Gillette is the largest, with about 300 people, and Arvada is the smallest, its population numbering between 50 and 75. Aside from these villages on the railroad, settlement is confined to the valleys of the main streams, the most desirable land lying along Crazy Woman and Clear creeks and Powder River. These streams are perennial, but all the others in the area are intermittent, flowing only about three months in the year. Along the intermittent streams windmills are used commonly for pumping water from deep wells for both stock and domestic use. The Burlington Railroad pumps water from deep wells at Felix and Gillette to supply its locomotives and section men. It is a common practice among the ranchers to store ice for drinking water during the summer, as the ice water contains much less alkali and sediment than the normal stream flow.

Timber is scarce in this area, being limited almost entirely to cottonwood along the main stream courses and to scattering pine and cedar in the hills.

TOPOGRAPHY.

The Powder River coal field lies in the Great Plains province, between the Bighorn Mountains and the Black Hills. Much of it is so deeply dissected that the original plains character is suggested and represented now only by the crests of the main ridges, which are all at about the same elevation. The topography of the region between Clearmont and Oriva is mainly of the badland type, especially close to the main streams, but there are small areas of more gentle relief in Tps. 54 and 55 N., R. 76 W. Vegetation is scanty and when rain falls numerous rivulets form, each carving a channel in the soft clay or sand. The result is an intricately dissected and irregular surface over which it is difficult to travel. East of Oriva the topography is in large part of moderate relief, although there are some areas of extreme dissection.

In the badland areas bare slopes are everywhere conspicuous. From elevated points in these areas one sees innumerable steep-sided ridges, buttes, domes, precipitous bluffs, and, in places of recent sharp dissection, pinnacles capping the ridges and old valley bottoms dissected by vertical-walled coulées.

In some parts of the area the coal beds are burned along the outcrop, the overlying clay being baked to a resistant mass that forms ledges in the steep sides and caps small mesas and numerous detached buttes.

The areas of more gentle topography are grass-covered and prairie-like and exposures of bed rock are much less common in them than in the badland areas.

The altitude of the region ranges from about 3,600 feet above sea level on Powder River at the mouth of Clear Creek to about 4,900 feet on the hilltops in the divide near Sparta, west of Gillette.

GEOLOGY.

The rocks of this area consist of a series of clay, shale, sandstone, and coal beds, alternately stratified, apparently conformable throughout, and belonging to the Fort Union formation. In the Sheridan field the formation was divided by Taff on lithologic grounds into a lower member, consisting of 2,500 to 2,800 feet of dull-drab, bluish, and brown shale, and an upper member, consisting of 2,200 feet of bluish and brownish shales and sandstones interstratified with many coal beds. He also subdivided the upper member into the Tongue

River, Intermediate, and Ulm coal groups, and this grouping will be followed in the present paper for convenience of description.

The lower member is exposed in this area only east of the line of burned rock extending north and south through Minturn and marking the eastern limit of the coal field. These beds are essentially all clay or shale and are prevailingly light colored. They contain bands of dull red and brown beds which, where weathered and washed down, may mask the lighter beds and give a dull color to the whole. These beds also contain numerous nodular concretions ranging up to several feet in length, which, because of their iron content, on weathering become yellow or rusty to dark brown. In clean-washed slopes these nodules make conspicuous dark spots in the light-colored clay; on deeply weathered slopes where the nodules are abundant and disintegrated to granular fragments they give a dark tone to the surface.

The thickness of the lower member in this area is not readily measurable, but may approximate 1,000 feet. The member contains two or three coal beds less than a foot thick.

Above these beds is a series of clay, sandstone, and coal beds called by Taff the Tongue River coal group, from their occurrence on that stream. At the type locality the group is about 800 feet thick and contains seven workable coal beds. In the Powder River field the group outcrops between Minturn and Gillette in a north-south belt, but it is so tilted and burned that its thickness can not be measured. A portion of the coal group is exposed also on Powder River, 6 to 10 miles below Arvada. Between the lowest rocks on Powder River at the state line and the highest beds of the group is an interval of 575 feet, containing at least five coal beds. As the base of the group is under cover at the state line the total thickness was not determined.

On Tongue River the sequence of coal beds is as follows:

Coal beds of the Tongue River coal group.

	Feet.
Roland coal bed (variable)	13
Interval	125
Smith coal bed (variable)	5
Interval	210
Dietz No. 1 bed	8
Interval	100
Dietz No. 2 bed	8
Interval	100
Dietz No. 3 bed (variable)	12
Blue shale, etc	120
Monarch coal bed	18–32
Interval	86
Carney coal bed	12–17

The clay beds of the Tongue River coal group vary from light fine-textured material to dark coaly shale on the one hand and to sandy shale on the other. The sand is in general only slightly consolidated and for the most part is light colored, white or slightly iron stained, giving to the coal group the name "yellow beds." In places the sand is cemented by iron or lime and forms ledges. The beds of sand vary in thickness from mere streaks to great masses measuring from 40 to 100 feet. Cross-bedding is common, but grits are rarely found. Owing to the horizontal position of the beds and the numerous large bare exposures in the badlands along the river, the thick beds of white sand can be traced with the eye for miles.

The Intermediate coal group, which is described by Taff as having a thickness of 1,150 feet in the Sheridan district and extending from the Roland coal bed up to the Lower Ulm coal bed, in this district seems to be about 900 feet thick. Sand and clay, with less abundant beds of shale, compose the group. It is more sandy in the lower than in the upper half. Bands of brown carbonaceous shale are scattered throughout, being the more numerous perhaps in the upper part. A conspicuous feature of the lower part of the group is a fossil shell bed which occurs about 175 feet above the Roland coal bed and which is so continuous and so readily seen as to make an excellent horizon marker. Above this shell bed, in places resting on it and elsewhere separated from it by 30 to 40 feet of sand, is a workable bed of coal. This is the lower coal of the two workable beds found in the group in this area. It is called the Arvada coal bed, from its occurrence at that place. The other is the Felix coal bed, which occurs about 350 feet higher in the section and has been mined at Felix, Echeta, and Croton, on Wildhorse Creek.

The Ulm coal group comprises the highest beds in the Powder River field. Its base is marked by a bed of coal which is widely distributed and which is found about 350 feet above the Felix coal bed. In the Sheridan district erosion has largely removed this bed and in the Powder River field it is found only in the highest hills, where it has been extensively burned along its outcrop. That part of the group which has not been eroded is nearly all white sand and is about 150 feet thick. Bands of carbonaceous shale, which may represent the horizon of the Upper Ulm coal bed, cap the geologic section in this district.

Baked shale and clay, made bright red by the burning of an underlying coal bed, occur at the various coal horizons in nearly all parts of the field.

Collections of fossil plants and shells made in this and adjoining districts have been examined by F. H. Knowlton and T. W. Stanton, who agree that the beds from which the fossils were obtained are of Fort Union age. This determination makes the age of the coal-bearing rocks basal Tertiary, or, more definitely, lower Eocene.

The geologic structure of the region is extremely simple. As has been described and figured by Darton,[a] the country between the Bighorn Mountains and the Black Hills is a shallow structural trough having a steep western rim. In this rim the rocks dip sharply away from the Bighorn Mountains, but in the vicinity of Clearmont they are practically horizontal. The beds lie flat through the Powder River and Wildhorse Creek country, but begin to dip slightly to the west near Oriva. From this point eastward to Minturn the dip increases to a maximum of about 2° and flattens again near Rozet. The westward dip near Gillette is sufficient to bring the Tongue River coal group to the surface within a short distance. This slight monocline, near Gillette, strikes nearly north and south and determines the eastern limit of the coal field. Besides the main structural features there are minor warpings of the strata, but the vertical control of the map work was not of sufficient accuracy nor the plan of the work detailed enough to determine the amount or extent of the irregularities. One of the most conspicuous of the minor features is a low wave in the structure at the mouth of Twentymile Creek, just east of Echeta.

THE COAL.

DESCRIPTION OF COAL BEDS.

GENERAL OUTLINE.

In a brief preliminary report it is not possible to offer all the details of the geologic section or to give a large number of close measurements of coal beds. Neither is it possible to state with definiteness the correlation of certain features throughout the area described or their relation to adjoining areas. For this reason the statements which follow are in part somewhat generalized. They are intended to give the conclusions concerning the area and a fair amount of the data on which the conclusions are based. The accompanying map (Pl. VIII) showing the distribution of the coal beds was reduced from the original map, contour lines being omitted. In a subsequent report, prepared after the material in hand has been more thoroughly studied, it will be possible to give more details of the numerous coal beds and to discuss scientific questions.

The principal coal beds in this area are five or more in number. They are generally free from partings of clay or shale and are of considerable known extent. The field work of 1908 was done under the coal-land classification schedule, which considered subbituminous coal less than 4 feet thick as nonworkable. Although it is possible that beds of coal less than 4 feet thick may be mined in this field in the distant future, the distribution of beds of much greater thickness is so widespread that those less than 4 feet thick were not mapped.

[a] Prof. Paper U. S. Geol. Survey No. 32, 1905.

The beds of coal which will be described are as follows:

Principal coal beds in Powder River field.

	Feet.
Lower Ulm or Healy coal bed	10- 15
Interval	300
Felix coal bed	6- 30
Interval	375-400
Arvada coal bed	5- 10
Interval	125-225
Roland coal bed	3- 7
Interval	80
Smith coal bed	4- 10

Besides the coal beds named above, there are numerous other beds of coal distributed throughout the geologic section above described. They range from a few inches to several feet in thickness, but the thicker beds are of small geographic extent.

The description of the coal beds will begin with the lowest in the geologic column exposed in this area and give briefly the character of the bed, its extent, and the points where it is well exposed.

SMITH COAL BED.

A coal bed which outcrops at or just above water level along the lower course of Clear Creek is believed to be the same as the Smith coal bed of the Sheridan field, described by Taff as occurring about 560 feet above the well-known Monarch coal bed. The best exposures of this bed are in the cut banks of Clear Creek in the northern part of T. 55 N., R. 78 W., where it has an almost constant thickness of 10 feet of clean coal. An analysis of a sample (No. 6460) cut from a fresh face in the creek bank (No. 2)[a] in the NW. ¼ NW. ¼ sec. 12, T. 55 N., R. 78 W., is given in the table on page 133. A coal bed at about the same horizon occurring about 75 feet above Powder River at the northwest corner of sec. 2, T. 55 N., R. 77 W., near the Lynn ranch has a thickness of 4 feet 3 inches. The outcrop of this bed along Powder River is not shown on the map.

Because of the practically horizontal position of the rocks and the fact that this coal is near water level in the lowest part of the district, it is readily seen that if this bed is continuous it must underlie the entire coal area of this field.

ROLAND COAL BED.

A coal bed at the top of the Tongue River coal group, described by Taff as having a thickness of 13 feet in the Sheridan district but diminishing to 2 feet toward the south, was called by him the Roland coal. A coal bed in the Powder River field having about the same geologic position, 150 feet below a conspicuous bed of fossil shells,

[a] Numbers in parentheses refer to locations on the map (Pl. VIII).

will be described here as the same coal bed. It is conspicuously exposed in the bank of Powder River at water level by the schoolhouse near David Campbell's (No. 5), in sec. 22, T. 55 N., R. 77 W., about 6 miles north of Arvada. Here it has a thickness of 7 feet, which it probably maintains for some distance, as it is 7 feet thick near the Lynn ranch on Powder River at the north edge of the same township. On Joe Creek just south of the township line (No. 7) in T. 55 N., R. 76 W., the Roland coal bed, lying beneath 20 to 30 feet of massive buff sandstone, is in two benches, the upper one 7 feet 8 inches thick and the lower one 2 feet 3 inches thick, separated by 3 feet of gray clay and shale.

On Clear Creek in sec. 31, T. 56 N., R. 77 W., in the hills north of the Culture ranch, what is believed to be the same bed has a thickness of 3 feet 8 inches, including a 6-inch parting of brown shale. The outcrop of this bed on Clear Creek is not shown on the map. As this coal bed passes beneath the river at Campbell's, the outcrop in the area here described is of small extent. The bed certainly is worthy of some consideration on Powder River, but whether it is of workable thickness for any great distance where deeply buried is a question which can not be answered until the area has been prospected by the drill.

ARVADA COAL BED.

The name Arvada is given to a coal bed in the lower part of the Intermediate coal group which has been mined on a small scale at Arvada, on Powder River. About 1 mile above Arvada this coal is at water level, and on Wildhorse Creek it disappears at the junction of the middle and south forks. It outcrops for a number of miles on Clear Creek, going below water level at the railroad bridge west of Cadiz. This coal bed is readily recognized by the occurrence beneath it of a bed of gray sandstone carrying an abundance of large and small gasteropods and a unio. It varies in thickness up to 12 feet, and is so much harder than the rock above and below that it is exposed as a ledge or breaks up into a talus of solid blocks. Usually the shells can be found in the soil or in the stream beds just below the outcrop. In some places the Arvada coal bed rests directly on the fossil bed, but in others the two are separated by 20 to 40 feet of sandstone.

Half a mile south of Arvada, where the coal bed has been mined in the bank of the river (No. 9), it has a thickness of 10 feet 8 inches. This is all clean coal, with the exception of mere streaks of mineral charcoal. The upper half is thin bedded and the lower half blocky. At Campbell's ranch, 6 miles north of Arvada (No. 6), the coal bed is from 6 feet 6 inches to 7 feet 6 inches thick, and at Lynn's, 4 miles farther down the river (No. 4), it measures 9 feet 9 inches. At Lynn's the coal is over 300 feet above the river and at Campbell's from 230 to 250 feet above the river. In a draw 1 mile below Davis ford, on the west side of Clear Creek (No. 1), in sec. 3, T. 55 N., R. 78 W., the Arvada coal bed has been dug by ranchers from the outcrop in the bank of a small tributary. The section of the coal bed at this point is as follows:

Section of Arvada coal bed near Davis ford (No. 1), sec. 3, T. 55 N., R. 78 W.

	Ft.	in.
Coal	9	
Shale, brown carbonaceous	2	
Coal	2	6
	13	6

The coal here is separated from the fossiliferous sandstone below by 3 feet of brown shale.

J. N. Sweat has opened a mine on this coal bed in a ravine 1½ miles north of Kendrick (No. 3), in the NE. ¼ sec. 13, T. 55 N., R. 78 W. Here the bed averages 9 feet in thickness and is free from partings other than a half-inch streak of mineral charcoal.

The record of a well drilled at Gillette by the Burlington Railroad shows at a depth of 350 feet a coal bed reported to be 55 feet thick. The writers believe that this bed is at about the same geologic position as the Arvada coal, but question whether its thickness is so great as stated. It is likely that there is coal of considerable thickness, but it is probable that a part of the bed is brown shale; at least the evidence afforded by sand pumpings from a churn drill is not wholly conclusive.

From the character of the Arvada coal bed on Clear Creek, Powder River, and Wildhorse Creek, it may be concluded with some certainty that this bed underlies a considerable part of the area mapped and that it is of workable thickness.

Samples of the Arvada coal were taken at the Sweat mine (No. 6798) near Kendrick (No. 3), and at the Arvada mine (No. 9). At the latter point two samples were taken, one (No. 6459) representing the whole bed, and the other (No. 6461) representing the lower half or blocky part of the bed. Analyses are given on page 133.

FELIX COAL BED.

At Felix, a station on the Burlington Railroad near the head of Wildhorse Creek, a thick bed of coal is conspicuously exposed both on the main stream and in a draw on the north. Being close to the railroad it attracted attention and a mine was opened here a dozen or more years ago. It will be called in this report the Felix coal bed, as this is probably the first place in the region where the bed was worked.

The position of the Felix coal bed is about 375 to 400 feet above the Arvada coal bed, or near the middle of the Intermediate coal group. East of Powder River it is for the most part 10 feet or more thick, is readily found in natural exposures in many coulées, and where burned is traced without difficulty by the red baked clay. Like the other beds of workable thickness in this area it consists of solid coal practically free from partings.

An exposure of this coal bed in the bank of Wildhorse Creek, one-third mile below Felix (No. 20) has an apparent thickness of 40 to 50 feet. That this is the result of a slip was proved by a drift at the base running through the coal into clay. The bed at this point is actually about 16 feet thick. A small mine was opened here and operated for a short time. On the first tributary of Wildhorse Creek entering from the north below Felix this bed is exposed at two or three points and is between 20 and 25 feet thick. The outcrop is maintained at water level for some distance by a slight westerly dip of the rocks.

The easternmost occurrence of the Felix coal bed in this area is at Gillette. Here the rise of the rocks brings the bed to the surface and carries it above the plains to the east. The coal is mined 1 mile west of town by W. F. Vines. The section at his mine is as follows:

Section of Felix coal bed at the Vines mine, Gillette.

	Ft.	in.
Coal, with clay bands up to 1 foot thick	9	10
Shale and clay	1	6
Coal	1	
Clay, drab	5	
Shale, bituminous		8
Coal, clean and solid	7	6
	25	6

Seven miles due south of Gillette on the west side of the road (No. 27) in sec. 34, T. 49 N., R. 72 W., the Felix coal bed, exposed in natural outcrop and also partly excavated, has a thickness of 22 feet, the upper 7 feet containing thin bands of shale. Where this bed crosses Caballo Creek, 7 miles farther south (No. 28), a thickness of 6 feet 8 inches of coal is exposed in the creek bank. The bottom of the bed is not visible.

B. H. Barker mines the Felix coal bed in a ravine about 2½ miles northwest of Gillette (No. 26), where it has the following section:

Section of Felix coal bed at Barker mine (No. 26).

	Feet.
Coal	13
Clay, carbonaceous	4
Coal	9
	26

The analysis of a sample taken in this mine about 150 feet from the surface is given (No. 6542) in the table on page 133. West of the Barker mine, on the head of Rawhide Creek, the bed is somewhat thicker. An exposure in the draw 2 to 3 miles north of Sparta is as follows (No. 24):

Section of Felix coal bed near Sparta (No. 24).

	Ft.	in.
Coal	14	
Clay, carbonaceous		3
Coal, woody structure, poor	2	
Shale and clay, carbonaceous	5	6
Coal	9	
	30	9

On a branch of Rawhide Creek 3 miles northeast of Oriva (No. 23) the Felix coal bed is in two benches, but shows some variations from the section last given.

Section of Felix coal bed northeast of Oriva (No. 23).

	Ft.	in.
Coal	13	
Shale and clay, carbonaceous	4	3
Coal, woody structure, poor	2	
Shale and clay, carbonaceous		4
Coal	8	
	27	7

In the vicinity of Echeta the thick Felix coal bed is contained in massive white sandstone. Talus from the sandstone above, which is readily traced for miles, commonly conceals the coal. Good exposures at wide intervals show that the coal bed maintains a considerable thickness over a large area in this part of the district. On Twentymile Creek, near the E. W. Haines ranch (No. 17), in sec. 18, T. 52 N., R. 74 W., the bed is well exposed and shows a clean face of 19 feet of coal with only three partings of clay, each less than 1 inch thick.

At Echeta the Felix coal bed has the greatest thickness seen in the district. In a ravine one-fourth mile west of the railroad station (No. 18) the bed is well exposed, one of the side gulches being wholly in the coal. Here the total thickness of the bed, which is free from partings, is fully 30 feet. An entry has been driven 60 feet on the coal. A sample taken at the face of the entry, including about 8 feet of the middle of the bed, gave the results (No. 6448) shown in the table of analyses, page 133.

The Martin mine was opened on the Felix coal bed at Croton (No. 16) in 1902. Its development, however, never extended beyond a single drift without rooms. The bed at this point is 11 feet thick and the quality of coal is shown in analysis No. 6432 on page 133. In the hills north of Croton, reached by a rough road from Whittenmeyer's ranch, this coal bed is exposed in a number of coulées (No. 15) and ranges in thickness from 12 to 14 feet. It is overlain by about 50 feet of white sandstone and underlain by 20 feet of similar material. On the north side of the ridge between the south and middle forks of Wildhorse Creek (No. 14), in sec. 36, T. 54 N., R. 76 W., this bed has a thickness of over 16 feet, but in the hills between the middle and north forks and in T. 55 N., R. 76 W., it is commonly from 4 to 6 feet thick. It is exposed at the road gaps in secs. 22 and 28 (No. 8), T. 55 N., R. 76 W., in the midst of a considerable thickness of brown shale, and in each place is 6 feet thick.

About 4 miles southeast of Arvada, in the hills behind Tinkham Butte (No. 10), the Felix coal bed is 10 feet thick without partings, and farther south, in the hills west of Lorah's ranch, 1 mile below the mouth of Crazy Woman Creek (No. 12), it measures 9 feet 6 inches. Here the massive yellowish-white sandstone commonly occurring above the coal is separated from it by 23 feet of drab clay. Near Pendergraft's ranch, on the west bank of Powder River 2 miles above the mouth of Crazy Woman Creek, the bed is much thinner.

Section of Felix coal bed near Pendergraft's ranch.

	Ft.	in.
Coal	4	10
Shale, carbonaceous		3
Coal		2
	5	3

On the east side of Powder River, however, about 1 mile above the mouth of Fortification Creek, the following section was measured:

Section of coal bed above Fortification Creek.

	Ft.	in.
Coal	2	2
Clay, drab	4	2
Coal	5	5
Shale, carbonaceous	1	2
Coal, part blocky	5	
Clay, drab		3
Coal	1	1
	19	3

A little farther south, about one-fourth mile east of the river, on the east side of sec. 29, T. 52 N., R. 77 W., the same bed shows 9 feet 6 inches of clean coal; and still farther south, on the east bank of the river in sec. 32, the section is as follows:

Section of Felix coal bed in sec. 32, T. 52 N., R. 77 W.

	Ft.	in.
Sandstone, gritty.		
Coal	3	
Shale, carbonaceous	1	
Coal	1	
Shale, carbonaceous	2	
Coal	4	3
	11	3

These sections show that the Felix coal bed near the Pendergraft ranch varies considerably in thickness. East of the mouth of Crazy Woman Creek the bed shows 9 feet of coal in clean exposure in the coulées a mile or more back from the river.

West of Powder River, in the valley of Crazy Woman Creek, the Felix coal bed is thinner, and where it passes below water level 5 miles above the mouth of the creek it measures 5 feet.

LOWER ULM COAL BED.

The Lower Ulm coal bed is about 400 feet above the Felix coal and is considered by Taff as the basal member of the subdivision which he calls the Ulm coal group. This coal in the Buffalo district is described by Gale as the Healy coal bed.

High in the hills over the greater portion of the area under discussion there is commonly a band of red baked clay which probably indicates the position of the burned outcrop of the Lower Ulm coal bed. In some portions of the area the abundance of baked rock suggests that practically the entire bed has been consumed, but in other portions the burning is limited to the spurs and unburned coal is found at the heads of the draws. The amount of burned material and outcrops of unburned coal indicate that the bed is of considerable thickness and therefore of some value.

This coal bed is not known to occur north of the railroad on the west side of Powder River, but between the railroad and Crazy Woman Creek its position is readily traced by the baked clay. Outcrops of the unburned coal in this locality are few. The best exposure known to the writers is about 8 miles south of Arvada and 3 miles northwest of the schoolhouse near Stott's ranch on Powder River (No. 11). At this point the section of the coal bed is as follows:

Section of Lower Ulm coal bed in sec. 29, T. 53 N., R. 77 W. (No. 11).

	Ft.	in.
Coal	2	6
Shale, carbonaceous	2	
Coal	11	
Shale, carbonaceous	1	
Coal	1	6
	18	

The coal in the upper and lower benches of this section is somewhat dirty and therefore of little value, but that of the 11-foot bench is hard and clean. An analysis of it (No. 6444, p. 134) shows only 3 per cent of ash and less than 7 per cent of moisture when air dried.

In the hills on the west side of T. 52 N., R. 78 W., there is a coal a little over 5 feet thick. This probably corresponds with what is known as the Healy coal in the townships farther west. In the high butte 4 miles southwest of the mouth of Crazy Woman Creek, about 400 feet above the Felix coal, there are two beds of coal separated by 10 feet of clay. The upper bed is 2 feet and the lower one 4 feet thick. Whether these are at the horizon of the Lower Ulm coal bed is a question. It is possible that a thick bed of brown carbonaceous shale occurring about 75 feet below is at the proper horizon for the coal bed under discussion.

East of Powder River the extent and thickness of the Lower Ulm coal bed are well determined by good exposures. Northwest of Croton, in the top of the ridge between Wildhorse and Deer creeks, this coal bed has a thickness of 12 feet 6 inches, and at the head of Deer Creek (No. 13) it was found at one point 10 feet thick and at another 11 feet 3 inches. West of Felix, in the SE. $\frac{1}{4}$ sec. 16, T. 51 N., R. 75 W., in the head of the coulée which drains to the east (No. 19) the Lower Ulm coal bed measures 11 feet 10 inches without partings. South of the last-mentioned locality, probably in sec. 32, T. 51 N., R. 75 W., there are good exposures which show at least 10 feet of coal, and on Caballo Creek east of the 4 J ranch, in the southern part of T. 48 N., R. 74 W., it is at least 8 feet thick.

On the heads of Wildhorse and Rawhide creeks, north of Oriva, the Lower Ulm coal bed is burned extensively and probably only a little of it remains. The baked clay that marks the horizon is so resistant that it forms small mesas and round buttes, which give to the topography of this area an appearance somewhat different from that observed elsewhere in the field. Instead of the badlands which abound along Powder River, the surface here is that of a prairie thickly set with small round buttes, each with a capping of red baked clay. The amount of burning suggests that the coal bed in this locality was thick. Evidence on this point is shown at an outcrop on the east face of the hill 1 mile northeast of Sparta (No. 25):

Section of Lower Ulm coal bed near Sparta (No. 25).

	Ft.	in.
Coal	9	
Shale, brown, woody		2
Coal	10	3
Shale, carbonaceous		5
Coal	6	3
Shale, brown, woody		4
Coal		6
	26	11

This outcrop marks practically the eastern limit of the Lower Ulm coal bed, for the monocline extending north and south brings lower rocks to the surface within a short distance. There are a few outliers farther east, but it is probable that in most of these the coal is burned. Antelope Butte, 8 miles south of Gillette, is capped by baked clay marking the horizon of this coal.

OTHER COAL BEDS.

The eastern limit of the Powder River coal field is determined by a broad irregular belt of baked clay and slag which extends north and south from the railroad in Rs. 71 and 72. The coal beds that have been the source of this burning are exposed at only a few places. Near Minturn a coal bed which has been prospected by Andrew Ditto in the NE. ¼ sec. 2, T. 49 N., R. 71 W., measures as follows:

Section of coal bed and associated rocks near Minturn.

	Ft.	in.
Clay, sandy	15	
Shale, brown, woody, with coal streaks	3	
Clay, drab	4	
Clay, sandy, yellow	3	
Shale, brown, woody, thin coal streaks	19	
Coal	2	6
Shale, brown, woody	1	10
Coal		10
Clay, brown and black	1	
Coal, base of bed not reached	8+	
Total coal	11	4+

It is reported that a prospect sunk 18 feet on this lower bench failed to reach the bottom of the coal.

Nine miles north of Gillette, in the NE. ¼ sec. 10, T. 51 N., R. 72 W., at what is known as the Hulbert mine (No. 22), there is a coal bed similar to the one at Minturn.

Section of coal bed at Hulbert mine (No. 22).

	Feet.
Sandstone, yellowish gray, with lenses of clay, brown	20
Coal and brown shale	6
Coal, good, bottom not reached	22+

Neighboring ranchers obtain fuel here and some has been hauled by wagon to Gillette. An analysis (No. 6602) of a sample taken at this mine is given in the table on page 134.

The following section (No. 21) was measured about 7 miles farther north, at the western edge of the burned area in the NE. ¼ sec. 3, T. 52 N., R. 72 W. It represents the coal bed 2 miles north of John Grant's ranch.

Section of coal bed in sec. 3, T. 52 N., R. 72 W. (No. 21).

	Feet.
Sand and sandstone	10±
Clay, drab	15±
Coal and brown shale	4
Coal, good, black	16
Coal, fair, brownish	5
Clay, yellow	1
Clay, drab	6
Total coal	25

This bed is well exposed in a bluff, and Mr. Grant obtains coal here by prying it from the outcrop with a crowbar.

The three outcrops described above are at the western limit of the slag-covered area. In view of this fact and the similarity of the sections, it seems possible that these are all sections of the same coal bed, but they could not be correlated owing to the lack of exposures.

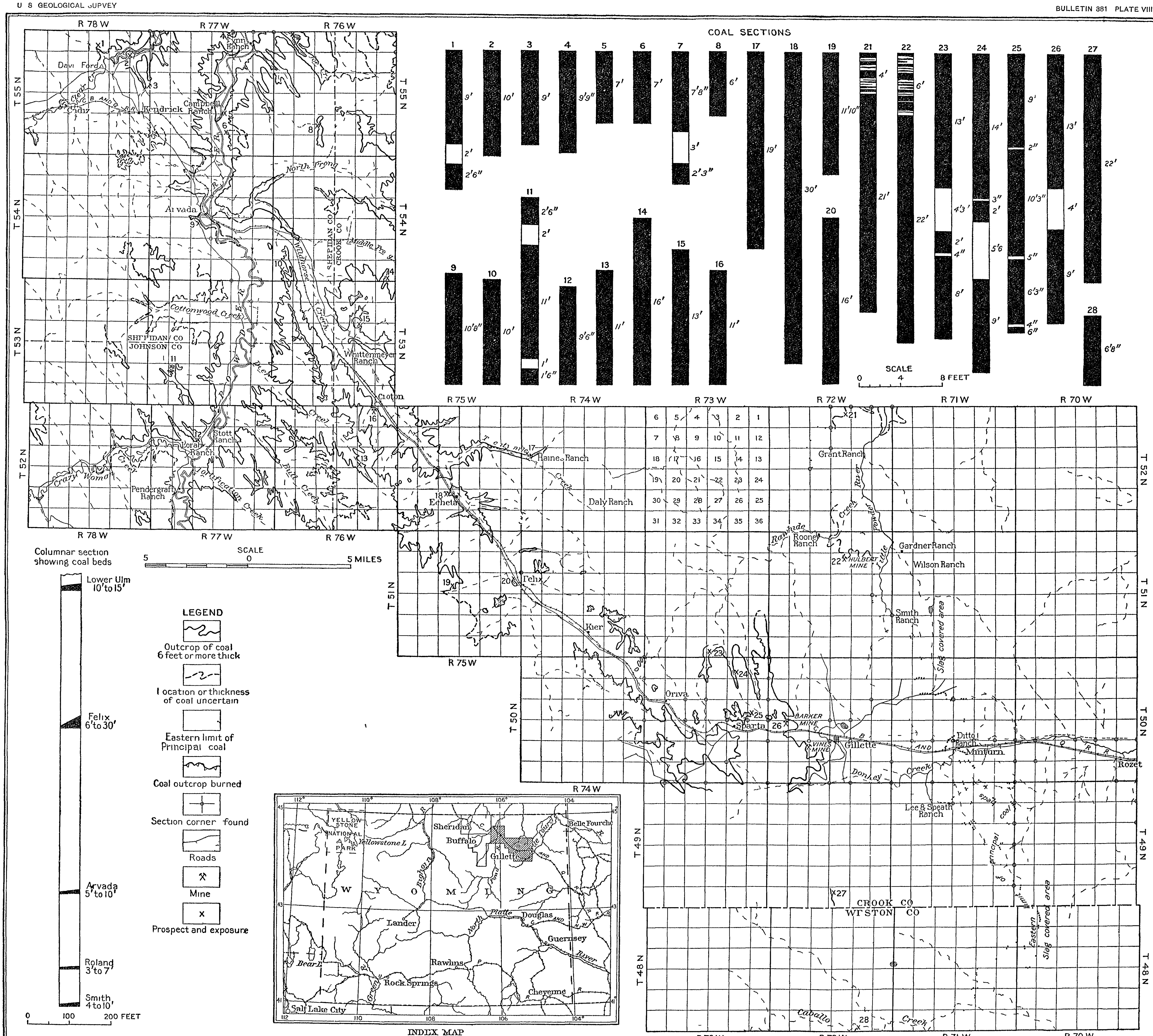
The Chicago, Burlington and Quincy Railroad Company sunk a churn-drill hole to a depth of 865 feet at Gillette in 1897 to procure a supply of water. In 1906 a second hole, within a few feet of the first, was drilled to a depth of 1,560 feet. Generalized sections of these wells as reported are given below:

Sections of water wells at Gillette.

No. 1.	Feet.	No. 2.	Feet.
Sandstone and shale	345	Soil, shale, and sandstone	335
Coal	55	Shale, dark, with coal streaks	65
Shale, white, black, and blue	85	Clay, shale, and sandstone	90
Coal	35	Coal	22
Shale and sandstone	345	Shale, sandstone, and limestone	1,048
	865		1,560

In the first well, at 345 feet below the surface, 55 feet of coal is recorded; in the second well, at the same depth, 65 feet of dark shale with coal streaks is reported. As the wells are only a few feet apart, and such an abrupt change in character in so short a distance is not common, this carbonaceous member is probably the same in both wells. Pumpings were not kept, however, and there is no way of telling whether it is actually a very thick bed of solid coal or a series of alternating beds of dark shale and coal. In both wells, at about 490 feet below the surface, or 85 to 90 feet below the upper coal, there is a second coal bed of considerable thickness. It is recorded in one as 35 feet and in the other as 22 feet thick. The first well was sunk 345 feet and the second well 1,048 feet below the lower coal without finding another coal bed. It seems probable that these two thick coal beds, 90 feet apart, the upper one at a depth of 340 feet below the surface, at Gillette, are the ones that outcrop at Minturn, 6 miles to the east, and have been the source of the burning over the broad, irregular belt mentioned above. At least they belong in the Tongue River coal group.

Besides the coal beds already described there are a number of others, probably of local extent only, which are in places of workable thickness. In the vicinity of Echeta there is a 5-foot coal bed about 150 feet above the Felix coal bed and overlain by white sandstone. What may be the same bed is present east of Tinkham Butte, also underlying a white sandstone but much thicker and with a number of partings, being in reality a mass of drab clay and brown, woody shale, containing beds of coal varying in thickness up to 2 feet 6



MAP OF POWDER RIVER COAL FIELD, WYOMING, ADJACENT TO THE BURLINGTON RAILWAY

By R W Stone and C T Lupton

inches. Still higher in the section, possibly 50 feet below the Lower Ulm coal, there is a bed exposed at the head of Deer Creek, which has the following section:

Section of coal bed at head of Deer Creek.

	Ft.	in.
Coal and fossil wood	2	
Clay, gray	3	4
Clay, drab	1	8
Coal	3	
Shale, brown, woody	2	
Clay, drab	4	
Coal	4	
	20	

Considering the number and extent of the coal beds, averaging over 10 feet in thickness, already described, it seems unnecessary to give further details of the lesser beds.

Location of mines, prospects, and outcrops in the Powder River coal field, Wyoming, adjacent to the Chicago, Burlington and Quincy Railroad.

No. on Pl. VIII.	Location.	Page.
1	Near Davis ford, sec. 3, T. 55 N., R. 78 W	123
2	Bank of Clear Creek, sec. 12, T. 55 N., R. 78 W	121
3	1½ miles north of Kendrick, sec. 13, T. 55 N., R. 78 W	123
4	Near Lynn's ranch, sec. 3, T. 55 N., R. 77 W	122
5	Campbell's ranch, sec. 22, T. 55 N., R. 77 W	122
6	Near Campbell's ranch, sec. 27, T. 55 N., R. 77 W	122
7	Joe Creek, sec. 6, T. 55 N., R. 76 W	122
8	7 miles northeast of Arvada, sec. 28, T. 55 N., R. 76 W	126
9	Near Arvada, sec. 21, T. 54 N., R. 77 W	122
10	4 miles southeast of Arvada, sec. 31, T. 54 N., R. 76 W	126
11	4 miles northwest of Stott's ranch, sec. 29, T. 53 N., R. 77 W	127
12	Lorah's ranch, sec. 9, T. 52 N., R. 77 W	126
13	Head of Deer Creek, sec. 14, T. 52 N., R. 76 W	128
14	6 miles north of Croton, sec. 36, T. 54 N., R. 76 W	126
15	4 miles north of Croton, sec. 14, T. 53 N., R. 76 W	125
16	Croton, sec. 2, T. 52 N., R. 76 W	125
17	Haines's ranch, sec. 18, T. 52 N., R. 74 W	125
18	Echeta, sec. 28, T. 52 N., R. 75 W	125
19	3 miles west of Felix, sec. 16, T. 51 N., R. 75 W	128
20	Felix, sec. 13, T. 51 N., R. 75 W	124
21	2 miles north of Grant's ranch, sec. 3, T. 52 N., R. 72 W	129
22	Hulbert mine, 9 miles north of Gillette, sec. 10, T. 51 N., R. 72 W	129
23	3 miles northeast of Oriva, sec. 34, T. 51 N., R. 73 W	125
24	3 miles north of Sparta, sec. 2, T. 50 N., R. 73 W	125
25	1 mile northeast of Sparta, sec. 13, T. 50 N., R. 73 W	128
26	Barker mine, 2½ miles west of Gillette, sec. 18, T. 50 N., R. 72 W	124
27	7 miles south of Gillette, sec. 34, T. 49 N., R. 72 W	124
28	Caballo Creek, sec. 35, T. 48 N., R. 72 W	124

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

All the coal in this district is subbituminous, of the variety commonly called black lignite, and varies but little in the different beds and in different parts of the area. The fresh coal is shiny black and the weathered coal is dull black. It reduces to a black powder, but the streak made on unglazed porcelain is dark brown. The fresh coal is tough and emits a dull sound when struck sharply with a hammer. In texture it is either dense or woody. In some of the coal having woody texture the grain of the wood from which it originated is perfectly preserved. This feature of the coal is most common in the eastern part of the field; it occurs at the Arvada mine and at other points as far west as Powder River, but is said to be rare in the coals mined in the vicinity of Sheridan. The specific gravity is about 1.3.

Close examination of the apparently dense and homogeneous coal shows that it is minutely banded. The predominating dull black is brightened by paper-thin discontinuous bands of jet-black coal.

When exposed to a dry atmosphere, subbituminous coal begins to check at once. The checking may be along the bedding and at right angles to it, or in irregularly disposed, hackley lines, resulting in chips very irregular in shape bounded by conchoidal faces. The checking is due to the evaporation of the moisture contained in the coal and is accompanied by a snapping sound. A lump of this coal freshly mined and exposed to the hot sun will be deeply checked in a few hours and will readily fall to pieces.

Subbituminous coal is distinguished from lignite by its color, the former being black and the latter brown, and from bituminous coal by the manner in which it weathers. Bituminous coal breaks along straight cleavage plains into prisms and disintegrates very slowly on exposure to the weather.

Subbituminous coal burns with a short yellowish-red flame and for a short time after ignition emits a white smoke that has a bituminous odor. After the early combustion of the volatile matter the coal continues to burn with scarcely perceptible smoke. It leaves a fine white ash.

Small globules of resin are found in some of the coal and commonly there is less than 2 per cent of sulphur. Thin bands of mineral charcoal are also present.

CHEMICAL PROPERTIES.

Nine samples of coal were collected in this district for chemical analysis. They were taken from freshly exposed faces of the beds in prospects and small mines in different parts of the field and should fairly represent the quality of the coal, so far as it may be represented by samples from a field where absolutely unweathered coal is unobtainable for lack of deep mines. In collecting these samples the surface of the coal bed was cleaned to get rid of any dirt, and all weathered or checked coal was carefully removed, so that the analysis might represent as nearly fresh coal as possible. A groove was then cut in this clean surface from the top to the bottom of the bed. The coal thus obtained was caught on a rubber blanket or piece of canvas to keep out dirt and moisture from the floor, was crushed to ½-inch size, thoroughly mixed, and quartered, the opposite quarters discarded, and the remainder remixed. This process was continued until the sample was reduced to 1 quart, which was carefully sealed in a galvanized-iron can and sent to the chemical laboratory.

Analyses of coal samples from the Powder River coal field, Wyoming.

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

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6460	NW. ¼ NW. ¼	12	55	78	10′	10′	24.0	As received	28.8	32.5	34.0	4.7	0.46					4,368	7,862
								Air dried	6.3	42.7	44.8	6.2	.60					5,747	10,345
								Dry coal		45.6	47.8	6.6	.64					6,132	11,038
								Pure coal [a]		48.8	51.2		.69					6,566	11,819
6798	NE. ¼	13	55	78	9′	9′	8.7	As received	18.3	34.6	40.7	6.37	1.15	5.66	53.93	1.05	31.84	5,115	9,207
								Air dried	10.5	37.9	44.6	6.98	1.26	5.14	59.07	1.15	26.40	5,602	10,084
								Dry coal		42.4	49.8	7.80	1.40	4.44	66.01	1.29	19.06	6,261	11,270
								Pure coal		46.0	54.0		1.52	4.82	71.59	1.40	20.67	6,791	12,224
6459	NE. ¼ NW. ¼	21	54	77	10′ 8″	10′ 8″	24.3	As received	29.3	28.6	36.4	5.67	1.21	6.27	45.09	.89	40.87	4,324	7,783
								Air dried	6.6	37.8	48.1	7.49	1.60	4.72	59.56	1.17	25.46	5,712	10,282
								Dry coal		40.5	51.5	8.02	1.71	4.26	63.80	1.26	20.95	6,118	11,012
								Pure coal		44.0	56.0		1.86	4.63	69.36	1.37	22.78	6,651	11,972
6461	NE. ¼ NW. ¼	21	54	77	10′ 8″	Lower half	24.0	As received	29.4	27.0	37.9	5.7	1.92					4,286	7,715
								Air dried	7.1	35.5	49.9	7.5	2.52					5,639	10,150
								Dry coal		38.2	53.7	8.1	2.71					6,070	10,926
								Pure coal		41.6	58.4		2.88					6,605	11,889
6432	NE. ¼	2	52	76	11′	6′ at bottom	19.3	As received	25.8	32.9	35.7	5.6	.39					4,703	8,465
								Air dried	8.1	40.7	44.3	6.9	.48					5,828	10,490
								Dry coal		44.3	48.2	7.5	.53					6,340	11,412
								Pure coal		47.9	52.1		.57					6,715	12,087
6448	NW. ¼ NE. ¼	28	52	75	30′	8′ in middle	18.7	As received	23.5	32.4	37.1	7.0	.60						
								Air dried	5.9	39.9	45.6	8.6	.74						
								Dry coal		42.4	48.5	9.1	.78						
								Pure coal		46.6	53.4		.86						
6542	SW. ¼	18	50	72	26′	7′ lower half of top bench.	25.4	As received	33.5	29.1	28.9	8.5	3.26						
								Air dried	10.9	39.0	38.7	11.4	4.37						
								Dry coal		43.8	43.5	12.7	4.90						
								Pure coal		50.2	49.8		5.62						

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term, it is used in this report as noted above.

Analyses of coal samples from the Powder River coal field, Wyoming—Continued.

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6444	NW. ¼	29	53	77	18′	11′ bench in middle.	25.3	As received	30.2	33.2	34.4	2.2	0.83						
								Air dried	6.5	44.4	46.1	3.0	1.11						
								Dry coal		47.5	49.3	3.2	1.19						
								Pure coal		49.1	50.9		1.23						
6602	NE. ¼	10	51	72	22′ +	22′	19.6	As received	28.1	33.2	33.1	5.6	.58						
								Air dried	10.6	41.2	41.2	7.0	.72						
								Dry coal		46.1	46.1	7.8	.81						
								Pure coal		50.0	50.0		.88						

6460. Taken from a fresh outcrop in the bank of Clear Creek at water level and above. Face of bed dressed and individual pieces shaved to remove checked surface. This coal necessarily is somewhat weathered. Sampled by R. W. Stone and F. D. Morrison.

6798. Taken from fresh working face in drift of Sweat & Smith, 1½ miles north of Kendrick, 40 feet from surface. This coal was only slightly weathered. Sampled by R. W. Stone and C. T. Lupton.

6459. Represents whole thickness of Arvada coal bed in mine one-half mile south of Arvada. Coal not absolutely fresh, for mine had not been worked in several months. Sampled by R. W. Stone and C. T. Lupton.

6461. Represents lower half of bed or blocky coal in mine one-half mile south of Arvada. Coal not absolutely fresh, for mine had not been worked for several months. Sampled by R. W. Stone and C. T. Lupton.

6432. Taken from face of mine at Croton, 120 feet from surface. Old working face; coal probably slightly weathered. Sampled by C. T. Lupton and C. M. Holmes, jr.

6448. Taken from face of drift 50 feet from surface in gulch one-fourth mile south of Echeta. Represents middle 8 feet of 30-foot bed of Felix coal. Coal probably slightly weathered. Sampled by F. D. Morrison and C. M. Holmes, jr.

6542. Taken from working face of drift 150 feet from the surface at Barker mine, west of Gillette. Coal as nearly fresh as possible. Represents lower 7 feet of upper bench of Felix coal. Sampled by F. D. Morrison and C. M. Holmes, jr.

6444. Taken from outcrop in sec. 29, T. 53 N., R. 77 W., by dressing it to get fresh coal and shaving individual pieces to remove checked surface. Coal probably slightly weathered. Sampled by R. W. Stone and C. T. Lupton.

6602. Taken from fresh face of open-cut coal bank. All checked coal carefully removed but sample was probably slightly weathered. Sampled by C. T. Lupton.

The air-dried samples show an average of 8.05 per cent moisture, 7.22 per cent ash, and 1.60 per cent sulphur. The heating value of these coals is shown by the calorific determinations to be practically the same as that of the coals in the Sheridan field.[a]

UTILIZATION.

The coal resources of this field are practically undeveloped. Scanty population in the area and the production of coal on a large scale in the Sheridan field have retarded development here. There are several openings and prospects from which ranchers and others obtain coal for winter use, but no active mining is carried on. The more important of these openings are described below.

A small mine was opened at Kendrick in 1908, and a few cars were loaded with coal from the Arvada bed. A company is now contemplating the sinking of a shaft near Kendrick. The plan is to sink deep enough to reach three or four coal beds and work them all from the same shaft. Development is being pushed by J. N. Sweat and J. W. Smith.

A small mine in the bank of Powder River, about half a mile south of Arvada, is the source of fuel supply for some of the people living near. This mine was opened in the winter of 1905 and several cars of coal were shipped. The coal was hauled to the railroad in wagons. Active mining continued only about five months, but the bank is kept open for the small supply which is obtained here each winter.

On the west side of Powder River, about 6 miles above Arvada, in the NW. ¼ sec. 22, T. 53 N., R. 77 W., there is a prospect in the Felix bed, from which near-by ranchers get an occasional load of coal. There are other small prospects in this bed at other points on Powder River and Crazy Woman Creek, but they are little more than cleaned outcrops where a rancher or two has taken a few loads of coal.

Near the station at Croton an entry has been driven 120 feet on the Felix coal bed. Four or five carloads were shipped to Gillette in 1902, but since then no coal has been mined here, except by one or two ranchers living in the neighborhood.

At Echeta, where the Felix coal bed has a thickness of 30 feet, a company is now preparing to strip the coal. As the cover is thin it is planned to strip and quarry as long as the overburden is not too great. The relation of the coal bed to the railroad is such that it will be possible to build a level track from the bottom of the strip pit to the tipple at the railroad, one-fourth mile away. The manager of this company, P. J. Barr, was grading the track in the fall of 1908.

A small mine was opened in the creek bottom at Felix several years ago, and it is reported that coal was shipped by rail. The industry was short lived, however, and the only output now is an occasional

[a] Bull. U. S. Geol. Survey No. 341, 1909, pp. 135-136.

load taken from prospects in the first draw north of Felix. The Felix coal bed is mined in a small way near Gillette by W. F. Vines and B. H. Barker. It sells in the village for $2.75 to $3 a ton.

A workable coal bed comes to the surface at Minturn. A prospect pit in the NW. ¼ sec. 2, T. 49 N., R. 71 W., about 1 mile south of the railroad, is said to have gone down 18 feet in coal and not reached the bottom of the bed. A few loads are dug here each winter by neighboring ranchers.

Another source of fuel supply of local reputation is the Hulbert mine, situated about 9 miles north of Gillette, in the NE. ¼ sec. 10, T. 51 N., R. 72 W. This is a bed 22 feet thick. An opening 15 feet wide extends probably 15 feet back into the hill. Eight feet of coal is left in the roof and from 6 to 7 feet of coal is mined. In spite of the distance some of this coal is hauled by wagon to Gillette.

CONCLUSION.

The production of coal in this field at present is limited practically to the small amounts taken by ranchers for their own use. The near future, however, is likely to see active mining of coal at various places along the railroad.

In 1900 the Chicago, Burlington and Quincy Railroad Company began a series of tests of the Sheridan coals in its locomotives and found that with specially constructed grates of large area and modified fire boxes and stacks the coal could be used successfully. Now all locomotives on the Wyoming division of this road are fired with Sheridan coal. As the Powder River coal field is the eastern continuation of the Sheridan field, and as the physical and chemical properties of the coal are practically the same, it is expected that the Powder River coal will prove equally efficient.

Experiments made by the United States Geological Survey show that subbituminous coal (such as that in the Powder River field) develops an efficiency 2.7 times greater with the gas producer and gas engine than when used in the common steam engine. In fact, the Powder River coals, when used in a gas producer and gas engine, will in all probability produce as much power per ton as the best West Virginia bituminous coals when used with a steam engine. With the further development of the producer and gas engine the mining of these low-grade coals should greatly increase.

As the demand for coal increases, capital will be invested in the development of the large beds described in this report. With a railroad already built through the area, and the Powder River valley north of Arvada offering an abundance of coal and an easy route for a new railroad, it may be expected that in a comparatively short time this portion of the great undeveloped region will be making a large addition to the annual coal production of Wyoming.

THE BUFFALO COAL FIELD, WYOMING.

By Hoyt S. Gale and Carroll H. Wegemann.

INTRODUCTION.

The Buffalo coal field of Wyoming is part of a broad area of coal-bearing strata in Wyoming, Montana, and the Dakotas, commonly known as the Northern Great Plains province. Certain fields or even local districts of this province have become more or less well known as coal-producing centers, but little authentic description of this great area has been available prior to the investigations that have been carried on by the United States Geological Survey in the last few years.

The examination of the Buffalo coal field in the summer of 1908 was a direct continuation of similar work that had been done in the preceding year by Joseph A. Taff in the Sheridan field, to the north. The Buffalo and Sheridan fields are also continuous with or a part of the extensive and valuable coal fields to the east and south of them. A part of this province contiguous with the Buffalo and Sheridan fields, including an area reaching eastward from the vicinity of Clearmont along the route of the Chicago, Burlington and Quincy Railroad, was examined in 1908 by R. W. Stone and C. T. Lupton, whose work forms the subject of the preceding paper in this volume.

The field party in the Buffalo area included, besides the authors, Doane Gardiner, temporary field assistant, who measured many of the detailed hand-level sections given on Plate IX, Alcott F. Elwell, and W. H. Beekly.

TOPOGRAPHY.

RELIEF.

The topography of the Buffalo field may be described in a very general way as that of more or less typical plains, although in detail it presents a variety of types and features which are in many places sharply contrasted. Considered broadly, it comprises portions of the foothill province of the Bighorn Mountains or front range of northern Wyoming and the extreme outer margin of the Great Plains area that stretches between the Bighorns and the Black

Hills. The area included in the coal field proper belongs both geographically and geologically to the plains province.

In a broad way the plains in this area exhibit two general types of topography. Along the foot of the mountains there is a belt characterized by broadly rolling and smoothly rounded slopes, largely covered with surficial deposits of sand, gravel, and bowlders, the surface of which is usually grass covered. Contrasted with these smooth grassy plains are the "red hills," which occupy a more extensive territory to the east and northeast, and which through the intricate systems of dissection and erosion slopes developed upon them merge into the most rugged badland forms. Each of these types may be again subdivided into two more or less distinct classes, so that the topography of the field as a whole may be described under four fairly comprehensive headings, as follows, the arrangement being the order of their position with respect to the mountains: Foothills and upper terraces; smooth grass-covered plains and lower terraces; red hills; badlands.

Skirting the foothills of the Bighorn Mountains and extending down the valleys of the principal streams that head within the mountains is a series of remarkably well-developed gravel-covered terraces. Some of them form broad alluvial plains for a distance of 5 to 10 miles from the mountains, but beyond these plains they are confined to the larger stream valleys, which they follow for great distances. In some places four or five of these gravel-covered terraces may be observed from one point, rising one above another. The slope of their surfaces away from the mountains is usually pronounced. The gravel cap is composed of rounded stream material which varies in size from small pebbles to fair-sized bowlders and whose constituents represent most of the igneous and sedimentary rocks exposed in the mountains near by, from which they were probably derived.

The mantle of sand and gravel on these surfaces is not heavy, a fair estimate being perhaps 5 to 10 feet on the stream terraces. Nearer the mountains the gravel is thicker, but probably its thickness does not exceed 40 or 50 feet in most places. On the surface the gravel has been concentrated by subaerial erosion into a layer 6 to 10 inches thick, forming a protecting cap to the terrace which tends to check its further degradation. This feature is well represented along Crazy Woman Creek near Trabing, where the gravel terraces form a line of low hills along the stream valley, the country back of them, which is covered by a thinner mantle of gravel, having been reduced to a somewhat lower level. Unmistakable glacial polishing was observed on bowlders included in some of these deposits. One locality in which the glacial pebbles were found is on a broad terrace 1 mile north of Buffalo, in the SW. ¼ sec. 23, T. 51 N., R. 82 W.

Between the terraces and the red hills to the northeast is an area of gentle slopes and broad, open valleys. At certain points remnants of terrace gravel occur within this area, and it seems not unlikely that at one time the greater part of it was covered by this deposit. Three miles southeast of Buffalo an extension of the terrace area forms the divide between Clear Creek and Dry Creek, and, as it were, bridges the gap between the terraces and the red hills.

In sharp contrast with the broad, grassy slopes described in the preceding paragraphs is the region of more rugged topography, made conspicuous by its red-capped summits and slag-covered slopes. As mentioned in the discussion of structure (p. 147), the baked rock formed by the burning of the Ulm group of coal beds ceases along a line which crosses the field from northwest to southeast in the line of the general strike of the beds. (See Pl. X.) The area of burned coal is not over 12 or 15 miles in width from northeast to southwest. It follows in general the trend of the mountains. On the northeast the slag has been removed by erosion and the boundary of the red hills is most irregular.

The topography of the red hills is in places very rugged. The beds of baked sandstone and shale resist the agencies of erosion and so form the cap rock of most of the hills. Below the protecting cap the slope of the softer rocks tends to remain steep. The slag beds are almost horizontal over most of the area, so that hills capped by the same bed are of nearly equal altitude. The topography thus developed is that of flat-topped mesas separated by canyon-like valleys. Where erosion has progressed further the mesas are reduced to cones and the valleys are broadened. The baked rock is of many shades of red, brown, and purple, the colors being due to the oxidation of the iron in the rocks by the heat of the burning coal. The contrast between the yellow sandstone and shale of the slopes and the brilliant red rock of the crests of the hills is most striking and enlivens a landscape in many ways dull and unattractive.

Badlands of the usual type occupy the territory of lower altitude to the northeast of the red hills. Here the coals have not burned to any great extent and the topography is not influenced by heavy beds of baked rock. Flat uplands exist at localities which are determined by the presence of thin beds of limestone that form the more resistant layers and prevent the erosion of underlying beds, but the topography is for the most part one of minute dissection. Sharp-crested ridges alternate with steep, narrow valleys. There is no water except that of a few miry springs that seep from the coal beds and what is left in depressions of the coulée bottoms after torrential rains. The slopes of the hills are covered with patches of sagebrush and scanty buffalo grass or are entirely bare. Travel over such an area is often exceedingly difficult.

DRAINAGE.

The drainage system which carries off the surplus water of the Buffalo field includes two important tributaries of upper Powder River—Crazy Woman and Clear creeks, both formerly referred to as "forks" of Powder River proper. Each of these streams is in turn fed by numerous branches of various sizes. Piney Creek, a fork of Clear Creek, is equal in size to that stream, so that the perennial streams of the field are really three in number.

The water in Crazy Woman Creek is somewhat alkaline, but that of Piney Creek and Clear Creek is remarkably pure, being derived directly from the wooded slopes and snow-capped peaks of the Bighorn Mountains. All the other streams of the area are of intermittent character.

Lake De Smet is a body of water about 3 miles in length by a mile in width, lying in the western part of T. 52 N., R. 82 W. Its long axis is approximately parallel to the strike of the rocks in this region, about N. 45° W. The lake has no outlet. At its north end it receives a small stream known as Shell Creek, which flows across a broad, flat meadow almost as wide as the lake itself. A narrow valley to the north connects this flat with the flood plain of Piney Creek. It is stated by General Carrington[a] that in 1866 Shell Creek flowed through this valley and emptied into Piney Creek, the lake having at that time no inlet. At the southeastern extremity of the lake a broad valley may be followed into that of Boxelder Creek.

The Buffalo region is one of comparatively scant precipitation, and away from the foot of the mountains springs are rather rare. The most common are small seeps along the channels of dry or intermittent stream courses. Many of these probably represent the underflow of the valley, a part of which may be brought to the surface by a barrier of some sort or by a relative shallowing of the detritus zone in which it flows. Such waters occurring in the area of comparatively less consolidated Fort Union (Tertiary) strata are in general rather heavily charged with alkaline salts, as are the soils over which they pass.

Springs of another type are locally somewhat common and many of them afford good water. These usually occur along the outcrops of coal beds and, like the underflow currents, are most common along stream channels or in valley bottoms, the most favorable points for water to reach the surface. The coal beds are the best water-bearing strata of the Fort Union ("De Smet") formation, the others being relatively impervious clays and clayey layers. Their waters are fre-

[a] Carrington, H. B., Absaraka, land of massacre, 1878, p. 142. "The water is deep and intensely alkaline and there is neither inlet nor outlet, as the little creek which is crossed before reaching the lake passes by the west end at a few hundred yards distance and turns westward to the Piney Forks, emptying its stream below their junction."

quently charged with iron and sulphur compounds and sometimes with alkaline salts, but usually not to a very objectionable degree. These springs are so numerous within the coal field that it may fairly be assumed that a spring is a good indication of a coal bed, although the coal itself may be concealed by alluvial wash.

STRATIGRAPHY.

INTRODUCTION.

So far as the older sedimentary formations are concerned, the general stratigraphy of this field has already been discussed at length in the reports by Darton [a] and others. In the present review of the Mesozoic and later rocks, however, some modification of the stratigraphic classification used in former reports is now required, to conform to more recent geologic and paleontologic information.

The vicinity of Buffalo does not offer very favorable opportunities for the study of the Cretaceous and older rocks in the foothill region of the Bighorn Mountains. The rocks on the east flank of the range are steeply tilted and the structure is complicated by faults that tend to obscure the normal relations of the strata. The chief difficulty is, however, that the extensive outwash deposits of bowlders and gravel along the base of the mountains have largely obscured the underlying rocks and only fragmentary information concerning them can be obtained.

PRE-TERTIARY ROCKS.

Of the several formations into which the Cretaceous rocks of this region are divisible, only the upper one, to which Darton has given the name Piney formation, contains coal in commercial quantities. For that reason the other Cretaceous formations will not be considered in this report.

PINEY FORMATION.

The name Piney was used by Darton [b] to designate "the lowest formation of the thick series of fresh-water sandstones and shales of later Cretaceous age formerly designated 'Laramie' lying in the great basin adjoining the Bighorn uplift." It embraces all the rocks between the Parkman sandstone below and the Kingsbury conglomerate member of the Fort Union above, or, in the absence of the Kingsbury conglomerate, between the Parkman below and the "De Smet" (now referred to Fort Union) above. Whether the rocks thus described are a formational unit as Darton considered them, or should

[a] Darton, N. H., Geology and underground water resources of the central Great Plains: Prof. Paper U. S. Geol. Survey No. 32, 1905; Geology of the Bighorn Mountains: Prof. Paper U. S. Geol. Survey No. 51, 1906; Cloud Peak-Fort McKinney folio (No. 142), Geol. Atlas U. S., U. S. Geol. Survey, 1906.

[b] Darton, N. H., Geology of the Bighorn Mountains: Prof. Paper U. S. Geol. Survey No. 51, 1906, p. 59.

be referred as a whole or in part to the Fort Union, is now an open question. On account of lack of more positive evidence on the subject the name Piney is here retained as originally used.

As described by Darton [a] the Piney formation southeast of Buffalo is about 2,000 feet thick.

> The lowest beds are sandstones and shales of light color, and the upper members consist of white, red, and green sands and sandstones alternating with layers of green and yellow clays, dark shales, and iron concretions, the latter composed of sand cemented by iron oxide. This formation is extensively exposed along the north side of Rock Creek southwest of Lake De Smet, also on the west slope of the high ridge, south of Johnson Creek, and notably in the slopes a mile southeast of T. A. ranch, where it forms badlands.

About 9 miles southeast of the T. A. ranch and 4 to 5 miles southwest of Trabing, in the western part of T. 47 N., R. 81 W., the upper portion of the Piney formation, together with the overlying Fort Union ("De Smet") formation, is well exposed. Near the top of the formation are several thin beds of coarse sandstone which breaks into sharp angular blocks. Associated with these sandstones are beds of pink shale. The underlying strata are dark-brown and drab shales containing numerous beds of coal, several of which are of economic importance. Here and there shale of a greenish cast may be noted. Coarse, friable sandstone also occurs and there are numerous thin beds of blue limestone which weathers to dark red or brown. Shale grades into sandstone and sandstone into shale, both vertically and horizontally. It is rare to find an individual bed which can be traced for any great distance. The coal beds form one exception to this statement, for, although varying in thickness and quality, many of them extend over considerable areas.

Near Buffalo no coal beds of importance are known in this formation, but south of Crazy Woman Creek coal is mined at various points in T. 44 N., R. 81 W.; T. 43 N., R. 79 W.; and T. 42 N., R. 77 W., in beds which probably correspond to those near Buffalo. Although this upper portion of the Piney formation resembles in many ways the somber-colored shale which underlies the typical Fort Union in the vicinity of Miles City, Mont., there is some doubt as to its exact correlation.

In T. 43 N., R. 79 W. (see Pl. XI) the rocks underlying the typical Fort Union come to the surface along the flank of a broad dome drained by Salt Creek. The northeastern portion of the township is covered by the fine-grained buff sandstones and shales of the lower portion of the Fort Union, which is here barren of coal beds. This sandy phase passes into darker shale below without any sharp line of contact between the two formations. The shale is approximately 600 feet thick. It is of various shades of gray, some layers

[a] Loc. cit.

being nearly black and others almost white. In its upper part are several pinkish beds. About 300 feet below the top are two beds of coal to be described later. Numerous thin beds of blue limestone which weather to a dark-red color occur, especially near the base of the shale and in the underlying sandstone. This sandstone, about 500 feet in thickness, forms a very prominent pine-covered ridge. It is for the most part bluish white in color and fine grained.

Below the sandstone is a mass of shale with thin sandstone and limestone beds and below this a white sandstone which forms a less prominent ridge than the one just described. In the shale valley between these two ridges some plant fragments were collected which, although they are not sufficient for a definite determination, are said by F. H. Knowlton to have decided Fort Union affinities. Below the lower of the sandstone beds is a great thickness of beds of alternating sandstone and shale with a few thin limestone layers. Dinosaur remains, including the frill bone of a *Triceratops*, were found in this formation in the NW. ¼ sec. 4, T. 42 N., R. 79 W. It would seem, therefore, that these beds may represent a formation in eastern Wyoming and Montana which has been called by various names, "Lance Creek beds;" "*Ceratops* beds," "Hell Creek beds," etc.

Barnum Brown, in an article on the "Hell Creek beds" of Montana,[a] described a series of lignite-bearing beds below the typical Fort Union and above the "Hell Creek beds." It is possible that the dark-colored shale which conformably underlies the Fort Union in the township under discussion may represent this same lignite-bearing formation. If so it is doubtful whether the sandstone ridges belong with the upper shale or with the *Ceratops*-bearing beds below. In passing northward along the base of the mountains the sandstone ridges become less and less conspicuous until they seem to give place to shale and are not observed as sandstone in the exposures west of Trabing.

Numerous plant fragments and some imperfectly preserved leaves were found in the beds underlying the Kingsbury conglomerate member, but unfortunately these were not adequate for a positive age determination.

TERTIARY ROCKS.

FORT UNION ("DE SMET") FORMATION.

The Kingsbury conglomerate member of the Fort Union formation is one of the most conspicuous and prominently exposed rock divisions in the Buffalo region. It takes its name from Kingsbury Ridge, a prominent topographic feature about 6 miles southwest of Buffalo,

[a] The Hell Creek beds of Montana: Bull. Am. Mus. Nat. Hist., vol. 23, 1907, p. 834.

near the Klondike-Hazleton road. Here it is characteristically exposed and probably attains its maximum thickness. It is also well exposed on Rock Creek, northeast of Buffalo, and still farther north beyond the area covered by this report. Darton treated it as an independent formation, although he stated that it was probably developed out of the "De Smet" formation. That the conglomerate is a member of the Fort Union formation there seems no longer any doubt, and it will be so treated in this report.

The conglomerate is composed of water-rounded gravel and bowlders, derived from the older sedimentary rocks of the adjacent mountain range and including also specimens of the granitic core of the range. So far as observed none of the basic dike rocks from that region are to be found in these beds. Among the pebbles identified are coarse red or gray granite; flat pebbles characteristic of the Deadwood (Cambrian) formation; brecciated and weather-pitted fragments or pebbles of the Bighorn (Ordovician) limestone; massive, crystalline rock of the Madison (Mississippian) limestone, containing numerous crinoids and spirifers; and other limestones, sandstones, and shales of the later formations, which are not so clearly identifiable as those of the older rocks. These pebbles are cemented in a coarse sandy matrix, and seem in their present state to have been laid down in channel deposits of exceedingly irregular bedding. The conglomeratic strata, which are in many places thick and massive, are interstratified with finer-grained, more uniformly bedded layers of sandstone and shale, dull greenish gray or drab in color, much resembling the rocks of the underlying somber-colored beds. In many places the conglomerate, even where forming prominent ledges, constitutes but a fractional part of the actual strata represented, the coarse débris resulting from its disintegration covering and concealing the softer beds.

The Kingsbury conglomerate member is evidently a shore, delta, or alluvial-fan deposit. It is clearly unconformable with the underlying formations, as its outcrop transgresses obliquely across them and its dip is somewhat discordant with that of the adjacent beds. Its deposition, therefore, appears to have followed or to have marked the culmination of a period of uplift and denudation at this particular locality and is thought to represent the erosional activity awakened at one of the more important stages of uplift of the Bighorn Mountains. The transition from the Kingsbury conglomerate to the finer sediments overlying it is by no means an abrupt one. Local beds of conglomerate, apparently of lenticular form, occur throughout a considerable thickness of strata, perhaps even thousands of feet above the main conglomerate mass.

To the north and also to the south the Kingsbury conglomerate member fingers out and disappears and the normal Fort Union ("De

Smet") strata succeed the dark shale of the Piney formation without sign of break between them. The Fort Union age of the Kingsbury conglomerate now seems very well determined by stratigraphic and paleontologic evidence.[a]

The shale and sandstone of the Fort Union ("De Smet") formation are prevailingly light yellow in tone, in more or less decided contrast to the dark shale of the Piney below. However, somber-colored shale occurs in the Fort Union at many localities, especially in association with coal beds, and in places it is necessary to examine a considerable exposure to distinguish the two formations. The Fort Union consists for the most part of shale and fine-grained sandstone, alternating here and there with thinner beds of calcareous sandstone that are commonly fossil bearing. Most of the valuable coal beds of the Buffalo region occur in the Fort Union ("De Smet") formation.

In the immediate vicinity of Buffalo, as already stated, the shale and sandy beds interstratified with the Kingsbury conglomerate member are of a dull-greenish cast, weathering to a drab or even yellowish clay or sand when dry. They are thus indistinguishable in appearance from much of the underlying Piney formation, but, as a rule, the Fort Union does not present the peculiar banded appearance, due to the alternation of light and dark shales, so characteristic of the Piney formation. Of these duller-colored strata of the Fort Union, there is a rather uncertain thickness below the principal coal-bearing group. An estimate based on observations along a section extending from Rock Creek to a point near Lake De Smet seems to indicate that there are about 2,000 feet of beds above the Kingsbury conglomerate member and below the lowest important coal of the Ulm coal group, as represented at the local coal banks or mines at the southwest side of the lake.

The coal-bearing portion of the Fort Union in the Buffalo region includes the upper 600 or 800 feet of the section as represented in the detailed stratigraphic sections made during the present investigation and published in this report. The coal is described in detail on pages 153–169.

Silicified trees are of common occurrence in association with the coal-bearing beds. They afford evidence of the climatic conditions and indicate rapidity of deposition during the period in which they and the coal beds were laid down.

The occurrence of surficial deposits of sand and gravel that cover the terraces along the base of the mountains has been noted under the heading "Topography." These deposits occupy very consider-

[a] Stanton, T. W., "*Ceratops* beds" of Wyoming and Montana: Proc. Washington Acad. Sci., vol. 2, No. 4, 1909, pp. 265–268. Knowlton, F. H., Stratigraphic relations and paleontology of the "Hell Creek beds," "*Ceratops* beds," and equivalents, and their reference to the Fort Union formation: Proc. Washington Acad. Sci., vol. 2, No. 3, 1909, pp. 209, 212.

able areas in the Buffalo field, and in many places mask the underlying rock formations continuously for miles, practically preventing any direct study of the bed-rock structure or strata.

ROCK STRUCTURE.

The rock structure of the Buffalo coal field is comparatively simple. The strata of the plains are practically horizontal or have dips so low that they are in places difficult to detect. Along the eastern flank of the Bighorn Range, however, the coal-bearing strata are upturned sharply, their outcrops occupying a comparatively narrow strip of territory along the base of the mountains. To a large extent details of the major structure are concealed by the outwash deposits of gravel and sand along the mountain foot. The structure where revealed, however, shows the fold to be fairly uniform, but broken here and there by faults of considerable extent. With the older, more sharply folded strata this report has little to do, for the coals are confined to the younger and relatively flat-lying rocks of the plains. The dips in the later formations are generally slight, but are important, as bearing on the extent and position of the valuable coals.

By a comparison of accurately determined altitudes, based on United States Geological Survey bench marks, of certain coal beds along Clear Creek between the mouth of Piney Creek and Buffalo, the dip of the rocks to the northeast is found to average but a fraction of a degree. This dip is far too slight to be recognized in any particular locality or outcrop, and is obscured by the creep of rocks on many of the steep slopes. On the east side of Lake De Smet the dip is too slight to be observed, but at the coal bank on the southwest side of the lake the beds dip 4½° away from the mountains, with a strike of N. 45° W. The dip increases toward the southwest, and near the corner of the township it is 25°. In sec. 3 of the township west of Lake De Smet a dip of 10° was observed, the strike being the same as that near the lake. Along the western shore of the lake, especially near the north end, occur several parallel ridges of slag, which correspond in direction with the strike of the beds. These ridges apparently represent the outcrop of coal beds at the Healy horizon, and the straight course and narrowness of the band of slag seems to indicate that the beds at this place dip more or less. No slag occurs southwest of this locality. The coal beds below the Healy do not, as a rule, form noticeable slag.

An inspection of the map will show that a line drawn along the southwest side of Lake De Smet and parallel to its long axis corresponds to the strike of the rocks in that locality, and if continued southeastward to the southern border of T. 50 N., R. 81 W., in general marks the western limit of the burned area. From that point on, the boundary of the slag swings a little more to the eastward, north of the Bilderbach Lakes. These facts may be significant of a structure that has not yet been determined from the observed bed-rock exposures.

Southeast of the Clear Creek valley at Buffalo, in secs. 16, 21, 22, and 27, T. 50 N., R. 81 W., several parallel ridges of slag similar to those near Lake De Smet mark the limit of the burned area. They are approximately on the line of strike of the beds at Lake De Smet. Slags from several different coal horizons are here so intermingled that it is difficult to make accurate determinations of the amount of the dip or the identity of the individual beds. The dip, if any, is but slight. A mile to the west, in sec. 18, a dip of 1½° NE. was observed on a bed of carbonaceous shale. West of this point the observed dips are low for about 6 miles, but in sec. 30, T. 50 N., R. 82 W., the beds are upturned sharply and within a mile stand almost vertical.

Southeast of Lake De Smet, in sec. 2, T. 51 N., R. 82 W., a dip of 10° 20′ was observed in a coal bed taken as representing the Walters coal. From that point for some distance southeastward the slag beds are so confused that no dip determinations could be made. Just east of Buffalo there appears to be a gently folded syncline, for in the Munkre and Mitchell mines the coal beds dip at low angles to the southwest, while at Buffalo and north of Buffalo the dips are to the east. About 2½ miles east of Buffalo the slags of the Healy and higher coal beds cease in a rather abrupt escarpment, but no marked dip was observed there.

In secs. 17, 20, and 29, T. 49 N., R. 80 W., occur two shallow ponds. Each depression is opposite a small tributary of Crazy Woman Creek and is separated from the Crazy Woman Creek drainage basin by a very low divide. In sec. 8 the rocks dip to the northwest and in sec. 21 to the east. There appears to be a low anticline just east of the lakes, its axis trending about north and south. The lakes themselves seem to occupy the former heads of the two valleys above mentioned, as if the drainage had been interrupted by the warping of the strata after the valleys were formed. In the township west of the lakes the dips are low and the surface so covered that but little is revealed of the structure.

Along Crazy Woman Creek at intervals for 25 miles below Trabing a coal known as the Dry Creek bed outcrops at water level, showing that the dip of the rocks to the northeast, although locally undulating, is on the average equivalent to the fall of the stream. Five miles west of Trabing, however, the base of the Fort Union is brought to the surface and the underlying dark shale of the Piney formation is exposed, showing a dip of 12°. The ridge formed by the upturn of the strata can be seen extending outside of the area studied. To the south it traverses T. 47 N., R. 81 W., with a strike of N. 27° W.

and dips of 6° to 8°. The ridge is formed chiefly by portions of the Piney formation. It appears to extend continuously southward to Powder River, which it crosses below the mouth of South Fork. From that point it turns somewhat toward the east, crossing the southern portion of T. 43 N., R. 79 W., and continuing southeastward along the periphery of a broad dome or anticline which occupies the general region drained by Salt Creek.

THE COAL.

QUALITY AND PHYSICAL PROPERTIES.

The coal of the Buffalo field should probably be classed as subbituminous, although in character it is not far removed from lignite. It differs from lignite in color, texture, and calorific value. Its color is dark brown or even black, in contrast to the more woody brown of lignite. Although the original grain of the wood is to be observed in much of the coal, the cellular structure is not so distinct as in lignite and in some beds or parts of beds is lacking entirely. The coal is more brittle than lignite, breaking with a conchoidal fracture. Its calorific value averages about 10,000 British thermal units; this is somewhat in excess of that of the lignite of North Dakota, which averages only about 8,400 British thermal units. It may be observed that the more woody layers of the coal, dark brown when first mined, quickly blacken on exposure and appear to lose much of their woody texture. The coal in this dried condition is brittle and, when freshly broken, lustrous black in color. It breaks as readily across the grain of the original wood as it does parallel to it. On continued exposure, however, the coal loses its luster and finally crumbles or "slacks" to a fine powder.

Small masses of resin are embedded in the coal at many places and it is reported that some of them are several inches in diameter. From this occurrence of resin and the amount of coal that shows evidence of woody structure it seems probable that the greater proportion of this coal was formed from tree trunks rather than from the finer deposits of a bog. The occurrence of silicified logs and tree stumps in many of the beds helps to substantiate this view. The logs are embedded in the coal, mostly in horizontal positions. In some cases it is evident that part of the log was changed to coal while other parts were silicified. The occurrence of petrified logs is not at all uncommon in the sandstone and shale above the coal beds. Some trunks of trees are standing in their original positions half covered by coarse sandstone formed from the sand which originally buried them. They range in diameter from a few inches to 3 or 4 feet.

The coal beds of this field range from thin seams of only a few inches to heavy beds over 30 feet thick. The thickness of some of the beds is comparatively constant over broad areas; that of others varies widely. However constant in thickness a bed may be over a large area, it is evident that toward the limits of the ancient marsh in which the coal was formed the coal must be expected to change in thickness and quality and finally to end entirely.

The various beds of coal in the section differ in quality as well as in extent and continuity. A coal clean at one point may be continuous with and merge into a bony coal or carbonaceous shale which is worthless, this difference being due apparently to a difference of conditions in the marsh at the time of formation of the coal, changes in the character of vegetation, the introduction of foreign matter by water currents, etc. In certain places along the outcrop of a coal bed is observed a thin parting of shale, which thickens in passing along the strike, separating the coal bed into benches in such a manner as to render worthless a bed that in other localities is valuable.

Although a coal bed may change greatly in character from place to place, as has been observed, its horizon may usually be recognized and the interval between it and the next important bed above or below may be determined. In many cases this interval seems to be constant and may be used in identifying beds in different portions of the field. The constancy of such an interval is probably the result of the uniform rise or fall of water level with respect to a low-lying land surface over a wide territory and the consequent uniform horizontal distribution of the material laid down below and filled up to the temporarily established water level.

CHEMICAL ANALYSES.

Owing to the location of this field at a distance from lines of transportation there is little demand for its coal and only a few mines have been opened to supply fuel for local consumption. On account of the scarcity of working mines it was impossible to procure many samples of coal for analysis. In the following table are given the analyses of the samples that were collected, followed by a description of the location and the conditions at the time of collection. Each sample was obtained by cutting a channel across the coal bed or the particular bench of coal to be sampled, and pulverizing and quartering the coal thus procured. The samples were sent to the chemical laboratory in sealed galvanized-iron cans.

Analyses of coal samples from the Buffalo coal field, Wyoming.

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

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6469	NE. ¼	26	51	82	19′	Upper bench 4′ 8″.	20.5	As received	26.8	32.8	27.9	12.47	0.64	6.04	42.72	0.60	37.53	4,080	7,344
								Air dried	7.9	41.3	35.1	15.69	.81	4.73	53.74	.75	24.28	5,132	9,238
								Dry coal	....	44.8	38.2	17.03	.87	4.18	58.34	.82	18.76	5,572	10,030
								Pure coal *a*	....	54.0	46.0	....	1.05	5.04	70.31	.99	22.61	6,715	12,087
6470	NE. ¼	26	51	82	19′	Lower bench 6′ 7″.	22.9	As received	29.0	29.1	34.7	7.21	.39	6.53	44.64	.50	40.73	4,237	7,627
								Air dried	8.0	37.7	45.0	9.35	.51	5.17	57.90	.65	26.42	5,495	9,891
								Dry coal	....	41.0	48.8	10.16	.55	4.65	62.92	.70	21.02	5,972	10,750
								Pure coal	....	45.6	54.4	....	.61	5.18	70.04	.78	23.39	6,647	11,965
6410	SW. ¼	36	51	82	18′	Middle bench 6′.	19.9	As received	28.0	29.7	32.8	9.47	.74	6.40	43.84	.60	38.95	4,212	7,582
								Air dried	10.1	37.1	41.0	11.82	.93	5.23	54.73	.75	26.54	5,258	9,464
								Dry coal	....	41.3	45.5	13.15	1.03	4.57	60.85	.83	19.57	5,847	10,525
								Pure coal	....	47.5	52.5	....	1.19	5.26	70.06	.96	22.53	6,732	12,118
6434	SE. ¼	3	52	82	2′ 6″	Upper part	21.2	As received	29.4	32.0	35.1	3.5	.31	....	....	....	....	....	....
								Air dried	10.4	40.6	44.6	4.4	.39	....	....	....	....	....	....
								Dry coal	....	45.3	49.8	4.9	.44	....	....	....	....	....	....
								Pure coal	....	47.6	52.4	....	.46	....	....	....	....	....	....
6435	SE. ¼	3	52	82	4′ 6″	Lower part	20.6	As received	28.4	31.0	34.1	6.48	.72	6.39	46.22	.73	39.46	4,443	7,997
								Air dried	9.8	39.1	42.9	8.16	.91	5.17	58.21	.92	26.63	5,596	10,073
								Dry coal	....	43.3	47.6	9.05	1.01	4.52	64.55	1.02	19.85	6,205	11,169
								Pure coal	....	47.7	52.3	....	1.11	4.97	70.97	1.12	21.83	6,822	12,280

a "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term it is used in this report as noted above.

6469 (Pl. X, 18). From the bench above the one at present worked in the Mitchell mine. The upper part of this bench is 1 foot 8½ inches thick, the lower part 2 feet 8 inches; the two parts are separated by 2 inches of bone, which was not included in the sample. The sample was taken from the wall of the slope near its foot. The coal had been exposed to the air of the mine for some months, but as there was considerable moisture present the face of the bed was as firm as when freshly mined. About 3 inches of the face was removed before the sample was cut. The cover above the coal at this point is about 100 feet thick and consists in great part of coal and coaly shale beds.

6470 (Pl. X, 18). From the bench at present worked in the Mitchell mine. This bench consists of four parts whose thicknesses, in descending order, are 3 feet 3 inches, 11 inches, 7 inches, and 1 foot 8 inches. The thin shale partings between them were thrown out in taking the sample, which was cut about 20 feet north of the foot of the slope. The mine had been opened the year before, but coal had been mined at this particular place only a few days before the sample was taken. The face of the coal showed no sign of weathering and no moisture was seen at this place. It is believed that the coal was practically unweathered. There is about 120 feet of cover above the coal.

6410 (Pl. X, 19). From the bench at present worked in the Munkre mine. The coal bed is 6 feet thick and carries a thin bone parting in some parts of the mine. This is an old mine, but the sample was obtained from a face of coal which has been worked recently about 200 feet from the foot of the slope. There is about 85 feet of cover at this point, consisting of shale and coal beds with a little alluvium at the surface. No moisture was to be seen and it is believed that the coal was practically unweathered.

6434 (Pl. X, 9). Represents an upper bench, 2 feet 6½ inches thick, of a coal bed exposed in the bank of a coulée from which coal is obtained for local use. This coal is under about 8 feet of cover, which is for the most part alluvium. Coal from this place had been mined on the day before the sample was taken, but the face of the coal had already begun to check. About 3 inches of the surface was removed before the sample was taken. Although the coal appeared hard and bright, it seems probable that changes had taken place in it due to long exposure to surface conditions. This description applies also to sample 6435.

6435 (Pl. X, 9). From lower part of same bed as sample 6434. Several thin shale partings are present, as shown on Plate X. These were thrown out and the sample was obtained from the three parts of the bench, 1 foot 7 inches, 11 inches, and 1 foot in thickness.

BURNING OF OUTCROP.

Certain of the coal beds of the Buffalo field have burned extensively along their outcrops, baking and partly melting the rocks above them. These baked rocks are of various shades of pink, brown, red, and even purple, and form one of the most conspicuous features of the landscape. Being hardened by the heat, they resist erosion much more effectively than the unaltered soft sandstone and shale, and thus form the capping rock of many of the hills. In certain localities coal beds are at present on fire, and the phenomena of the burning, the settling of the overlying beds, and the formation of fissures may be observed in actual process of development. It seems probable that the beds take fire by spontaneous combustion. Such firing of piles of slack of subbituminous coal is of common occurrence. In nature the undercutting of coal banks by streams and the consequent caving of the coal furnishes similar slack piles, and it is not unreasonable to suppose that they take fire in a similar manner.

It should be remarked, however, that certain beds seem to have burned much more extensively than others. The Fort Union coals of the Buffalo field (the Ulm coal group as defined by Taff [a]) form marked areas of slag, but the coal beds of the Intermediate coal group, which being lower in the section are exposed farther to the northeast, are not burned to any considerable extent. The lowest coals of the Fort Union, which have been termed by Taff the Tongue River coal group, are widely burned. The coals of the underlying somber-colored shale have burned but little. All these coals are subject to practically the same conditions of climate and erosion and it seems probable that the differences in the amount of burning are due to slight differences in composition that render some more prone to spontaneous combustion than others.

Many facts are difficult of explanation, however. For example, the Healy coal is universally burned along its outcrop over broad areas to the northwest of Crazy Woman Creek, but southeast of that stream, although the same coal bed is present, it is very little burned, the creek marking the boundary between the burned and unburned areas.

CORRELATION WITH OTHER FIELDS.

As already mentioned, the coal beds of the Buffalo field belong to the group designated by Taff in the field to the north the Ulm coal group. They occur in the upper portion of the Fort Union formation. Theoretically the coals of the Intermediate and Tongue River coal groups, as defined by Taff and exposed in the fields to the east and north of Buffalo, if continuous should underlie this area. Along the base of the Bighorn Mountains the flat-lying strata of the plains are tilted slightly eastward, so that in approaching the mountains one passes across the edges of the upturned beds. It is significant that no outcrops of coal beds much below the Ulm coal group can be found in this area except in one place west of Trabing, where coals at the base of the Fort Union are brought to the surface. The margins or shores of the ancient marshes in which the coals are supposed to have been formed probably lay somewhere along the base of these mountains, and along these lines the vegetal deposits would therefore cease. In the absence of more positive data as to the extent and character of coal beds lower in the section it seems impossible to make definite statements concerning any beds lower than those exposed at the surface within this area.

[a] Taff, J. A., The Sheridan coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, pp. 123-250.

IMPORTANT COAL BEDS OF THE BUFFALO FIELD.

There are, to speak generally, three horizons at which coal occurs throughout the Buffalo field. The lowest coal is termed for convenience the Dry Creek bed, from its occurrence along that stream. About 130 feet above this bed is the coal that is mined near the Healy ranch, which is referred to in this report as the Healy coal (*d*).[a] In some parts of the field there are at this horizon two workable beds with an interval of 50 or 60 feet between them. About 175 feet above the Healy horizon is a thick coal bed workable in some portions of the field, which has been mined to a small extent in the NE. ¼ sec. 16, T. 52 N., R. 81 W., for use at the Walters ranch on Clear Creek, and which is here termed the Walters coal. Other beds occur at intermediate horizons and are locally important. There are also remnants of higher coal beds preserved in some parts of the field.

DESCRIPTION BY TOWNSHIPS.

In describing the coals of the Buffalo field the area will be considered by townships, beginning at the northeast corner and going from east to west across the field, each tier of townships being discussed in order from north to south.

T. 53 N., R. 79 W.—The principal coal bed within this township is the Healy, which occurs at an elevation of about 4,400 feet above sea level. The bed has been removed by erosion over the larger portion of the township. Its remnants appear principally along the divide between Clear and Crazy Woman creeks. In many places, especially where the coal has been left in small patches upon hilltops, it has burned, forming a marked slag. Near the west side of sec. 20 a detailed section (No. 8)[b] was made that shows the bed to be 18 feet 6 inches thick counting the included shale partings.

About 40 feet below this bed occurs another coal that is usually over 3 feet thick. The outcrops of the two as represented on the map are practically identical, although the endeavor has been made to map the upper bed only. In the strata from 100 to 200 feet below these coals are several thin beds of coal and carbonaceous shale, none of which are known to be over 2 feet 6 inches thick and none of which form noticeable slag by burning. (*hh*, *ii*.)

Practically nothing is positively known concerning other valuable coals that doubtless occur in the strata below water level in this area.

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[a] Letters in parentheses refer to sections on Plate IX.

[b] Numbers in parentheses refer to sections of coal beds on Plates X and XI.

SECTIONS ON PLATE IX.

a. Sec. 24, T. 50 N., R. 81 W. Section starts at coal in bed of Dry Creek and extends to hills on the east.

b. Secs. 13 and 14, T. 51 N., R. 82 W. Section starts at the burning coal bed in SE. ¼ sec. 14.

c. Sec. 25, T. 51 N., R. 81 W. Section extends from coal exposed in dry stream bed to slag-capped hill on the east.

d. Secs. 9 and 14, T. 51 N., R. 81 W. The lowest coal shown is that reported in the well at the Healy ranch in sec. 9. Its quality is unknown. The second coal is that opened at the Healy mine in sec. 14.

e. Sec. 8, T. 51 N., R. 81 W. Section starts from bench mark 4395 at gate of Healy ranch.

f. NE. ¼ SW. ¼ sec. 3, T. 51 N., R. 81 W., and southeast into sec. 10. Section begins at level of Clear Creek.

g. Sec. 32, T. 51 N., R. 80 W. Section starts at coal in creek bank and extends southeast to slag-capped butte.

h. NE. ¼ NE. ¼ sec. 12, T. 52 N., R. 82 W. Section starts at level of Boxelder Creek.

i. NW. ¼ NE. ¼ sec. 10, T. 52 N., R. 82 W.

j. NW. ¼ sec. 8, T. 52 N., R. 82 W. Section begins at water level of Lake De Smet and extends to peak west of Kennedy ranch.

k. SE. ¼ sec. 3, T. 52 N., R. 82 W. Section starts at an opening on a coal taken to represent the Healy bed and extends to a hill one-fourth mile to the northwest.

l. Sec. 36, T. 52 N., R. 81 W. Section starts at opening on Healy coal.

m. Secs. 26 and 35, T. 52 N., R. 81 W. Section starts at creek level.

n. Sec. 24, T. 52 N., R. 81 W. Below C. N. Walters ranch on Clear Creek. Section starts at creek level.

o. Sec. 24, T. 52 N., R. 81 W. About 1 mile above Watts ranch on the east side of Clear Creek. Section starts at creek level.

p. Sec. 12, T. 52 N., R. 81 W. Section begins at water level on Clear Creek, half a mile above Copp ranch.

q. NE. ¼ sec. 1, T. 52 N., R. 81 W. The lowest coal shown is 10 feet above water level of Clear Creek below Copp ranch.

r. Sec. 35, T. 52 N., R. 80 W. The heavy coal is that about 60 feet above the Healy bed. The slag represents the "upper coal."

s. T. 52 N., R. 80 W. A general section for the eastern portion of the township. The thickest coal shown outcrops in sec. 3; the higher coals were noted in sec. 23.

t. Sec. 13, T. 52 N., R. 80 W. Section extends from the coal at Rattlesnake Springs to the slag capping the butte to the northwest.

u. T. 52 N., R. 79 W. A composite section for the western portion of the township. The highest coal shown occurs in the hill on the east side of sec. 18.

v. Secs. 3 and 24, T. 52 N., R. 79 W. A barometer section. The lowest coal shown is at creek level in sec. 30 of the township east.

w. NE. ¼ sec. 33, T. 53 N., R. 82 W. Section extends from creek level below the old Senff ranch to the peak above the road.

x. Sec. 27, T. 53 N., R. 82 W. Section extends from creek level near the Flying E ranch to the old mine shaft 1 mile southeast.

y. NW. ¼ sec. 26, T. 53 N., R. 82 W. Section extends from the "upper slag" to the monument on Monument Peak.

z. Sec. 23, T. 53 N., R. 82 W. Section extends from creek level near Collin ranch to the mine on the "upper coal," thence south to Monument Peak.

aa. SW. ¼ sec. 14, T. 53 N., R. 82 W. Section extends from mine above Collin ranch to the "upper slag" farther south.

bb. NE. ¼ sec. 14, T. 53 N., R. 82 W. Section starts at creek level.

cc. SE. ¼ sec. 12, T. 53 N., R. 82 W. Section starts at creek level.

dd. NE. ¼ NE. ¼ sec. 24, T. 53 N., R. 81 W. Section starts from bench mark 4153.

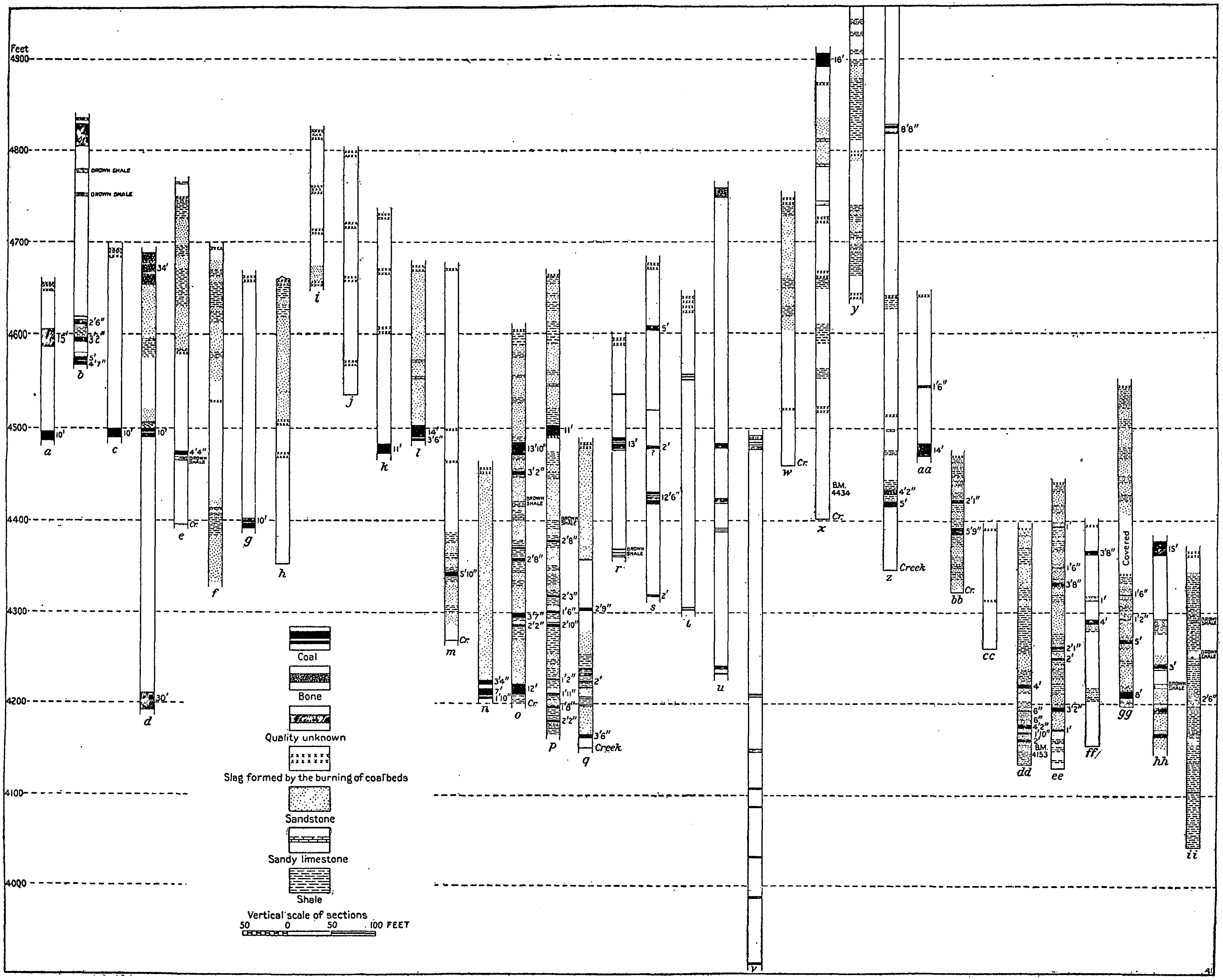
ee. NW. ¼ NW. ¼ sec. 13, T. 53 N., R. 81 W. Section starts from level of Piney Creek.

ff. SE. ¼ sec. 10, T. 53 N., R. 81 W. Section starts from level of Piney Creek.

gg. SE. ¼ sec. 5 and NE. ¼ sec. 8, T. 53 N., R. 81 W. The highest slag is that of the "upper coal."

hh. SE. ¼ sec. 4, T. 53 N., R. 79 W. Section from bed of coulée to supposed Healy coal.

ii. T. 53 N., R. 79 W. A general section for the northwestern portion of the township, compiled from a profile section from Clearmont to the "double crossing" of Clear Creek.



COLUMNAR SECTIONS, BUFFALO COAL FIELD, WYOMING.

The record of the deep well at Clearmont, about 4 miles north of the township line, showing a section doubtless equivalent to that underlying most of this area, is as follows:

Record of deep well at Clearmont.

	Feet.
Sandstone and shale	195
Coal	12
Sandstone and shale	101
Coal	18

No evidence of the quality or value of the beds thus reported has been obtained.

T. 53 N., R. 80 W.—The lowest coal bed exposed in this township is represented in the western part, where a rather pronounced group of coal beds outcrops on Clear Creek, approximately at water level, but the group is so broken by shale and bony partings that it rarely contains 30 inches of solid coal, so far as it has been observed within this particular township. This bed is doubtfully correlated with the Dry Creek bed to the south.

The Healy coal, which is the principal workable bed, is approximately 15 feet thick and occurs at an elevation of about 4,400 feet above sea level. It has been removed by erosion from the greater part of the township, but some areas remain, especially in the southwestern part, and to a smaller extent in the northwest corner. In many places, especially where the coal has been left in small areas on hilltops, it has burned, forming a conspicuous slag. A still higher bed, the Walters coal, about 170 feet above the 15-foot bed, remains in a few places. It is about 35 feet thick where exposed at its full thickness, but contains a great number of shale partings which render it of doubtful value.

Several other coal beds also are exposed, but though they are of good quality none of them are known to be above 2 feet 6 inches in thickness.

T. 53 N., R. 81 W.—The coal occurring near water level along Piney and Clear creeks, at the eastern edge of this township, clearly contains workable benches at some points. At this horizon 3 feet 9 inches of coal was measured at the mouth of Boxelder Creek, near the Hogerson ranch in sec. 14 (No. 7). Approximately the same bed, 6 feet or more in thickness, has been mined in the bank of Piney Creek opposite the old Sam Dickey ranch in sec. 8 (No. 5). It may be noted that this horizon is described as of no value in the report on the township to the east. A coal from 5 to 15 feet thick which probably represents the Healy bed is recognized at a horizon from 130 to 150 feet above this lowest coal, and another bed occurs from 150 to 170 feet above the Healy. (*dd, ee, ff, gg.*)

The upper coal beds occurring above water level are largely burned along their outcrops. The uppermost bed is burned more extensively than those below and for this reason probably the greater part of the area noted as occupied by slag from this bed may be entirely devoid of this coal. In many places the underground extent of the burning is a matter of much uncertainty.

T. 53 N., R. 82 W.—Two principal beds are here recognized—the Healy and the Walters. Other coals near water level have been noted along the valley of Piney Creek and doubtless belong to the same group as that described at approximately the same elevation in the township to the east. Nothing is known concerning the coal beds that may be present below water level. The Healy bed is approximately 120 to 150 feet above water level and the Walters coal 150 to 170 feet above the Healy. The Walters coal is extensively burned on its outcrops along the summits of the higher ridges and may be completely burned out over a large part of the area occupied by the slag of this bed. In a small area in the southern portion of the township coal beds at still higher horizons remain and have been prospected to a slight extent. (*w, x, y, z, aa, bb, cc.*)

T. 53 N., R. 83 W.—No complete sections of the coal-bearing rocks were obtained in this township. But one bed of coal was noted which may be over 30 inches thick. Unfortunately, no good exposures of this bed were found in which the coal could be measured or sampled. It is represented in the northeastern part of the township by an extensive bed of heavy slag, which was traced as shown on the map. It is thought to be the bed elsewhere described as the Healy coal of the Ulm coal group. A natural bank in the NE. ¼ sec. 2 revealed coal and brown carbonaceous shale to a thickness of 15 feet or more without exposing any bench that appeared of workable quality. This is, however, but negative evidence, for the great amount of burning at or near this horizon may be interpreted as indicating the possible existence of some more valuable portion of the bed. The western limit of this and other possible coal beds is concealed by the overwash of gravel. Coal is reported by several inhabitants at Kearney to have been mined for local use from a pit in the bed of Piney Creek, about one-fourth mile below the bridge that crosses that creek near the post-office. This locality, which would be about in the NW. ¼ SE. ¼ sec. 26, was searched, and, although considerable coal of a woody, subbituminous quality was found scattered about in and near the creek, the coal bed was not seen in place and was probably covered by stream wash. An old map of Fort Phil Kearney published in Carrington's description of this territory in the pioneer days of early settlement[a] shows a bed of coal

[a] Carrington, H. B., Absaraka, land of massacre, 1878, p. 147.

in the bank of Little Piney Creek, evidently somewhat west of the present road crossing. This coal was not found in the present work. A well at Chris Hepps's ranch, a little over one-fourth mile south of the above-mentioned locality, is also reported locally to have been drilled to a depth of 200 feet, encountering much coal through a thickness of 100 feet. These beds are thought to represent approximately the horizon of the Healy coal.

Much slag was noted in the SE. ¼ sec. 36 and extending beyond the limits of this township, continuous with the one or more coals that are extensively burned about Lake De Smet. It can not be stated from the evidence at hand whether coal is or is not present at the horizon of the upper burned bed, but if valuable coal exists near stream level in Piney Creek near by, that lower bed, unburned, doubtless underlies much of the adjoining area.

Little can be said as to the possible existence of other coal beds which may exist at considerable depth and whose outcrops are buried under the terrace and alluvial cover. Valuable coals of a considerably lower horizon than those exposed here are described by Taff as existing in the Sheridan field, composing the intermediate and Tongue River coal groups. He also notes, however, that as that part of the Fort Union including these lower coal groups is traced southward the coal beds thin out and disappear as the outer fringe of the conglomerate strata is approached, presumably owing to the more abrupt changes in sedimentation at places where the coarser deposits were accumulating in strong currents of water. It seems likely that the Kingsbury conglomerate member is a broad alluvial or delta deposit which locally represents the coal-bearing strata of adjoining fields and the extent of which, beyond the base of the mountain mass, is very uncertain.

T. 52 N., R. 79 W.—As in the township to the west, three principal coal beds are here represented. The highest occurs at an elevation of 4,650 feet above sea level. It has been almost entirely removed by erosion. One exposure was found in the eastern part of sec. 18, where the coal measured about 9 feet (*u*). If this is to be correlated with the Walters coal in the township to the west, the bed evidently thins toward the east.

The only important beds in the township are the two at altitudes of 4,530 and 4,470 feet, which are taken to represent the general horizon of the Healy coal. Exposures of the two beds one above the other were found in the NE. ¼ sec. 21. They are both of workable thickness and quality. A good exposure of the lower bed occurs in the NW. ¼ sec. 3 (No. 16) and another near the south line of sec. 30. The two beds occur also near the east line of sec. 1. Their thickness varies but is everywhere more than 3 feet. They do not, however, form marked areas of slag in this township, although they are in many places burned to a slight extent. Owing to the character of the surface and the absence of burning it was impossible to trace a continuous outcrop of the coal, and for purposes of classification dependence must be placed on the contours with some allowance for possible errors in vertical control.

Numerous other beds of coal occur in this township, especially in the lower part of the stratigraphic section. It is thought, however, that none of them are constantly over 30 inches in thickness. They are too thin, too poor in quality, or too variant to be considered valuable.

According to R. W. Stone, as already stated, a 5-foot bed of coal outcrops at the level of Crazy Woman Creek, about the middle of the township east of this. It should be stated, however, that this bed seems to thin toward the west. Along Wildhorse Creek, 18 miles farther east, it varies from 8 to 30 feet in thickness, and along Clear Creek it seems to be represented by a bed which is not over 2 feet thick. Still lower valuable beds outcrop on Powder River above and below Arvada, 9 miles northeast of this township.

In the deep well at Clearmont, 9 miles north of this township, a 12-foot bed of coal is reported at 195 feet and an 18-foot bed at 308 feet; these beds may extend continuously underneath this area.

T. 52 N., R. 80 W.—There are three beds of coal that deserve attention in this township. The highest, which is here termed the Walters coal, occurs at an altitude of 4,650 feet and where not removed by erosion has been for the most part burned. It is from 25 to 30 feet thick, but contains many bony seams and appears to vary much in quality from place to place.

At 120 feet below the bed just described occurs another, which, as measured in sec. 35, has a thickness of 13 feet (*r*). It is of good quality. Several exposures of this bed were found in the southeastern part of the township on the northeast flank of the divide, but in the northwestern part of the township no measurements were obtained, although several sections indicate coal or slag at this horizon.

Sixty feet below this bed, at an elevation of 4,470 feet above sea level, occurs another coal bed of about the same thickness. The two beds were found, one above the other, in sec. 3 of the township just south of this. They are taken to represent the general horizon of the Healy coal. In sec. 11 of this township a coal bed 13 feet thick appears to correspond to the lower of the two beds (No. 14). Heavy slag commonly occurs along the outcrop of these coal beds in the township. As the two beds are but 60 feet apart and are similar to each other, it is very difficult to distinguish between them in isolated exposures.

In the NW. ¼ sec. 32 of the township to the south, 11 feet 8 inches of coal is exposed in the bed of Dry Creek. If this bed is constant it should underlie the greater part of this township, but its equivalent was not found here.

T. 52 N., R. 81 W.—The lowest coal recognized in this township is approximately at water level. It was noted in sec. 35 and also in sec. 1. As it appears to differ in thickness and quality in different places and is usually much broken by shale and bony partings, it is doubtful if it can be considered generally workable. (*n, o, p, q.*)

In the NW. ¼ sec. 35 a coal bed 5 feet 10 inches thick was discovered 70 feet above water level (*m*). It seems probable, however, that this coal is not above 30 inches thick over an extensive area.

Probably the most important bed in this part of the field is that designated the Healy coal. This is noted at altitudes of 4,450 to 4,475 feet in the southern half of the township, west of Clear Creek. The altitude of a bed thought to be the same in the northwestern part of the area is slightly above 4,500 feet. A number of sections of this bed show the thickness to be from 13 to 19 feet, including shale partings, which are, however, of minor importance. This bed has been mined for local use in the SW. ¼ SW. ¼ sec. 36, and a detailed section of the bed is given in Plate X, No. 13. It seems fair to assume that this is a workable coal bed throughout the township wherever it exists. Its outcrop is commonly indicated by a marked slag.

The so-called Walters coal, 170 feet above the Healy bed, is extensively burned in the higher ridges in this township, but where it remains unburned it is of considerable thickness. It measured 28 feet of coal, including partings in the NE. ¼ NW. ¼ sec. 3; 34 feet in the NW. ¼ NE. ¼ sec. 16; and 28 feet 4 inches in the NW. ¼ SE. ¼ sec. 18. The character of this coal bed is similar in nearly all the exposures. In each place some of the coal is evidently good. The weathering of the bed, however, brings out numerous thin bone and shale partings that break up the coal into minor benches, making the bed difficult to mine. If mined the coal would probably be high in ash. It is doubtful if the bed in many places is at present commercially valuable.

T. 52 N., R. 82 W.—The principal coal bed within this township is somewhat doubtfully correlated with the Healy coal. The slag of three higher beds is present, but the coal is for the most part completely burned. No good exposures of the higher coal beds occur, although in the hill on the south side of sec. 4 an old entry on one of these beds was observed.

One of the principal coal openings in this township is on the Healy bed in the SE. ¼ SE. ¼ sec. 3. The coal is exposed in the bed of a draw. The bed as shown in section No. 9, Plate X, contains about 9 feet of coal, excluding the shale partings. (See also *k.*)

In the SW. ¼ sec. 12 is exposed a coal bed which is supposed to be the same as that in sec. 3, just described. The total thickness of the bed is 18 feet 7 inches, but the coal is too badly weathered to permit a detailed section.

In secs. 19 and 20, on the southwest side of Lake De Smet, two workable beds come to the surface at a horizon that seems to correspond to the Healy. The beds dip 4½° NE. The interval between them was not measured but is approximately 60 feet. The upper bed is 6 feet, the lower 5 feet in thickness (No. 10). The coal in both is of good quality and has been mined to a small extent.

In the SE. ¼ sec. 1 of the township to the west at least 4 feet of coal is exposed in the bank of Shell Creek. This coal has probably been removed by erosion from portions of the alluvial flat north of Lake De Smet. No other exposures of the bed occur.

No coal beds were discovered southwest of those just mentioned near Lake De Smet. The coal beds near Arvada described by Stone and those of the Sheridan district described by Taff, were they continuous, should underlie this area and come to the surface between it and the mountains. No trace of those coal beds was found, however. The surface is partly obscured by the mantle of gravel that skirts the mountains, yet outcrops of bed rock may be found along the stream beds. It seems probable that the lower coal beds do not exist here and that they may be represented and replaced by the Kingsbury conglomerate member. (See also *h*, *i*, *j*.)

T. 52 N., R. 83 W.—No coal bed is known in this township, the southwest half of which is occupied by rocks older than the Fort Union. The strata dip to the northeast.

Slag in the northeast corner of the township (in and near sec. 1) indicates a coal bed that appears to be for the most part burned. This bed is very doubtfully correlated with the Walters coal to the east. If this correlation is correct, there should be workable coal 170 feet below this bed. Little weight should be attached to such an assumption, however, as the information is too meager to warrant much more than a guess. The outcrop of the workable coal at the southwest end of Lake De Smet would probably be exposed through a part of this area were it not concealed by the extensive gravel and bowlder beds, but that coal bed is known to vary in quality and thickness and can not be assumed to be continuously workable.

Coal was observed in the stream wash on the upper waters of Rock Creek, in the northwest corner of sec. 24. This is of a quality similar to that of the workable coals of this district, but no evidence of its source was found. It is assumed to be from some of the carbonaceous beds of the Piney formation, which are of no value in this general region.

T. 51 N., R. 80 W.—The Dry Creek coal bed is exposed along the stream of that name in secs. 22, 29, and 32 (Nos. 23, 24, *g*). In sec. 32, 11 feet 8 inches of good coal was measured. No outcrops of this bed were found in the northeastern portion of the township.

The coal elsewhere referred to as the Healy bed occurs about 150 feet above the Dry Creek bed. It measures 16 feet in the NW. ¼ sec. 16, the coal being of good quality. It underlies an area of about 6 square miles in the northern part of the township and about 2 square miles in the southern part.

A thick bed of carbonaceous shale, including some coal, represents the Walters coal in this area and is found from 150 to 170 feet above the Healy.

T. 51 N., R. 81 W.—There are two principal coal beds in this township. The lower, which is here termed the Healy, occurs at an elevation of 4,500 feet above sea level. The Walters coal is 175 feet above the Healy bed.

A good exposure of the Healy coal occurs in the NW. ¼ SE. ¼ sec. 14 (*d*). Coal is obtained here for the Healy ranch on Clear Creek. The portion of the bed exposed is 10 feet thick and the coal is of excellent quality (No. 21). An exposure of the same bed occurs in the SW. ¼ SW. ¼ sec. 36 of the township to the north, where 17 feet 6 inches of coal is exposed (No. 13). A bed taken to be the Healy outcrops in the southern part of sec. 5 and in the NE. ¼ sec. 7. Just west of the township line, between sec. 18, T 51 N., R. 81 W., and sec. 13, T. 51 N., R. 82 W., are several abandoned entries which appear to be at the same horizon. A little east of the center of sec. 25 coal appears in the bed of a draw. It is of excellent quality and has been mined to a moderate extent. It appears to be at the Healy horizon (*c*). Coal of rather poor quality has been mined from a bed exposed in a draw in the western part of sec. 36. The interval to the next slag above is 150 feet. This coal is probably somewhat above the Healy horizon.

The Walters coal appears in small isolated areas along the divide between Clear and Dry creeks. In the southern part of sec. 13 the bed was formerly worked as an open bank. It measures 34 feet in thickness, but is so broken by partings of bone that it is inferior in quality to the Healy coal.

In the SW. ¼ sec. 20 a coal bed 12 feet thick is exposed which seems to be about 50 feet below the Healy (No. 22). In sec. 9 a bed of coal 3 feet thick appears at about this horizon, but no other exposures of the bed were found. It seems not unlikely that it varies in thickness and quality.

It is reported that in drilling a well at the Healy ranch a coal bed 30 feet thick was struck at 160 feet below the flood plain of Clear Creek. A few miles down Clear Creek, in the next township north, a coal bed at this horizon comes to the surface, but is much broken by shale and is of little value. (See also *e*, *f*.)

T. 51 N., R. 82 W.—The slag that occurs along the east township line probably represents the Healy and Walters coals, the latter being 175 feet above the former. In many places the slag beds are so badly confused by slumping that it is difficult to distinguish the different horizons. Just east of sec. 13 several entries have been opened on a bed of coal, which is taken to be the Healy. In the SE. ¼ sec. 23 an entry has been opened at about the same horizon. This coal is said to have been rather poor in quality. In the SE. ¼ sec. 14 a series of beds at the same horizon is exposed in a coulée (No. 17, *b*). One of the beds is burning to a slight extent.

The Mitchell mine, in the NE. ¼ sec. 26, was opened in 1907. A section of the coal beds exposed in the slope is given in No. 18, Plate X. The bed at the top of the section was first worked. It contained good coal, but is so broken by shale partings that an attempt was made to reach other beds. A series of coals was encountered, of which the lowest bed is the one at present mined. Another bed over 4 feet thick occurs 10 feet above it. The coal beds dip slightly in a direction S. 40° W. When visited the mine was putting out about 50 tons a month. The slope is 220 feet in length and has an inclination of 33° from the horizontal. It is necessary to pump 3,000 gallons of water from the mine every twenty-four hours.

In the western part of sec. 36 is the oldest mine in this township, owned by G. W. Munkre. The coal bed here mined is 85 feet below the surface. Above it are numerous beds of bony coal, said to be of no value. The coal dips slightly toward the southwest. A section is given on Plate X (No. 19). The output of the mine during the winter months is about 27 tons a day.

It is reported that on the hill just southeast of Buffalo a drill hole was put down to the depth of 185 feet and that 52 feet of coal was encountered in the last 64 feet, but none of the beds was over 2½ feet in thickness.

In the western portion of the township outcrops are obscured by extensive gravel beds, and no coal is known.

T. 51 N., R. 83 W.—So far as known no coal of value occurs within this township. In the northeast corner, however, some beds of coal and brown carbonaceous shale were found overlying the Kingsbury conglomerate member. The largest of these is in the bank of Rock Creek, near the township corner. Here one bed of coal measures about 6 feet in thickness, but is so poor in quality that it is probably of no value. Other carbonaceous beds doubtless occur in the older Cretaceous rocks of the area; but, as elsewhere stated, they are, so far as known, of no commercial value.

The rocks that outcrop in this township consist of the lower part of the Fort Union ("De Smet") and older formations. As these have a general northeasterly dip, they pass beneath and normally underlie the more valuable coal beds of this region, which occur at a horizon well up in the Fort Union formation, their base being estimated to lie from 1,500 to 2,000 feet above the Kingsbury conglomerate member. Several of the lower beds of this group are represented at the mines near Lake De Smet, about 2 miles northeast of this township, as already described.

T. 50 N., R. 80 W.—A thick bed of coal has been observed outcropping at many localities near water level on Crazy Woman Creek in this township. It is thought to represent the bed elsewhere described as the Dry Creek coal, which is well exposed near the Healy sheep pens, on Dry Creek, a short distance north of this township. The measured sections of this bed near the southeast corner of the township are shown graphically in Plate X (No. 27). As this bed appears to be workable both northwest and southeast of this township, ranging from 6 to 12 feet in thickness, and as it also outcrops in sec. 8, T. 49 N., R. 80 W., with a thickness of 6 feet, it seems fair to assume that it underlies the whole area and is also workable there.

The coal elsewhere referred to as the Healy bed occurs about 150 feet above the Dry Creek bed. Just west of the township line, in sec. 24, T. 50 N., R. 81 W., this coal is exposed in the creek bank. It is 11 feet thick and the quality is good (No. 26). The same bed outcrops in the NE. ¼ sec. 7, the NW. ¼ sec. 8, the SE. ¼ sec. 3, and the NE. ¼ sec. 10. Exact measurements were not obtained, but the bed appears to be of fairly uniform thickness. It underlies a considerable area along the divide between Dry and Crazy Woman creeks, as shown on the map.

From 150 to 170 feet above the Healy bed is found the Walters coal, which is here a thick bed composed largely of carbonaceous shale with coaly streaks and is of doubtful commercial value. Slag on one or two of the highest summits near the center of the township represents coal beds higher than the Walters coal. These are, however, completely burned out.

T. 50 N., R. 81 W.—Above the road in the NW. ¼ sec. 5 of this township several entries have been made on a coal bed just below the slag that caps the ridge. The old workings are now abandoned and no exposure of the coal was seen. On the flat in the SW. ¼ sec. 5, a slope has been sunk to a bed some 25 feet below the surface. This coal is reported to be of excellent quality and to have a thickness of about 10 feet (No. 25).

In the NE. ¼ sec. 24 a coal bed that is taken to represent the Healy occurs at creek level (*a*). It is 11 feet in thickness and of excellent quality (No. 26). In the NW. ¼ sec. 12 an exposure of a bed of bony coal occurs at almost the same horizon. These beds may be identical, but it is the opinion of the authors that one occurs a little above the other, the two being so near together that it is impossible to distinguish them in isolated exposures. A good coal appears at this horizon in sec. 25 of the township north of this.

The coal beds above the Healy coal in this area may be disregarded so far as present availability is concerned. They occupy only a small area and are for the most part burned.

About a mile northeast of this township a 10-foot bed of good coal outcrops at water level in Dry Creek. On Clear Creek a bed at the same horizon is so broken by shale partings as to be of little value, but to the south along Crazy Woman Creek this bed runs from 6 to 8 feet in thickness as far as Trabing. It seems probable that this coal underlies the township under discussion, but, as stated, it may vary in quality and section.

T. 50 N., R. 82 W.—The southwestern half of this township is occupied by rocks older than the Fort Union. Of the Fort Union itself chiefly the lower portion, which is apparently barren of workable coal beds, is exposed within the area. The strata dip to the northeast at very slight angles. The upper Fort Union coal beds occur just north and east of the township. The Munkre mine in sec. 36, T. 51 N., R. 82 W., is about half a mile due north of sec. 1 in this township. An exposure of coal over 3 feet thick outcrops less than one-fourth mile east of the southeast corner of sec. 1. A well on the Jones ranch in the center of sec. 7, T. 50 N., R. 81 W., half a mile east of sec. 12 of this township, is reported to have shown the following strata:

Section of coal beds in well in sec. 7, T. 50 N., R. 81 W.

	Feet.
Clay and gravel	20
Coal	32
Clay	5
Coal	8
Clay	4
Coal	8
Clay	1
Coal	32
Interval drilled below this, but showing no coal	50
	160

In interpreting this well record, however, it must be remembered that the thick beds of coal noted therein may not have been of workable quality and that a carbonaceous shale might easily have been interpreted as coal by a driller not experienced in the identification of workable coal. From the evidence in the adjoining townships it would seem fair to assume that at least a portion of the valley area in the northeast corner of the township may be underlain by beds of workable value.

T. 49 N., R. 80 W.—The township is underlain by the upper beds of Fort Union age, including the coal beds of the Ulm coal group as distinguished by Taff in the Sheridan district. The strata show a low dip to the southeast through the northern part of the township, although the principal workable coal bed remains approximately at water level along Crazy Woman Creek across the whole township. Some slight structural irregularity was noted east and northeast of the Bilderbach Lakes, this being apparently a low anticlinal warp separating them from the valley of Crazy Woman Creek.

A large part of the western half of the township is composed of low, broad, flat valleys and slopes covered by a white clay soil strewn with scattered pebbles and bowlders, but showing no bed-rock exposures. Beyond these lower valley lands are terrace or mesa remnants capped by heavy deposits of gravel and bowlders. Over most of this area no evidence whatever of the underlying bed rock or the coals that it may contain was to be had from a mere examination of the surface.

The Dry Creek coal is exposed at various points along Crazy Woman Creek throughout the township, as already mentioned. In the northern portion of sec. 23, 10 feet of coal was measured. The bed is of considerable thickness also on the north side of sec. 1. In the NW. ¼ sec. 8 is exposed 6 feet of good coal which is thought to represent the same bed. The slight doming of the strata in the central part of the township makes the distribution of this coal bed uncertain. Over portions of the area it has been removed by erosion and the rolling grassy surface makes the outcrop difficult or impossible to trace.

A bed of good coal that occupies small areas in the central and southeastern portions of the township is about 130 feet above the bed of Dry Creek. It is thought to represent one of the coal beds at the Healy horizon. In the SE. ¼ sec. 22, 5½ feet of good coal is exposed in this bed. In the SE. ¼ sec. 15, 5 feet of coal is exposed, but in the SW. ¼ sec. 11 this bed appears to be worthless. Because of the doming of the strata the area underlain by this coal in the central part of the township is probably not over 2 square miles. In the southeastern portion of the township the same bed was noted in the SW. ¼ sec. 35, where 5 feet of good coal is exposed.

T. 49 N., R. 81 W.—The greater part of this township is occupied by the gravel terraces that skirt the mountains. The rocks belong to the lower portion of the Fort Union formation. They dip northeastward at very low angles. So far as known only one exposure of coal occurs within the township, and this bed is but 2 feet in thickness. It occurs in the NE. ¼ sec. 35. In sec. 2 an exposure of slag occurs, but the coal by which it was formed was evidently much broken by shale partings. The valuable coal beds lie to the northeast outside the limits of the township.

T. 48 N., R. 80 W.—As in adjoining townships, the geologic structure and stratigraphy of this area are very simple. The underlying strata are of Fort Union age, including the Ulm coal group as distinguished by Taff in the Sheridan district. They lie nearly horizontal, showing at places a low dip to the east, but in the absence of accurate level data the dip can not be positively determined. The northwestern part of the township is largely covered by surficial beds of bowlders and gravel that form an upland terrace or area of rolling topography and conceal most of the bed rock. The broad bottom lands of Crazy Woman Creek are largely concealed in a similar manner by the more recent alluvial deposits. The outcrops of coal from 6 to 8 feet thick that were discovered at various places along the creek valley apparently represent an approximately continuous horizon, which is taken to be that of the Dry Creek coal bed, but its extent beyond the limits of the actual outcrops is very uncertain. East of Crazy Woman Creek the bed-rock formations are more continuously exposed but show very little evidence of coal either in outcrops or by burning. Coal reported on the Powder River side of the divide, east of this township, may correspond to the coal found in Crazy Woman Creek. This appears to give some warrant for supposing the whole area east of the creek to be underlain by workable coal.

The Dry Creek coal mentioned above is mined in the bank of the creek in the SE. ¼ sec. 30, where about 10 feet of good coal is exposed. In the SW. ¼ sec. 21 this coal appears in two benches of 7 feet and 4 feet (No. 30). In the NW. ¼ sec. 15, 10 feet of coal is exposed (No. 29), and in the SE. ¼ sec. 3, 5 feet on the same bed (No. 28). Other exposures occur along the creek at intervals throughout the township.

T. 48 N., R. 81 W.—The greater portion of this township is covered by the Fort Union formation. The beds rise gradually from northeast to southwest across the township, and in secs. 30 and 31 the underlying shale of the Piney formation comes to the surface with a dip of 10° and a strike of N. 17° W. For the most part the country is gently rolling and grass covered. Along Crazy Woman Creek marked gravel terraces are developed. No coal is exposed within this township.

In the SE. ¼ sec. 30 of the township to the east 10 feet of good coal outcrops in the bank of Crazy Woman Creek, as already described, and this bed may be traced downstream throughout the township, its dip being about equivalent to the grade of the creek. This coal bed may or may not underlie the eastern part of the township under discussion. No trace of it was found, as there are very few bed-rock exposures of any kind in this area.

In sec. 17 of the township to the south two coal beds 8 feet thick come to the surface with a dip of 7½° and a strike of N. 18° W. These beds appear to vary in thickness along the outcrop. No exposures of them were found north of Crazy Woman Creek, and it seems doubtful whether or not they are present in this township.

T. 47 N., R. 80 W.—Very few exposures of any sort occur within this township. The country is for the most part gently rolling and grass covered. The rocks are probably of Fort Union age. To judge by dip readings north and west of the area, there appears to be a slight dip to the southeast in the northwestern part of the township. For the most part, however, the rocks seem to be horizontal.

In the SE. ¼ sec. 30 of the township to the north 10 feet of coal has been worked in the bank of Crazy Woman Creek. This bed can be traced downstream throughout the township. If it is continuous southward it underlies the township under discussion, but no definite statements can be made concerning it.

In the western portion of the township to the west several coal beds from 3 to 8 feet thick come to the surface with a dip of about 7° and a strike of N. 18° W. These beds do not, however, appear to be constant in thickness along the outcrop. It is not unlikely that they vary in quality and thickness from place to place and that they underlie this township at too great depth for profitable mining.

T. 47 N., R. 81 W.—The eastern half of this township is covered by the rocks of the Fort Union formation. These rise gradually toward the west, and in the middle of the township the basal beds come to the surface with a dip of 9° and a strike of N. 18° W. Farther west the shale of the Piney formation appears below the Fort Union.

There are two groups of workable coal beds in this township, one at the base of the Fort Union and one at the top of the Piney. The best exposure of the Fort Union coals occurs in the eastern part of sec. 28 in a deep coulée (No. 36). At the base of the section exposed is a bed of good coal about 6 feet thick. Above this are a number of unimportant beds of coal and coaly shale. The bed may be traced for three-fourths of a mile northeastward, but beyond this point it is covered. No exposure of a bed comparable in thickness to this one is to be found to the southeast, and it is impossible to say how regular this coal may be in thickness and quality.

Considerably above this horizon, about three-fourths of a mile to the east, a bank has been opened in the NE. ¼ sec. 27, where 4 feet of good coal is exposed. This bed seems to be about on the strike of the line of slag hills in secs. 10 and 15 and may represent the same bed. No other exposures of the coal bed are to be found, however.

Two workable beds of coal near the top of the Piney formation are exposed in sec. 17. The upper bed contains 7 feet 6 inches of solid coal. An entry 60 feet in length has been run in on this bed, in the SE. ¼ SW. ¼ sec. 17, to supply coal for local use (No. 33). Ten feet above this bed is another one 3 feet 4 inches thick.

Some 30 or 40 feet lower in the section is a bed containing 8 feet of coal (No. 32). Although somewhat broken by shale partings, this bed is still workable.

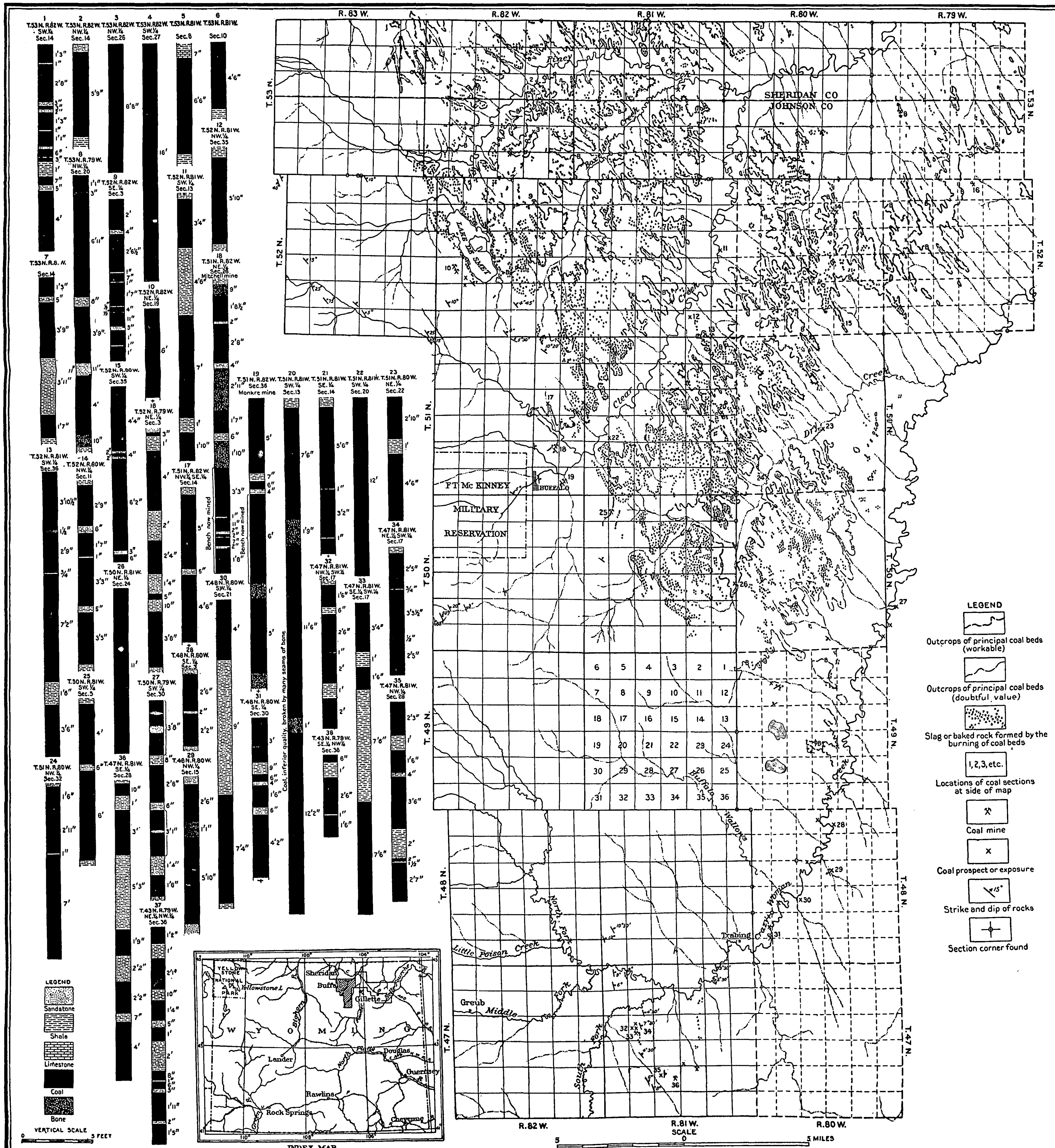
In the NE. ¼ sec. 29 and the NW. ¼ sec. 28 (No. 35) coal beds 30 inches or more in thickness were found, but they are in no way comparable to the beds above described. If they represent those coals, the beds have decreased greatly in value. In the northwestern portion of the township, along the line of strike of these coals, exposures are obscured by the alluvium of Crazy Woman Creek or by gravel.

T. 43 N., R. 79 W.—This township is situated on Powder River, 18 miles south of the area shown on Plate X. It was examined at the close of the field season, after the disbanding of the party, in anticipation of future work. It gives a general idea of the geology of a considerable belt of coal-bearing rocks which come to the surface along the flank of the Salt Creek dome in this region. As the township is outside of the area of the large map, a separate diagram from the original field sheet is here reproduced (Pl. XI).

The general succession of the rocks has been described under "Stratigraphy." On the north side of the river most outcrops are obscured by extensive gravel-covered terraces. Here the rocks appear to be for the most part horizontal, but in the NE. ¼ sec. 8 a dip of 1° NE. was observed, with a strike of N. 75° W. South of the river the beds rise gradually, with increasing dips, until they form a marked ridge extending across the southern portion of the township, in which the beds dip from 15° to 18°. Behind this first ridge is a valley and south of that still another ridge, the rocks dipping 22°. The strike in the southwestern portion of the township is N. 81° W. In following the ridge westward the strike swings somewhat toward the north.

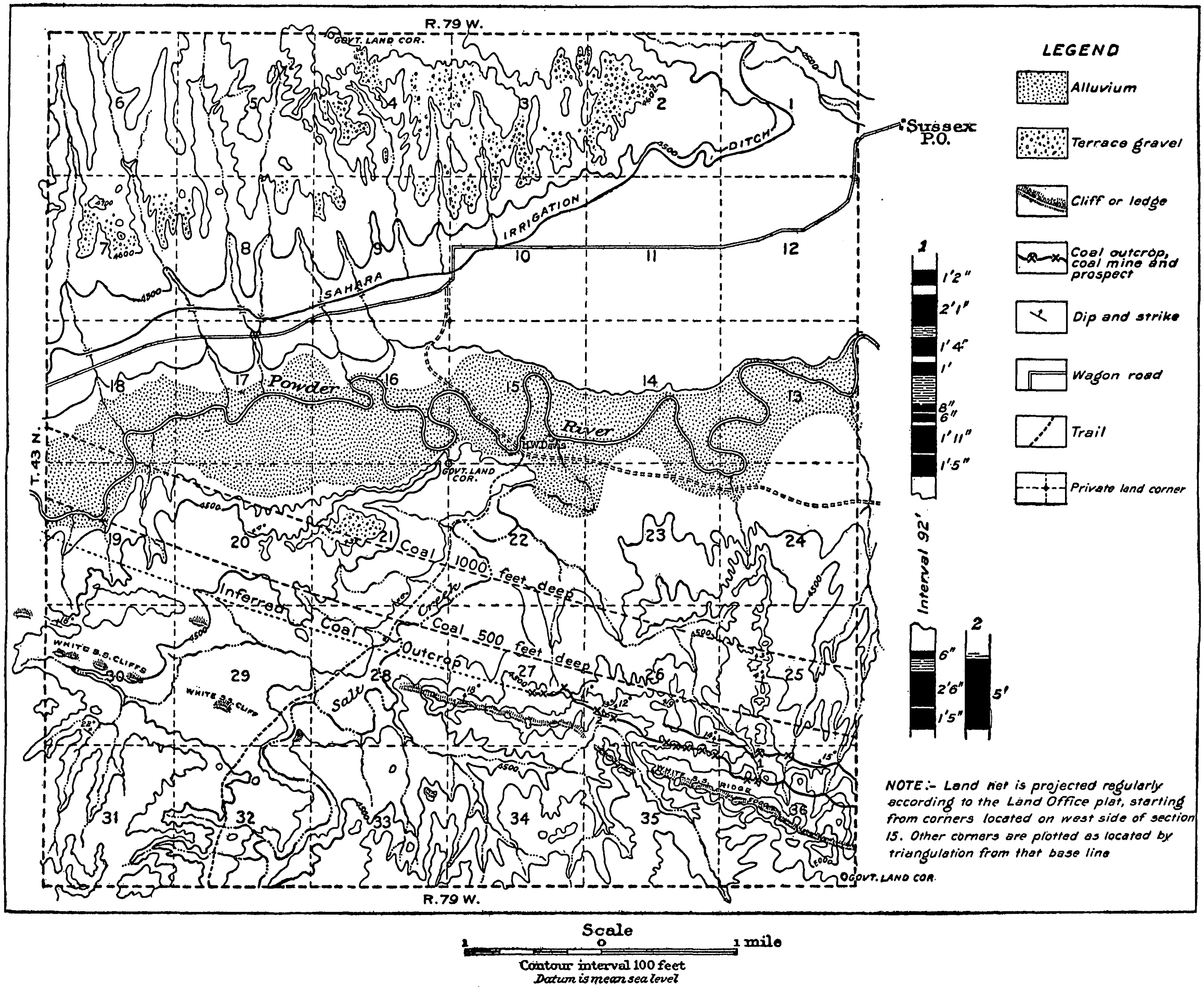
In the SW. ¼ sec. 30 a dip of 22° was observed. It is estimated that from that point northeastward about 5,100 feet of strata are exposed. No dips were measured southwest of this point, but the beds gradually flatten in that direction. The coals are confined to a narrow belt just north of the marked sandstone ridge. Detailed stratigraphic sections of the barren strata were not made.

Coal occurs at only one horizon in this township, flanking the high pine ridge on the northeast. There are two principal coal beds 90 feet apart (Nos. 37, 38, Pl. X, 1, 2; Pl. XI). In the northern portion of sec. 36 both are good, and coal is obtained for local use from the upper bed. In sec. 26, only three-fourths of a mile northwest of the open mine, the upper bed is bony and of no value, but the lower bed



MAP OF BUFFALO COAL FIELD, WYOMING, SHOWING SECTIONS OF COAL BEDS.

By H. S. Gale and C. H. Wegemann.



MAP OF T. 43 N., R. 79 W., WYOMING.

By C. H. Wegemann.

appears to be good and was formerly worked in the SW. ¼ sec. 26 for a short time (Pl. XI, 2). H. W. Davis states, however, that the coal ran so high in sulphur that it could not be used as a domestic fuel. It is impossible to trace the coal beds beyond the middle of sec. 27, for they are concealed in the Salt Creek valley and on the rolling grassy divide beyond. Beds which appear to represent the same horizon are worked in T. 44 N., R. 81 W.

There seems to be no doubt that these coal beds vary in quality and thickness. It is calculated that the upper bed is approximately 1,200 to 1,300 feet below the surface at the Davis ranch. It probably underlies all the northeastern portion of the township at about that depth, as the rocks are nearly horizontal.

THE COAL FIELD IN THE SOUTHEASTERN PART OF THE BIGHORN BASIN, WYOMING.

By E. G. Woodruff.

INTRODUCTION.

This paper is a preliminary report on the coal field in the southeastern part of the Bighorn Basin, Wyoming,[a] extending from No Wood Creek, on the north, around the southeastern point of the basin to Bighorn River.

During the summer of 1907 C. W. Washburne examined the coal fields on the east side of the basin from a point north of the Montana line as far south as No Wood Creek, and during the same time the writer examined the coal fields on the west side from the Montana line to Bighorn River. The field described in this report lies between the two just mentioned and the work in it completes the study of the coal beds of the Bighorn Basin. All of this work was done under the immediate supervision of C. A. Fisher, who had previously made a reconnaissance survey to obtain data for a report on the geology and water resources of the region.[b]

Max A. Pishel served as principal assistant in the field and rendered valuable services in the office in compiling data for the map. Jay H. Cather and Roy L. Nelson also assisted in the field work and much of the value of this report is due to their intelligent cooperation. The purpose of the work was to examine the coal beds and to determine their situation with respect to the points located by the land surveys of the area, in order that the public land containing coal might be segregated from noncoal land and a value placed on each legal subdivision containing a workable bed of coal. As a basis for this classification the coal beds and geologic formations were studied in the field and their position and extent were shown on a map made during the progress of the work. A copy of the map is included in this report as Plate XII. The relative positions of objects shown on this map were determined by horse pacing in the northern part of the field and by a system of triangulation by plane table in the southern part.

Marked land corners were found to be lacking except along No Wood Creek and Bighorn River, where resurveys have been made.

[a] A detailed report on the coal beds of the Bighorn Basin is now in course of preparation, to be issued later as a separate bulletin.

[b] Fisher, C. A., The geology and water resources of the Bighorn Basin, Wyoming: Prof. Paper U. S. Geol. Survey No. 53, 1906.

As a result of this condition the outcrops of coal beds can not be accurately located with regard to land lines. It should be borne in mind, therefore, in consulting the map, that locations in the interior of the field are only relative and not determined with reference to land corners.

LOCATION AND EXTENT OF THE FIELD.

The coal-bearing rocks outcrop in a belt 6 to 12 miles wide, extending southeastward from the lower course of No Wood Creek along Sand and Cottonwood creeks to the east side of the "Honeycombs," then turning west across No Water Creek to Bighorn River. The field contains about 600 square miles. It is limited on the west and northwest by badlands and on the east and southwest by the dissected plains adjacent to No Wood and Kirby creeks. The region partakes of the character of both provinces—badlands on one side and broken plains on the other. The extent of the field is shown on the map (Pl. XII), and its location in a larger area by the smaller index map on the same plate.

TOPOGRAPHY.

The accessibility of coal and the ease with which it is transported from any region depend on the topography; hence a detailed description of the surface features is given. Erosion is rapidly progressing everywhere, forming deep, narrow valleys, across which wagon roads are maintained with difficulty. In the northern part of the field Sand Creek follows the strike of the beds from the southern part of T. 47 N., R. 91 W., to No Wood Creek, in a narrow gorge joined by many small branches flowing in deeply cut channels from the moderately dissected regions on either side. One wagon road from Bonanza to Worland crosses this coulée in the northwestern part of T. 48 N., R. 91 W., and another from Tensleep to Worland extends across the badlands near the head of the stream. On both of these roads the grades are so steep that heavy loads can be hauled over them only with great difficulty.

Cottonwood Creek, which drains the region east of Sand Creek, has a number of branches in the badlands in T. 46 N., Rs. 89 and 90 W., that join near the north line of the township to form the main channel. From the junction of these branches the creek flows northward in a broad, moderately open valley. The Worland-Tensleep road crosses this creek $1\frac{1}{2}$ miles north of the junction of the main branches. Another wagon road from the north extends up the valley to the small coal mine in sec. 34, T. 47 N., R. 90 W., and thence over the divide to Little Cottonwood Creek. The road to Tensleep is very hilly, but the one in the valley crosses only a few hills and most of these are short.

The head branches of Little Cottonwood Creek have cut the area north and northwest of Tensleep Butte into sharp ridges, spurs, and points separated by narrow V-shaped valleys. Though no wagon road crosses this area, it would be possible to construct one from Bud Kimball Draw leading through the badlands west of Tensleep Butte and along a divide into the valley of Cottonwood Creek.

Bud Kimball Draw and Buffalo Creek rise on the edge of the badlands locally known as the "Honeycombs" and extend eastward across the area. There is a narrow belt of badlands about the heads of these streams along that part of the west side of the field, but elsewhere the topography is that of a moderately dissected plain crossed by coulées or narrow steep-sided gorges. This portion of the field can be traversed with moderate ease along the streams or divides, but passage across them is difficult. The only wagon road leading to this district enters from the east and terminates in the district; the badlands on the west and coulées difficult to cross in a north-south direction prevent access over roads from other directions. One of the minor roads follows Bud Kimball Draw from the valley of No Wood Creek to the mine at the head of the draw and has a north-east branch to Tensleep; another leads along the divide between Buffalo Creek and Bud Kimball Draw to coal prospect No. 6, near North Butte.

The southeastern part of the field is traversed by No Water Creek and its branches. The name aptly describes the character of this stream, though at times the flood water from a large area finds its way to Bighorn River through its channel. The stream enters the field from the southeast in T. 44 N., R. 90 W., and continues in a northwest course for about 15 miles. The branches from the south-west are short and steep from their source along an escarpment of northeastward-dipping beds; the branches from the northeast are longer and have a smaller gradient. A road with many short, steep grades follows the valley in general, but is forced away in many places by deep, narrow gorges cut by the branches where they enter the main channel. This road passes the No Water mine and furnishes a difficult outlet for the coal. Other roads enter the No Water Valley from the area across the divide to the east.

Kirby Creek drains the southwestern part of the field, and a few short, steep-sided ravines rise in the high rugged Winchester Hills and extend directly to the narrow valley of Bighorn River. Wagon roads extending down the Kirby Creek valley and coming into it from the north lead to fords at several places along the river.

The workable coal beds of this field are not easily accessible, because of the rough character of the country as described above. They lie in badlands or slightly dissected plains, and, with the exception of the beds near Bighorn River, are more than 10 miles from market. The region is uninhabited except along No Wood Creek and Bighorn River, and the only running water found throughout a great part of the area is derived from alkaline springs. One well in the valley of Buffalo Creek contains a small quantity of slightly alkaline water, and another in the valley of Cottonwood Creek at the crossing of the Worland-Tensleep road furnishes about a barrel a day. No railroad crosses the coal field, though a branch of the Chicago, Burlington and Quincy Railroad runs along Bighorn River, on the western edge of the area mapped, to Kirby. In many places the wagon roads are poor and have uneven gradients.

GEOLOGY.

STRATIGRAPHY.

The only geologic report on this field is that of C. A. Fisher,[a] who recognized that the coal-bearing rocks were susceptible of subdivision into several formations, but the time at his command and the nature of his work demanded the mapping of only broad divisions.

As recognized by the present writer, the order, age, character, and thickness of the formations are shown by the following table:

Coal-bearing and associated formations in the southeastern part of the Bighorn Basin.

System.	Group.	Formation.	Character.[b]	Thickness (feet).
Tertiary.		Wasatch formation.	Sandy shale and conglomerate, gray, pink, and yellow colors alternating.	Not wholly exposed in this field.
		Unconformity.		
		Fort Union formation.	This formation occurs in two divisions; the upper member is yellowish tan, gray, and lavender colored sandy shale and sandstone; the lower member is yellowish tan and rusty colored, slightly sandy shale, with lenses of coal locally developed in the lower part.	1,200 to 2,900
		Unconformity.		
Cretaceous.	Montana.	Undifferentiated Montana.	These rocks may be separated into three divisions. The upper member consists of gray and yellowish tan sandy shales, alternating with brown carbonaceous shale and coal beds. These where recently eroded form a somber-colored banded exposure. The middle member consists of very soft yellow sandstone and sandy shale and soft sandstone concretions. This member thins rapidly to the west. The lowest member is made up of soft gray sandstone, slightly cross-bedded, containing occasional thin layers of mud-ball conglomerate and macerated carbonaceous material.	500
		Claggett (?) formation.	Yellowish-tan massive thick-bedded sandstone and tan-colored sandy shale, and a few beds of gray and brown sandy carbonaceous shale.	200 to 300
		Eagle (?) sandstone.	Yellowish-gray massive thick-bedded sandstone and yellowish-gray sandy shale Beds of carbonaceous shale and coal occur here and there in the sandy shale member.	100 to 200
		Colorado shale.	The upper part of this formation is tan-colored thin-bedded sandstone and sandy shale.	Not wholly exposed in this field.

[a] The geology and water resources of the Bighorn Basin, Wyoming: Prof. Paper U. S. Geol. Survey No. 53, 1906.

[b] In the eastern part of the area all these formations are more shaly than elsewhere.

The lines between the formations given in the above table are based on a consideration of both stratigraphic and paleontologic evidence. The beds have been examined by T. W. Stanton at several points between the type localities in Montana and the Bighorn Basin, and by C. A. Fisher at closer intervals in the same area, and have been traced from Bridger, Mont., in the Clark Fork valley, to Basin, on Bighorn River, by C. W. Washburne. Mainly on stratigraphic evidence these observers report beds which probably represent the Eagle and Claggett, and they find some indications pointing to the presence of the Bearpaw and Judith River, though the evidence for exact correlation of these upper rocks with formations recognized elsewhere is insufficient. T. W. Stanton and F. H. Knowlton visited the field discussed in this report and have since examined the fossils collected during the progress of this work. They report that the fossils are not sufficiently distinctive to prove with certainty that the Eagle sandstone and Claggett formation are represented, and are still more doubtful concerning the correlation of the upper beds. Some species found elsewhere in the Judith River formation occur in the lowest members of the undifferentiated Montana, but they are not sufficiently distinctive to prove that these beds are of Judith River age. A consideration of the combined stratigraphic, lithologic, and paleontologic evidence, however, points to the presence of the divisions of the Montana group given in the table. The identification of the Fort Union is based on fossil plants, which have been identified by F. H. Knowlton as undoubted Fort Union forms. Some species of fossil plants found in these beds also occur in the "Laramie" of neighboring regions, but no fossils clearly distinctive of that formation were found in the southeastern part of the Bighorn Basin.

The upper part of the Colorado shale is exposed on the eastern and southern borders of the area mapped on Plate XII. It is a mass of yellowish, slightly ferruginous, thin-bedded sandy shale and shaly sandstone, 200 to 300 feet thick. North of Kirby Creek it contains lenses of massive sandstone 20 to 30 feet thick and several miles long. The middle part of the formation, which is exposed just outside of the area mapped but passes beneath it, consists of several hundred feet of dark-colored shale, which grades upward into the rocks of the upper part, just described.

The Eagle(?) sandstone consists generally of two yellowish-gray massive members, one at the top and the other at the bottom of the formation, and a thick bed of sandy shale between them, but locally three or four beds of sandstone and intervening shale are present.

Where it is exposed just east of Bighorn River, near Kirby, the formation is composed of a massive yellowish-tan sandstone 50 feet thick at the bottom, overlain by 80 feet of gray sandy shale containing beds of carbonaceous matter and two coal beds of workable thickness, and at the top a massive yellowish-gray sandstone 60 to 75 feet thick. The formation contains similar members where it is exposed at the north end of the field near No Wood Creek, but toward the middle of the area the sandy beds lose their massive character and become more shaly, until the formation is changed entirely from its typical aspect, the carbonaceous shale becoming less abundant and the coal beds disappearing.

The Claggett(?) formation lies conformably above the Eagle(?) sandstone, but differs from it in lithologic character. Near Bighorn River it consists of yellowish-tan massive beds, but to the east the sandstone gradually becomes shaly until the whole formation is composed of yellowish-tan shale beds with a few irregular sandstone members. Beds of brown carbonaceous shale and coal are numerous within the sandy shale, but none of the coal beds is thick enough to be mined.

The beds lying above the Claggett(?) formation and below the unconformity that separates the Montana group from the Fort Union are undifferentiated in this area because of insufficient paleontologic evidence. The fossils show that the beds are of Montana age, but they are not distinctive of either the Judith River or the Bearpaw formation. On lithologic grounds the rocks are divided into a lower, a middle, and an upper member. The lower division consists of gray cross-bedded sandstone, containing thin, irregular layers of flat and mud-ball conglomerate with macerated plant fragments and mineral charcoal. East of Bighorn River and about Tensleep Butte this member is eroded into prominent gray cliffs, and between Buffalo Creek and Bud Kimball Draw small areas of toadstool forms mark its line of outcrop. This member contains only small amounts of carbonaceous matter and no coal.

The middle division of the undifferentiated Montana is formed of beds of rusty-colored shale with here and there a layer of ferruginous sandstone. It diminishes in thickness from 90 feet at the north to less than 40 feet at the south. It is uniform in character from top to bottom, and contains no coal beds. No fossils were found except a few casts of small worm burrows.

The upper division of the undifferentiated Montana is composed of beds of ash-colored, tan, and drab sandy shale and brown carbonaceous shale with beds of coal. These beds range in thickness from a few inches to several feet. When freshly eroded the member is easily recognized by the somber-colored banded exposure. On account of an erosional unconformity above, the thickness varies greatly. Fossil leaves found in various localities indicate that the beds are of fresh-water origin and possibly of Judith River age. Beds of coal are found in the member wherever it is exposed, and beds of workable thickness occur in the valley of No Water Creek on both sides of the channel. A section of one of these beds (No. 7 [a]) where it has been mined on No Water Creek shows 4 feet 11 inches of good coal, above which there is 7 inches of drab shale, then 6 inches of coal. Other beds almost thick enough to mine are exposed along Sandy Creek and between Buffalo Creek and Bud Kimball Draw, east of the "Honeycombs."

The Fort Union formation comprises two members, which can be distinguished more or less clearly throughout the field. The lower one consists of yellowish sandy shale and rusty sandstone resting unconformably upon the undifferentiated Montana. These beds weather so uniformly to yellow that in the field they were termed "yellow beds." The member is about 775 feet thick where it is crossed by the Worland-Tensleep road, and 2,300 feet near Bighorn River east of Kirby. These two measurements represent about the average limit of variation. This part of the Fort Union contains coal at the head of Bud Kimball Draw, where a mine has been opened on a lenticular bed 5 feet 6 inches thick at its maximum (No. 4), and also at the head of Cottonwood Creek (No. 3), where a little mining has been done. Some coal has also been mined from a small outlier northwest of Cedar Ridge (No. 6).

The upper member of the Fort Union in the northern part of the field is composed of gray and grayish-drab sandy shales and many thin lenses of yellow sandstone. To the south, however, the sandstone members become more numerous, massive, and yellow, but are still darker than the yellow beds below. This member contains no coal beds. Where crossed by the Worland-Tensleep road it is 225 feet thick; east of Kirby it is 600 feet thick.

The Fort Union as a whole contains an abundance of leaves, from which its age has been determined. It is composed of beds rapidly deposited under climatic conditions unfavorable to the accumulation of vegetable matter and consequently contains little coal. The formation is separated from the Wasatch above by an unconformity which is not clearly displayed in most localities but is sufficiently well shown at a few points to establish the break with certainty.

The Wasatch formation consists of sandy shale, mostly tan-colored, with some yellow, brick-red, and maroon beds. The bright colors give a banded appearance to the freshly eroded surface and where the rocks are weathered impart a pinkish cast to the detritus. The formation is exposed along the western and northern margins of the field, and in the great badland area to the west in the central part of the Bighorn Basin. The Wasatch contains no coal in this field.

[a] Numbers in parentheses refer to locations on Plate XII.

Its age is fixed by vertebrate fossils found elsewhere in the Bighorn Basin by previous workers.

STRUCTURE.

The area here considered lies on the edge of a broad, moderately depressed structural basin. The beds have a general dip to the west-northwest, north, or northeast, varying from 3° to 56°, modified in only a few localities by minor folds or faults. From north to south the minor structural features may be described as follows: Between the north line of the field and the Worland-Tensleep wagon road the beds dip between 3° and 32° a little south of west. To the southeast, about Tensleep Butte, the dip is less and the strike changes more to the south. Northeast of this butte a small fault cuts the lower beds. The direction of this and other faults in the field is shown on the map (Pl. XII). Farther south, in the vicinity of the "Honeycombs," the rocks have a gentle dip, but to the east of that locality they are broken by a small fault. In the southern part of T. 45 N., R. 89 W., the beds are moderately folded, the strike turns sharply to the west, and the dip increases to 56° in sec. 35, T. 45 N., R. 90 W., but toward Bighorn River the dip again decreases to 10°. Near the river the beds are broken by several small faults. Wherever the coal beds are exposed in the area, however, the structure is not unfavorable to coal mining.

THE COAL.

OCCURRENCE AND DEVELOPMENT.

This field contains coal beds of workable thickness in four separate districts—near the head of Cottonwood Creek, on Bud Kimball Draw, along No Water Creek, and north of Kirby Creek, near Bighorn River. Beds of considerable thickness, but too thin to mine, outcrop along Sand Creek, between Bud Kimball Draw and Buffalo Creek, along No Water Creek, and in the region between Kirby and No Water creeks. Beds of coal are widely distributed throughout the area, but their location is not given on the map, because they are too thin and of too small extent to be commercially valuable now. The outcrop of the beds of coal and sections measured at various places along the exposures are shown on the map (Pl. XII).

It has been stated previously that one object of the survey was to determine the relation of the coal beds to land lines. This object could not be successfully accomplished because no reliable corner stones or posts were found, except along No Wood Creek and in the southwestern part of the area, near Bighorn River. The land lines could, therefore, not be established in the field, and the lines shown on the map are only suggestive and are not supposed to show the exact position the lines will occupy when they are resurveyed. Locations in the greater part of the area were found by a system of triangulation that established with a fair degree of accuracy the position of the coal beds in relation to hills, streams, and other landmarks.

Beds of coal thick enough to be mined occur in the Eagle (?) sandstone, the upper member of the undifferentiated Montana, and the lower member of the Fort Union formation. In adjoining areas, notably in sec. 29, T. 48 N., R. 89 W., a coal bed occurs in rocks which are geologically older than any that outcrop in this area and to which Darton[a] has given the name Cloverly formation.

It is generally supposed that the coal in the older geologic formations is of better quality than the coals deposited later. In this field only a few hundred feet of strata separate the lowest and highest beds and all have been influenced by the same structural movements. If there is a difference between the lower and higher coals due to geologic conditions it has not been detected by field study; however, the analyses given in the table (p. 183) seem to show that the coal in the lower beds is slightly better than that in the upper beds.

The mines of this field are small; in fact, none of them are more than prospects, though at several places a few tons of coal have been mined annually for a number of years. To begin at the north end of the field, the first coal bed which has been prospected is on Sand Creek, in the NW. ¼ NE. ¼ sec. 10, T. 49 N., R. 92 W., in the undifferentiated Montana. At this locality there is a prospect 100 feet deep on a bed which dips 18°. A section of the coal bed measured at a point 25 feet down the slope from the mouth is shown by section No. 1 on Plate XII. An examination along the entry and the outcrop of the bed shows that it is very lenticular and contains a large amount of shale and sandstone. The coal is subbituminous.

The next opening to the southeast has been made on a bed of coal in sec. 8, T. 48 N., R. 91 W., also in undifferentiated Montana rocks. The location of this prospect and a section of the bed at that point are shown on the map (No. 2). The dip of the beds here is 27° SW. The prospect in which the section was measured was driven about 75 feet and abandoned. It was found by following along the outcrop that this bed of coal disappears beneath surface cover a short distance to the north, but where last seen it is thinner than at the prospect. In the opposite direction from the opening there is only 14 inches of coal in an exposure one-fourth of a mile south, and in sec. 17 only a few inches of coal occur at this horizon.

Farther south along Sand Creek thin beds of coal outcrop at a number of points. The thickest bed in this group is exposed on the east side of Sand Creek, about 3 miles northwest of the Worland-

[a] Darton, N. H., The geology of the Bighorn Mountains: Prof. Paper U. S. Geol. Survey No. 51, 1906, p. 50.

Tensleep wagon road. The coal at this place is in two benches, the thicker of which contains 1 foot 8 inches of good coal capped by 6 inches of carbonaceous shale. A bed of coal about 2 feet thick is exposed about 1 mile farther southeast along the outcrop.

The only mine in the northern part of the field which is operated, even at intervals, is located on the east side of Cottonwood Creek, about 1¼ miles south of the crossing of the Worland-Tensleep road. The opening is at least 50 feet deep and widens out irregularly, but the extent of the development could not be determined because of the quantity of water in the mine at the time of examination. A section measured near the entry is shown by No. 3 on the map (Pl. XII). The bed is a lens in the lower part of the Fort Union formation. Valley wash covers the outcrop a short distance west of the mine and the bed is only a few inches thick one-fourth of a mile to the east. Some coal from this mine has been burned by ranchmen in the valley of No Wood Creek and plans have been made for its further development.

The most important mine in the area south of Tensleep Butte is in the badlands at the head of the north fork of Bud Kimball Draw, in sec. 33, T. 46 N., R. 89 W. More coal has been taken from this mine than from any other in the southeastern part of the Bighorn Basin. A section of the bed at the mine is shown by No. 4 on the map. The mine consists of an irregularly widened entry about 75 feet deep. Owing to its mode of weathering, the coal is classed as subbituminous. It has a pitchy luster, medium hardness, and subcubical jointing or cleavage. It contains small nodules of amber-colored resin and thin bands of mineral charcoal. It is probably a noncoking coal and does not stock well. The chemical properties of the coal are shown by analysis 6709, on page 183. The coal is in the Fort Union formation, and, like most of the beds in the field, is lenticular. One-fourth of a mile to the northeast the bed contains only 6 inches of coal, and an equal distance along the strike to the southeast an exposure shows an 8-inch bed included in carbonaceous shale. Although there is sufficient coal in the bed to furnish considerable fuel for local consumption, development has been prevented by the distance to settlements and the difficulty of maintaining wagon roads for transportation.

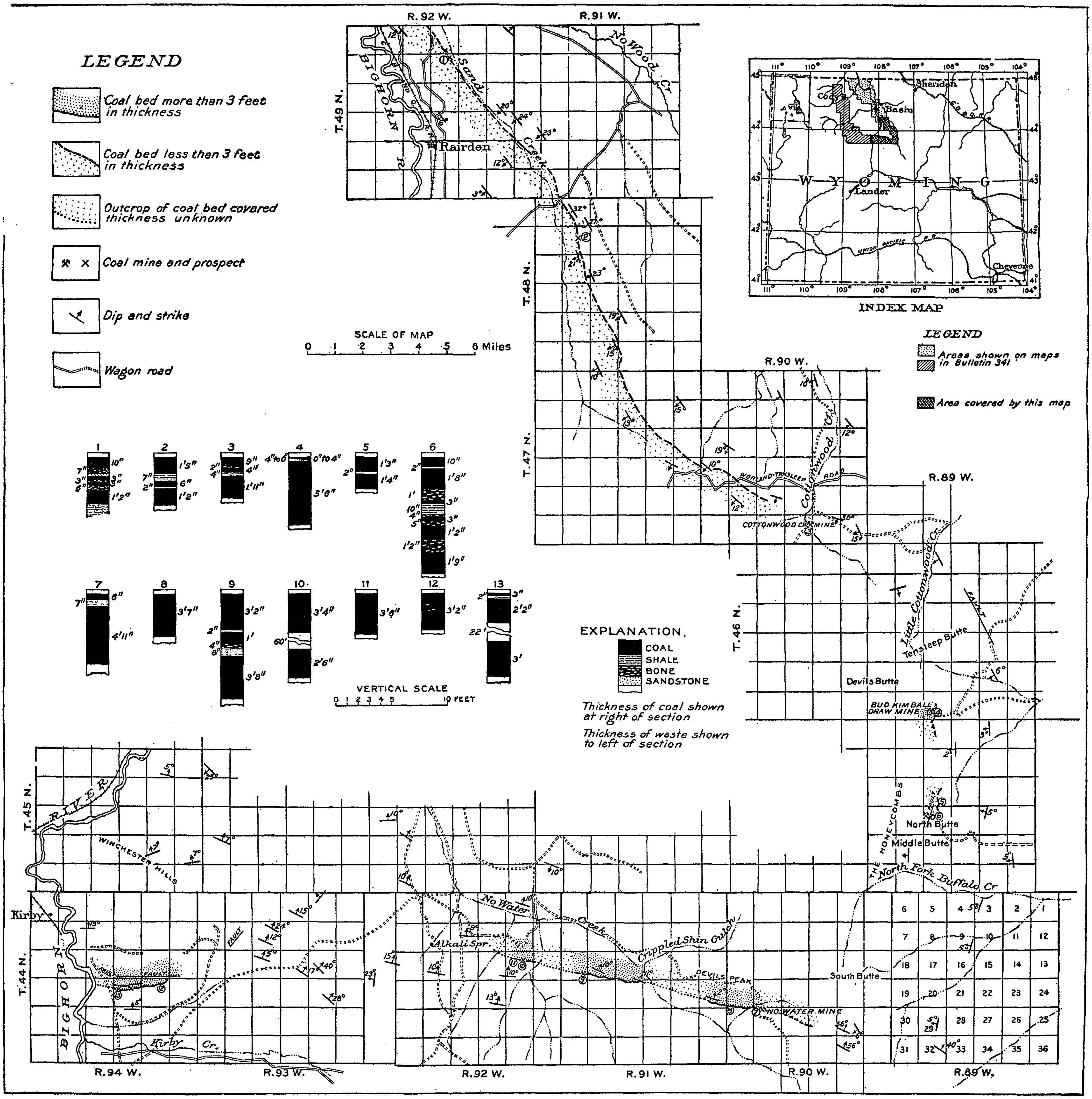
About 3½ miles south of the mine on Bud Kimball Draw there is an exposure of a coal bed at the base of a small isolated hill northwest of North Butte. The body of coal at this place is about 1 acre in extent and forms an outlier of a lens which originally was thinner toward the northwest, but now a dry coulée cuts the west side of this outlier. Where the bed is exposed across the coulée, it contains only 18 inches of coal at the thickest place. A section of the coal bed, shown by No. 6 on the map (Pl. XII), was measured in an open-pit mine on the west side of the hill, where the most favorable conditions for working the coal are found. The small extent of the bed at this place and its thin cover make it impossible for this mine to be more than a small country bank. A few tons of coal have been mined at this place by ranchmen and hauled over the divide road to the valley of No Wood Creek for fuel, but the coal is so dirty and the distance so great that the effort is scarcely repaid.

There are several coal beds in the upper member of the undifferentiated Montana where it is exposed east and northeast of the "Honeycombs," in T. 45 N., R. 89 W. Section No. 5 was measured a short distance north of the wagon road leading from the mine northwest of North Butte to No Wood Creek. The coal is subbituminous and occurs as a lenticular deposit. An entry driven into the bed in any direction may show an increasing or a decreasing thickness of coal, depending on whether the entry is driven toward the center of the lens or toward its margin. The locality is not favorable for mining.

A lower formation (the Cloverly of Darton), which is exposed to the east and dips under this field, contains a bed of coal where it is exposed in the valley of No Wood Creek, on the ranch of Dr. G. H. Walker, in sec. 29, T. 48 N., R. 89 W. The coal occurs as a lens, which extends for less than one-eighth of a mile along the outcrop. When examined in July, 1908, the mine was filled with water and an examination of the unweathered coal was impossible. At the mouth of the mine there is 2 feet of coal in a thick bed of carbonaceous shale. The bed is reported to be much thicker below the surface and this is probably true, because of the lenticular nature of the bed and the cross-bedded condition of the rocks above it. An opening was first made in this bed twelve years ago, and since then coal has been mined periodically. Mr. Diehl, who owns the property jointly with Doctor Walker, estimates that 2,000 tons have been taken out. The owners expect to reopen the mine and produce coal for the local ranch trade. The Cloverly formation does not outcrop in the area covered by this map, and in adjoining areas cursory observation and the reconnaissance by C. A. Fisher show that it contains only a small amount of coal.

The southern part of the field from the head of No Water Creek to Bighorn River contains more coal than the northern part, but owing to the lack of water and the entire absence of settlers there has been little development. Sections of coal beds measured at various points in the No Water area are shown on the map.

The only mine which has been opened in the No Water district is about 1 mile northwest of the creek, near the wagon road, about 3 miles southwest of South Butte. A section of the bed is shown by No. 7 on the map. The beds dip 23° N. The mine consists of an entry about 100 feet long with no side entries or rooms. The coal



MAP OF COAL FIELD IN SOUTHEASTERN PART OF BIGHORN BASIN, WYOMING.

By E. G. Woodruff and M. A. Pishel.

seems to be subbituminous and of excellent grade. It is pitch-black with a vitreous luster, has a conchoidal fracture, and appears to slack slowly on exposure. A sample of the coal from this opening was analyzed with the result shown by No. 6708 in the table on page 183. About 150 tons of coal have been mined and the conditions at the mine are favorable for more extensive development, but its isolation in an uninhabited region which can be reached only over poor roads will probably prevent extensive working for some time to come. Along the strike to the east the bed is concealed for more than a mile, but where it reappears the dip is steeper and the coal bed is considerably thinner. West of the mine the coal bed dips less steeply and is more favorably situated for mining.

Coal is found on the east side of Bighorn River in the same formation that contains the beds mined at Gebo and Crosby, west of the river. The dip of the beds in this area is only 10°, which is less than it is farther west. Two coal beds separated by 22 feet of sandstone and shale are exposed in the low hills north of the valley of Kirby Creek, east of Bighorn River. These beds have been prospected at a number of places with very promising results and some coal has been mined for local markets. It is probable that the cheaper production of coal by the large companies west of the river has prevented further development, because they supply the only market open to the area that lies east of the river. The coal is of the same quality as that west of the river, but probably the beds are not so thick. The region is traversed by small coulées, along which roads can be constructed easily and railroad grades leading to mines would be moderate. There is no doubt that as the coal beds west of the river become exhausted the coal to the east will be developed.

CHARACTER OF THE COAL.

The coal of this field has the same general physical properties as that from other fields in the Bighorn Basin at corresponding geologic horizons. It is of pitch-black color, vitreous luster, cubical jointing or cleavage, and moderate hardness, and shows a dark-brown powder or streak on glazed paper. Small nodules of amber-colored resin are abundant. Sulphide of iron forms little flat disks along the joint planes, but seems to be absent in the body of the blocks. Minute seams parallel to the bedding planes are more highly bituminous than the body of the coal and when broken produce thin but highly vitreous and shiny bands. The coal appears to stock well, but from samples exposed at the mines it is thought that this property is apparent rather than real. It is probably explained by the dryness of the mines and is due to the condition which arises when dry coal is exposed. Very little moisture finds ready escape, the coal does not shrink much or unequally, and the blocks do not fall to pieces as soon as wet blocks of coal, which lose moisture rapidly.

The coal weathers on dumps to brown, slightly fissile, irregular grains, but where longer exposed to slower weathering becomes a fine brown powder resembling carbonaceous shale. So close is this resemblance that it is difficult to determine on surface exposures the line of separation between the coal bed and the associated carbonaceous shale. Fragments no larger than half an inch in diameter, though weathered outside, generally contain less altered material within, which shows some of the properties of the unweathered coal in the bed.

There were only two places in this field at which samples for chemical analyses could be taken, where the coal had been exposed recently below the zone of weathering. These two points were the mines on Bud Kimball Draw and on No Water Creek. Samples were taken at these mines by selecting a representative face of coal, freeing it from powder stain and surface impurities, and cutting a channel across the face about 1 foot wide and deep enough to yield 5 pounds of coal per foot of thickness of bed. From this cutting partings and binders more than three-eighths of an inch thick were rejected. The sample was then broken to pass a ½-inch mesh sieve and then repeatedly quartered, the opposite quarters being rejected until a small representative sample was obtained. A galvanized-iron can holding about a quart was filled from this sample, sealed with adhesive tape, and forwarded to the chemical laboratory for analysis. The table below shows the result of analyses of coal samples from this field and from the Gebo field west of Bighorn River.

Analyses of coal samples from the southeastern part of the Bighorn Basin coal field, Wyoming.

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

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B.t.u.
6708	19	44	90	5′ 5″	5′ 5″	18.3	As received	25.4	38.6	27.8	8.2	0.38					4,573	8,231
							Air dried	8.7	47.3	34.0	10.0	.46					5,597	10,075
							Dry coal		51.8	37.3	10.9	.51					6,132	11,038
							Pure coal[a]		58.1	41.9		.57					6,884	12,391
6709	33	46	89	5′ 8″	5′ 8″	8.20	As received	16.3	35.8	32.6	15.27	.96	5.63	50.84	0.71	26.59	4,921	8,858
							Air dried	8.8	39.0	35.6	16.63	1.05	5.14	55.38	.77	21.03	5,361	9,650
							Dry coal		42.8	39.0	18.24	1.15	4.56	60.74	.85	14.46	5,879	10,582
							Pure coal		52.3	47.7		1.41	5.58	74.29	1.04	17.68	7,191	12,944
6707	18	44	94	7′ 6″	7′ 6″	9.90	As received	16.9	34.1	44.0	5.01	.54	6.06	60.56	1.35	26.48	5,855	10,539
							Air dried	7.7	37.8	48.9	5.56	.60	5.51	67.21	1.50	19.62	6,498	11,696
							Dry coal		41.0	53.0	6.03	.65	5.04	72.84	1.62	13.82	7,042	12,676
							Pure coal		43.6	56.4		.69	5.36	77.52	1.72	14.71	7,494	13,489

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term it is used in this report as noted above.

6708. The coal for this analysis was dug at the bottom of a slope about 100 feet long, at a point where the cover is nearly 75 feet thick. The face had been exposed to the dry air of the region for several months previous to sampling. This condition probably has produced oxidation and a lower moisture content than will be found where the mine is extended to a depth of several hundred feet.

6709. This sample was taken in a dry unoperated mine 75 feet from the mouth of the entry and under about 50 feet of cover. Though the face from which the sample was taken had been exposed for several months, there was no evidence of weathering, but probably some change had taken place due to the action either of water percolating from above or of dry air absorbing some of the moisture. The coal was dry and the mine dusty; consequently, the analysis probably shows the result of oxidation and less moisture than will be found when the mine is extended deeper.

6707. The mine from which this sample was taken is not located in the field described in this report, but is 2 miles farther west across Bighorn River. This analysis is introduced because the sample is believed to be fairly representative of the unweathered coal in the Eagle (?) sandstone. The sample was taken at a point 615 feet down the slope from the main entry, where mining was progressing at that time at a depth of about 150 feet below the surface, and the coal seemed to be entirely unweathered.

The coal burns with a yellow flame and only a small amount of smoke. The ash is fine and does not clinker badly.

The coal is best adapted for domestic use, though with proper grates and drafts it can be used for steaming purposes. It is too light and slacks too readily to give the highest efficiency under forced draft, because in such fire boxes small particles of the coal are blown from the fires before they have a chance to burn.

In stoves the coal burns freely with a quick heat and little smoke and does not clinker. It slacks readily but may be kept in small quantities for a long time, so that this property is not objectionable at present, because the local ranch men usually mine only a few tons at a time.

AMOUNT OF COAL AVAILABLE.

It is difficult to estimate the amount of coal in this field, owing to the uncertainty which the occurrence in lenticular beds gives to such computation. Any estimate may be as much as 25 per cent too small or too large. The northern part of the field contains a little coal in very irregular lenses. As the badlands to the west of the Cottonwood Creek and Bud Kimball Draw districts form a barrier to any market except that of the ranchers along the valley of No Wood Creek, it may be stated that in this part of the field there is coal to furnish sufficient fuel for many years if the mines are properly laid out and maintained, but the present unscientific, wasteful methods will greatly shorten the period of profitable production. The southern part of the field contains more coal than the northern part. It is estimated, on the assumption that the coal has a specific gravity of 1.3, that there are 62,000,000 tons of coal in this region in beds more than 3 feet thick and less than 2,000 feet deep. It is impossible to mine more than 75 per cent of this amount by present mining methods; hence not more than 46,500,000 tons are available as a future source of supply.

MARKET.

It has been stated that market conditions are unfavorable except for a small area in the extreme southwestern part of the field. The coal must be hauled by wagon at least 10 miles over rough roads and much of it a considerably greater distance. The demand is for fuel on ranches, as no towns are near enough to afford a market. The coal to the southwest near Bighorn River is within a few miles of a railroad, where it can be marketed now by hauling a short distance by team. It can be reached by a short railroad spur when the coal is in sufficient demand. The only competing fuel in the field is wood, which is not abundant.

FUTURE DEVELOPMENT.

It is expected that the area of coal near Bighorn River east of Kirby will receive attention from miners as soon as the coal to the west becomes a little more difficult to obtain. Elsewhere in the field the conditions are not promising for future development beyond the mining of a few tons each year by local ranch men who can overcome the difficulties of haulage. Further, owing to poor land surveys the coal areas can not be segregated and valued; hence title to them can not be obtained from the Government until a resurvey is made. These conditions will delay development.

THE EASTERN PART OF THE LITTLE SNAKE RIVER COAL FIELD, WYOMING.

By Max W. Ball and Eugene Stebinger.

INTRODUCTION.

The Little Snake River coal field includes an area of about 1,150 square miles, approximately 900 square miles of which is in Carbon and Sweetwater counties, Wyo., and 250 square miles in Routt County, Colo. It is separated from the Yampa field on the south by the crest of the Elkhead Mountains, and from the Great Divide Basin field on the north by the watershed between the Pacific drainage and that of the Great Divide Basin. It was first mapped geologically by the King Survey in 1871–72. In 1902 the part of the field lying generally north of Little Snake River and east of Battle Mountain was included in Spencer's map of the Encampment copper district.[a] The Wyoming portion of the field has been the subject of two seasons' field work with especial reference to coal. During the summer of 1907 a party consisting of Max W. Ball, B. L. Johnson, J. T. Singewald, jr., L. Reinecke, Robert D. Sawin, and Ray D. Sawin surveyed the area north of Little Snake River and west of a line passing through Dixon, Five Buttes, and Bridger Pass, including that portion of the Great Divide Basin which lies south of the Union Pacific Railroad. In the season of 1908 a party comprising Max W. Ball, Eugene Stebinger, C. L. Baker, and Arthur M. Douglass completed the mapping of the Wyoming part of the field, as well as of a few small areas in Colorado north of Little Snake River, and in addition made a further study of some of the area examined during the previous season. This paper is a brief report of the results of the investigations of 1908 and of necessity duplicates or revises, both in map and text, many of the statements presented in the preliminary paper on the western part of the field.[b]

[a] Spencer, A. C., Copper deposits of the Encampment district, Wyoming: Prof. Paper U. S. Geol. Survey No. 25, 1904.

[b] Ball, M. W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, pp. 243–255.

The mapping in the field was done on a scale of 2 inches to the mile, with contour intervals of 100 feet. A few small areas were sketched by plane-table methods, but the greater part of the work was done by pacing land lines on horseback from section corner to section corner, each corner found being used as a new and correct location for continued work. The horizontal control of the map thus depends largely on the presence of land corners, and the location of features with respect to land lines is accurate in proportion to the number of monuments found. North of the fourth standard parallel north corners are rather numerous and easily discovered; south of that line they are relatively scarce. E. Lambert, as county surveyor, established corner stones in most of T. 16 N., R. 92 W., and in portions of T. 15 N., Rs. 91 and 92 W. From the township corner just southeast of Five Buttes a line of original corners extends 3 miles west; another runs possibly 3 miles south; about one-third of the original corner stones are present for 6 miles on the line north; and a line of unmarked stones continues 3 miles east. A number of corner stones were found in T. 12 N., Rs. 89, 90, and 91 W., and T. 13 N., Rs. 90 and 91 W., and a very few in T. 14 N., R. 89 W.

In the summer of 1907 a line of levels was run diagonally across the field from a United States Coast and Geodetic Survey bench mark at Rawlins, on the Union Pacific Railroad, to Baggs, bench marks being set about every 3 miles from Rawlins to Muddy Bridge and two between Muddy Bridge and Baggs. From these bench marks and from those in the area east of Battle Mountain established during the topographic survey of the Encampment special quadrangle in 1901, flying levels were carried by telescopic alidade and stadia to the various temporary camps of the party, furnishing control for the aneroid and hand-level altitudes used in sketching.

From the field sheets a complete contour map on a scale of 1 inch to the mile was compiled in which the lengths of the land lines as given by the official Land Office surveys were accepted as correct and were plotted by so balancing the recorded distances about a vertical and a horizontal right line intersecting near the southeast corner of T. 16 N., R. 91 W., that the distortions due to convergence of meridians and errors of survey are theoretically distributed equally over the sheet. As a result of this balanced plotting of the recorded lengths of land lines rather than their bearings, the length of the sides of any particular township or section is the same as that given on the corresponding Land Office plat, but the shape of the township or section may be different from the shape shown on that plat. From the contour map, by reducing the scale and eliminating everything but the more important drainage and cultural features, the base was prepared for the accompanying map (Pl. XIII), on which are indicated the different geologic formations in the coal area, the locations of the principal coal openings, and such other geologic facts as have a direct bearing on the occurrence or development of the coal. No attempt is made to show the subdivisions of the geologic column except in the coal-bearing part.

There are represented in the field and its vicinity sedimentary rocks down to the "Red Beds" of the Triassic, but neither the formations below the Mesaverde nor the igneous rocks upon which the "Red Beds" rest unconformably are indicated on the map. All the beds above the "Upper Laramie," including the Wasatch and later Tertiary formations and part of the alluvial deposits are shown by a single pattern.

Acknowledgment is due to a large number of persons in the field who in person and by correspondence have facilitated the work through information given and courtesies extended.

SURFACE FEATURES.

The Little Snake River coal field presents every topographic gradation from the heavily timbered slopes of the Elkhead Mountains and Sierra Madre to the alkali flats of the Red Desert. Little Snake River, in the drainage basin of which the field lies and from which it takes its name, originates in the confluence of three tributary streams a short distance east of the coal field and crosses it in a course trending almost directly west through a fertile flat-bottomed valley from half a mile to 2 miles wide, flanked here and there by benches or mesas which increase in number toward the western margin of the field. Immediately north of the river in the eastern part of the field the lava-capped eminences of Sheep Mountain, Mule Mountain, Horse Mountains, and, highest and most prominent, Battle Mountain, overlook abruptly a great plateau extending eastward to the base of the Sierra Madre and northwestward to Browns Hill and Five Buttes. In this comparatively level upland Savery and Battle creeks and their tributaries have cut precipitous canyons, whose bottoms in many places are rich agricultural land. The regularity of this upland is interrupted in the vicinity of Browns Canyon and Rubey Springs by a higher mesa, with white escarpment faces. North of this higher mesa, toward Sulphur and Bridger Pass, the upland loses most of its plateau characteristics and becomes a series of high ridges with cliffs toward the east and dip slopes toward the west. Muddy Creek crosses this highland in a deep, narrow canyon known as the Upper Narrows of the Muddy, and its headwaters have hollowed out a valley called Muddy Basin between the eastward-facing cliffs and the higher mesa that extends northward and eastward from Rubey Springs. West of the plateau is a depression, in places a simple valley, elsewhere a broad area of low, irregular relief, terminated on the west by a series of hogbacks and transverse ridges, with a few high points such as Muddy Mountain. In the area described in this paper the western limit of the hogback region is marked by a brilliantly colored escarpment, which constitutes approximately the western margin of the coal field and the eastern border of a great, almost waterless area of badlands, broken dip slopes, and isolated buttes locally known as "the desert." Along the face of this scarp from the old Washakie stage station southward Muddy Creek meanders through a flat-bottomed valley to its junction with Little Snake River at Baggs.

GEOLOGY.

STRUCTURE.

The geologic structure of this area is dominated by the uplift of the Sierra Madre just east of the field. The attitude of the coal-bearing formations varies from horizontality to a dip of 35°, the dip being generally greatest near the western margin of the area. The direction of dip is slightly west of north in the north end of the field and swings through due west to southwest in the vicinity of Little Snake River. Along this river above Savery Creek there are many minor folds which produce dips of as much as 4° in every direction and give to the outcrop of the lowest coal-bearing formation, the Mesaverde, a width of approximately 15 miles, as compared with 3 miles, both in the vicinity of Bridger Pass, near the north end of this field, and at Wolf Mountain, in the Yampa field.[a] The dips of the beds overlying the coal-bearing formations are uniformly low. The Wasatch dips generally from 1° to 4° W., although in places it has a higher dip immediately in contact with the older beds; the Bishop (?) conglomerate (Tertiary) is either horizontal or dips 1° or 2° E.

Only one fault of any magnitude was observed in the field. This crosses the river in sec. 16, Wyoming, and sec. 17, Colorado, T. 12 N., R. 88 W. Its throw could not be ascertained, but probably is not less than 50 feet. The location is within a mile and a quarter of the highest point on Battle Mountain, which is probably, like its neighbor, Sheep Mountain, the site of the vent whence issued the basalt now forming its cap.

STRATIGRAPHY.

GENERAL SECTION.

A section of the rocks of the field from the Sierra Madre westward would give an incomplete succession of the formations from the pre-Cambrian upward. In the following table the general char-

[a] Fenneman, N. M., and Gale H. S., The Yampa coal field, Routt County, Colo.: Bull U. S. Geol. Survey No. 297, 1906.

acter and approximate thicknesses are given for only the coal-bearing and associated formations:

Generalized section of coal-bearing and associated rocks in the southern part of the Little Snake River coal field, Wyoming.

System.	Series.	Formation.	Thickness (feet).	Characteristics.	Coal resources.
Tertiary.		Bishop (?) conglomerate.	1,000±	White to light-gray calcareous sandstone and sandy limestone north of Bird Gulch; yellow to white beds of poorly consolidated sand and gravel in south end of field. Basal conglomerate.	Not coal bearing.
		Unconformity			
	Eocene series.	Wasatch formation.	Top not seen.	Variegated clay, passing upward into brown and gray shales, sand, and sandstone. Highly calcareous conglomerate at base in some parts of field.	Not coal bearing.
		Unconformity			
		"Upper Laramie" formation.	0 to 4,000.	Gray and brown sandstones and gray and drab shales, with many coal beds. White to dark clay shale. Heavy sandstone, with interbedded shale and numerous beds of good coal; conglomerate at base.	Coal bearing throughout except in white to dark clay shale member. Bottom part contains best coal beds.
Cretaceous.		"Laramie" formation.	3,500.	Brown and gray shaly and concretionary sandstones and dark shale, with several beds of coal. In parts of the field the lower half is yellow, softer, and more sandy, and apparently contains less coal than the upper half.	Contains some coal.
	Montana group.	Lewis shale.	1,600.	Drab, slightly sandy, highly gypsiferous shale, with a few beds of thin soft sandstone.	Not coal bearing.
		Mesaverde formation.	2,000.	Upper two-thirds alternating sandstone and shale beds, with heavier sandstone beds in upper part. Bottom third made up of massive cross-bedded sandstone with some interbedded shale.	Upper two-thirds contains many coal beds and principal mines in the field. Bottom third not coal bearing.
				Dark-drab concretionary calcareous shale, with several thin beds of soft brown sandstone.	Not coal bearing.

MONTANA GROUP.

SHALE.

Immediately underlying the lowest coal-bearing formation in this field is a non coal-bearing shale, the equivalent of the upper part of the Mancos shale as mapped and described in western Colorado. It has a thickness of not less than 2,000 feet, is dark drab in color, weathers almost white in places, is somewhat concretionary and very calcareous, and contains numerous thin beds of soft brown sandstone, especially near the top. A particularly persistent sandstone, which has been observed throughout this field, the Great Divide Basin, and the east-central Carbon County field, occurs about 200 feet below the base of the Mesaverde, and as the dips are high or low forms either a hogback or a secondary scarp a short distance out from the foot of the Mesaverde escarpment.

MESAVERDE FORMATION.

The Mesaverde formation may be divided readily, though not definitely, into three practically equal parts. The lower third is made up of massive white, gray, and rusty-brown cross-bedded sandstone, with some interbedded shale and shaly sandstone. North of the Upper Narrows of the Muddy a bed of limestone 25 feet thick was observed about 150 feet above the base of the formation. The line of demarcation between this lower member, which is not coal bearing, and the underlying shale is not everywhere distinct. Near Standard Headquarters on Savery Creek the transition is marked for 300 feet or more by an alternation of beds of heavy sandstone 2 to 50 feet thick, with beds of drab, white-weathering shale 1 to 30 feet thick. The upper two-thirds of the formation is composed of alternating thin-bedded and shaly sandstones, gray, brown, and drab shales, and a few beds of massive sandstone that increase in number toward the top of the formation, so that where the beds are tilted the upper and lower members of the formation stand out as high ridges and the middle member occupies a depression between. In the southeastern part of the area shown on the accompanying map (Pl. XIII), where the beds are nearly flat and are covered by the Bishop (?) conglomerate, the Mesaverde produces a great plateau with deep canyons. The middle member is coal bearing in the south end of the field, containing the Carbondale (1),[a] Stemp Springs (2), and probably the Linde (3) and Lucksinger (4) mines. Toward the north the coal beds become less numerous, thinner, and dirtier. In a section across the formation at the Upper Narrows of the Muddy no coal was found in the middle member, although the outcrop is covered in a few places and may contain coal beds. The upper member contains a number of coal beds throughout the field, the Robertson (16), Angier (7), Darling (6), Martin (5), O. P. Beeler (18), and possibly the Lucksinger and Linde openings being on coal beds in this member. The following section through the Upper Narrows of the Muddy just east of Sulphur shows the location, number, and thickness of the coal beds in the upper member in the northern part of the field:

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[a] Numbers refer to locations on Plate XIII.

Section of a part of the Mesaverde formation north of Muddy Creek in Tps. 17 and 18 N., R. 90 W., Wyoming.

	Thickness.	Distance from base of formation.
	Feet.	*Feet.*
Covered, shale, chocolate or drab, thin-bedded sandstone and coal, approximately	300	1,973
Sandstone, thin bedded, buff, somewhat reddened by heat, with small amount of shale	30	1,673
Sandstone, thin bedded	3	1,643
Shales, black, carbonaceous, and brick-red, giving evidence of a burned coal bed	12	1,640
Sandstone, thin bedded, buff, with thin streaks of buff shale	45	1,628
Shales, bituminous and drab	14	1,583
Coal (Robertson opening)	11	1,569
Shales, bituminous and chocolate drab	10	1,558
Sandstone, thin bedded, buff	44	1,548
Coal	1	1,504
Sandstone, thin bedded, buff	20	1,503
Shale, drab, with thin beds of coal	9	1,483
Coal, at least	7	1,474
Shale, chocolate or drab, with thin beds of coal	6	1,467
Sandstone, massive, buff	18	1,461
Shale, dark, with abundant plant remains and at least six beds of poor shaly coal less than 1 foot thick	15	1,443
Coal	5	1,428
Covered	15	1,423
Sandstone, thin bedded, buff	2	1,408
Shale, dark brown	5	1,406
Sandstone, massive, buff	15	1,401
Coal	10	1,386
Shale, black	5	1,376
Sandstone, massive, buff	35	1,371
	637	

Lack of continuous exposures makes it impossible to tell whether or not individual beds of Mesaverde coal extend continuously for long distances. Some of the prominent sandstone ledges of the lower part of the formation may be traced for many miles, but the sandstone beds of the coal-bearing members of the formation do not appear to be so persistent. It seems probable that the beds are more or less lenticular and that in general where one bed thins out and disappears another one is present, so that the number of beds remains about the same and the coal maintains an approximately constant aggregate thickness, but no one bed is continuous over a great area.

LEWIS SHALE.

The Lewis shale is soft, dark drab to black in color, and highly gypsiferous, with a few beds of soft shaly sandstone that increase in number toward the top of the formation. The sandstone varies in color from white to rusty brown, and the shale is slightly more sandy near the top of the formation than it is lower down. The shale weathers rapidly, producing between the highlands of the Mesaverde, on the one hand, and the less prominent "Laramie" hogbacks, on the other, an almost continuous valley, or series of valleys, of which advantage has been taken in locating a great part of the Rawlins-Baggs stage road (formerly the government road from the

Union Pacific Railroad to the White River Indian Agency), as well as a number of other roads. No coal was observed in the Lewis shale in this field.

"LARAMIE" FORMATION.

The "Laramie" formation is made up of interstratified beds of gray, buff, and rusty-brown sandstone, and gray, brown, drab, and black shale. The sandstone as a rule is thin bedded, but some beds are massive and a few are concretionary. In some parts of the area, notably along Cherokee Creek, there is a marked difference between the upper and lower parts of the formation, the sandstone in the lower half appearing more shaly and less consolidated and the shale zones more numerous and sandy than in the upper half. The result is a sandy shale member with a few beds of resistant sandstone about midway in character between the normal upper part of the formation and the underlying Lewis shale. In the northern part of the field the formation is uniform throughout, the base of the formation as mapped being a massive white sandstone,[a] which as a rule forms either an escarpment or a prominent hogback. At Muddy Mountain, south of Cherokee Creek, the lower half of the formation seems to be even more resistant than the upper, with a greater percentage of indurated sandstone.

The "Laramie" formation is undoubtedly coal bearing throughout the Wyoming portion of the field, but the number, thickness, and relative location of the coal beds could not be definitely determined in the area treated in this paper, owing to the prevalent cover of hill wash over the formation and the fact that most of the coal beds do not occur between beds of sandstone but in shale that weathers rapidly and hence produces a minimum of exposures. In the field no mines are located in the "Laramie" and only one prospect, that in the SW. ¼ NE. ¼ sec. 15, T. 12 N., R. 90 W. (No. 8), opposite the Deary ranch. Owing to the presence of valley filling, river terrace, and Tertiary deposits several miles in extent between this location and the nearest "Laramie" exposure to the north, the reference of even this coal bed to the "Laramie" is a matter of no great certainty.

"UPPER LARAMIE" FORMATION.

The lowest member of the "Upper Laramie" formation is composed of beds of gray and brown sandstone, with intercalated gray, brown, and drab shale and numerous beds of coal. The beds of sandstone

[a] This mapping is based on the fact that the formation from the bottom of this sandstone upward is a lithologic unit. Paleontologically the formation probably begins some 400 feet higher, as marine Montana fossils have been found to that distance above the massive sandstone, thus associating the lower 400 feet of the formation as mapped with the Lewis shale.

are thicker, more numerous, and more massive toward the base, which is marked by a bed that is extremely massive, cross-bedded, in many places highly ferruginous, and as a rule somewhat conglomeratic. The pebbles are composed of well-rounded crystalline and cryptocrystalline materials, chert predominating, and as a rule they are small, but lenses of conglomerate with pebbles up to 18 inches in diameter appear locally. In the southern part of the field a basal conglomerate is present, in places in contact with or forming a part of the massive sandstone. In other places, notably just east of the Standard ranch on Muddy Creek, the basal conglomerate is represented by two beds, each about 8 feet thick, approximately 100 and 200 feet below the massive sandstone and separated from it and from one another by dark shale. The pebbles are mainly chert, held in a matrix of chert and crystalline quartz grains about the size of coarse sand.

On the coal beds of the lowest member are the Muddy Bridge opening, the openings in Coal and Cutoff gulches, northeast of Baggs, and a number of other prospects. The individual coal beds appear to be continuous for long distances. An idea of the lithologic character, number, and position of the coal beds may be gained from the following section taken along the Lower Narrows of the Muddy near the old Washakie stage station. Farther south some of the beds are thicker than any shown in this section.

Section of a part of the "Upper Laramie" formation near old Washakie stage station, north of Muddy Creek, in Tps. 17 and 18 N., R. 91 W., Wyoming.

	Feet.
Shale, brown	70
Sandstone and burned coal bed, intensely red	20
Covered mainly; where exposed brown, black, and gray shale, with thin-bedded brown sandstone	80
Sandstone, massive and thin bedded, yellow	50
Shale, brown	8
Coal	5
Shales, sandy, yellowish and brown, with shaly sandstone	61
Shale, gypsiferous, brown, with thin coal beds	10
Sandstone, shaly and thin bedded, yellow and brown, with sandy shale	33
Shale, gypsiferous, brownish black	3
Coal	5
Shale, sandy, light gray	5
Sandstone, thin bedded, yellow	6
Coal, impure	7
Shale, brown	2
Shale, sandy, yellowish brown	4
Coal	2
Shale, gray	5
Shale, sandy and yellowish brown, shaly sandstone	10

Shale, bluish gray, with plant remains	4
Coal, burned in places	5
Covered; creamy sandstone near middle, brown shale at top	344
Sandstone, cross-bedded, conglomeratic, grayish and light brown	25
Sandstone, buff, conglomeratic. Small pebbles of diabase, chert, and crystalline quartz scattered sparingly throughout except near top, which is full of pebbles one-fourth inch to 18 inches in diameter, with evidences of local unconformity	80
	844

Overlying the lowest member of the "Upper Laramie" is a non coal-bearing member, consisting of clay shale and sandy clay, with a small amount of soft sandstone, either massive or thin bedded. In the northern portion of the field the clay is almost pure white, whereas in some of the exposures near the river it is dark drab, bordering on black, with rare tinges of red, which may have been leached from the adjacent Wasatch. The beds of sandstone in this member, which are extremely varied in number, thickness, and location, are as a rule gray. Throughout the greater part of the area the member appears to be free from conglomerate, but in many places between Cherokee Creek and Deep Gulch large quantities of rather coarse cherty conglomerate are present. Although this clay shale member is easily and definitely recognizable wherever exposed from the Union Pacific Railroad to its disappearance under the Wasatch just north of Little Snake River, its thickness seems to vary markedly through lithologic encroachment upon it of the underlying and overlying members.

The uppermost member of the "Upper Laramie" is composed of gray and brown sandstones with interbedded shale. Some of the shale beds closely resemble those of the clay shale member, from which the upper member is, however, distinguished by the greater number and superior resistance of its beds of sandstone and by the presence, where exposures are satisfactory, of numerous beds of coal. In the area specifically treated in this paper outcrops of this member are not numerous, owing to the overlapping of the Wasatch formation, which through most of the area covers it completely. The coal beds of the member have not been carefully prospected, although from Riner, on the Union Pacific Railroad, to Coalbank Spring,[a] the beds are very prominently exposed.

Regarding the geologic age and the equivalence of this formation there has been some uncertainty. It doubtless constitutes the earliest Tertiary deposit of the area, and from paleobotanical evidence F. H. Knowlton now considers it to be of Fort Union age. The formation as mapped is the equivalent of the "Upper Laramie"

[a] Ball, M. W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, Plate XIII.

of Veatch[a] in the Hanna field, where it is separated from the "Laramie" ("Lower Laramie" of Veatch) by a great unconformity. This unconformity was also observed by Smith in the Great Divide Basin[b] north of the Union Pacific Railroad, but though evidence of local unconformity appears in one or two places, no general unconformity was observed in the Little Snake River field. In secs. 25 and 26, T. 13 N., R. 91 W., a few isolated exposures were found with strikes trending much more toward the east than any of the underlying formations, but the cover of Wasatch and later deposits southward to the state line made it impossible to determine whether these exposures represent a local fold or a definite trend of the formation which could only be accommodated by its unconformably overriding some of the older beds.

WASATCH FORMATION.

The Wasatch is separated from the underlying formations by a pronounced unconformity. West of the old Washakie stage station the base of the formation rests on the upper member of the "Upper Laramie." South of the Standard ranch on Muddy Creek it rests on the lowest member of the "Upper Laramie." From this point south it oscillates between these two positions as far as the Dixon Cutoff, where it swings abruptly eastward and overlaps the formations down to the top of the Mesaverde. The Wasatch formation is composed mainly of rather sandy clay, with a few beds of shale and soft sandstone, the latter mostly massive and in places finely conglomeratic. Higher in the formation the proportion of clay to shale decreases, the beds of sandstone increase in number, and the sandstone is thin bedded and more resistant. The usual coloring of the clay, which is roughly bedded, is brilliantly banded red and white, although purple, green, drab, and yellow colors are common, and in places, notably along the north bank of Little Snake River just below Dixon and the south bank just above that point, the color is almost entirely leached out. Locally the shale partakes of the brilliant coloring of the clay but as a rule it is green, yellow, brown, and drab and the sandstone is gray and rusty brown. As the proportion of clay decreases toward the upper part of the formation the red color becomes less prominent, appearing here and there in a diminishing number of isolated patches, until the formation is almost entirely composed of white, gray, brown, and drab shales and clays, with a number of thin bedded gray and rusty brown sandstones. In some places it is difficult to distinguish

[a] Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 244–260.

[b] Smith, E. E., The Great Divide Basin coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, pp. 224, 233.

at first glance between the uppermost part of the Wasatch and the "Laramie" or the upper member of the "Upper Laramie," but a careful search over any considerable area will almost invariably show one or more patches of bright red color. The lowest member of the formation in the region just south of Muddy Mountain seems to be a yellow or white conglomeratic sandstone, in places highly calcareous.

The Wasatch is very prominently exposed along Little Snake River for many miles below Baggs and south of the river in the lower slopes of Black Mountain.

BISHOP (?) CONGLOMERATE.

In his mapping of the geology of the Encampment district, Spencer,[a] following the usage of the King Survey, adopted the name "Wyoming" conglomerate for the sandstone conglomerate which caps the interstream areas in the southwestern part of the district that he examined, including that part of the Little Snake River field lying north of the river and east of a north-south line along the east base of Battle Mountain. It is probably the equivalent of the "Bishop Mountain" conglomerate of the Powell Survey, now called Bishop conglomerate. The basal conglomerate of the formation covers the greater part of the level upland from the vicinity of Bridger Pass to the river. It is 50 feet or more in thickness and obscurely bedded, with poorly assorted pebbles of all sizes up to bowlders 2 feet in diameter, and with lenses of white and yellow sandstone, rather soft and more or less massive.

Above the basal conglomerate on Sheep and Battle mountains and in the Elkhead Mountains south of the river lie several hundred feet of poorly consolidated sand and gravel. On the north slope of Battle Mountain some of the sand is of extreme fineness, whereas other beds are very pebbly, and on the north face of Black Mountain, south of Dixon, a great thickness of very coarse unconsolidated conglomerate is exposed. In the vicinity of Sheep and Mule mountains the beds are consolidated into a gray massive sandstone, highly cross-bedded, showing mud cracks in many places. On the north wall of Bird Gulch just above Savery Creek (sec. 26, T. 15 N., R. 89 W.) the basal conglomerate is well exposed, lying unconformably upon the westward-dipping sandstone of the Mesaverde formation and dipping slightly northward to Browns Canyon and Rubey Springs, where it apparently forms the base of a series of white sandy limestone and calcareous sandstone, the westward continuation of the formation which Veatch[b]

[a] Spencer, A. C., Copper deposits of the Encampment district, Wyoming: Prof. Paper U. S. Geol. Survey No. 25, 1904.

[b] Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, Plate XIV.

mapped near Platte River and elsewhere as North Park. It thus seems highly probable that the Bishop (?) conglomerate is a phase of the North Park Tertiary, differences in lithology being produced by different sources of materials, closer proximity to those sources, and somewhat different conditions of deposition.

ERUPTIVE ROCKS.

Battle, Sheep, and Mule mountains and the Horse Mountains are covered with lava caps from a few feet to 300 feet and more in thickness. One vent from which the eruptive mass issued was located on Sheep Mountain. Probably Battle Mountain and possibly one of the Horse Mountains also were sites of openings.

LATER DEPOSITS.

Along the sides of Little Snake River valley are benches at different elevations, covered by gravel which either was deposited by the river at its former levels or represents remnants of alluvial slopes. The higher ones are difficult to distinguish from the apparent terraces formed by the lowest beds of the Bishop (?) conglomerate.

The river since reaching its present level has filled with alluvium the valley through which, with numerous riffles, it meanders. Its principal tributaries from the north, Battle, Savery, and Muddy creeks, also occupy aggraded valleys in their lower courses. This is especially noticeable in Muddy Creek, which flows through alluvium for nearly 40 miles, the last 25 miles being almost entirely through reworked clay of the Wasatch formation, which has not the fertility shown in the bottom land along Savery and Battle creeks.

In the vicinity of The Willows is a great area of dunes built up by sands brought from the desert by the prevailing southwest winds. These dunes are traveling toward the Upper Narrows of the Muddy and from present indications may in time partly fill that canyon. A second small sand-dune area exists south of the Standard ranch, on Muddy Creek.

Finally, over a great part of the field is spread a mantle of overwash derived mainly from the beds which it covers, with a sprinkling of igneous pebbles probably left from the erosion of some overlying conglomerate.

The areas covered by all these later deposits are only partly shown on Plate XIII.

THE COAL.

CHEMICAL PROPERTIES.

The prime object of the survey of this field was the classification and valuation of the coal lands. With this end in view samples of the freshest coal obtainable were taken, but it was impossible to get completely unweathered coal owing to the lack of adequate openings and fresh working faces. The samples are therefore not comparable to many of those obtained in the same formations by Veatch in the Hanna field [a] and by Schultz [b] in the Rock Springs field, where the samples were taken from fresh faces in large working mines.

The coal samples, which were taken according to the method described in Bulletin 341,[c] were analyzed at the Geological Survey fuel-testing plant at Pittsburg, Pa. In the table below are given the analyses of all samples taken in the portion of the field represented on the accompanying map, including some which were published in the report on the western part of the field.[d] In addition, to illustrate the character of the "Laramie" coal, of which it was not possible to procure an unweathered sample in the field, two previously published analyses of the coals of this formation in neighboring fields are given.

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[a] Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 253-258.

[b] Schultz, A. R., The northern part of the Rock Springs coal field, Sweetwater County, Wyo.: Bull. U. S. Geol. Survey No. 341, 1909, pp. 270-273. See also paper on the southern part of the Rock Springs field, pp. 104-171 of this volume.

[c] Campbell, M. R., Bull. U. S. Geol. Survey No. 341, 1909, p. 12.

[d] Ball, Max W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, p. 251.

Analyses of coal samples from the Little Snake River coal field, Wyoming.

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

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. N.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6642	SE. ¼ SW. ¼	7	13	87	2′ 10″	2′ 10″	7.9	As received	13.0	33.4	45.5	8.10	1.10	5.70	60.39	1.35	23.36	5,955	10,719
								Air dried	5.6	36.2	49.4	8.79	1.19	5.23	65.57	1.47	17.75	6,466	11,639
								Dry coal	....	38.4	52.3	9.31	1.26	4.89	69.43	1.55	13.56	6,846	12,323
								Pure coal [a]	....	42.3	57.7	....	1.39	5.39	76.56	1.71	14.95	7,549	13,588
6644	NE. ¼ SW. ¼	13	13	88	2′ 10″	2′ 10″	5.1	As received	10.8	36.0	46.3	6.94	2.25	5.78	62.77	1.40	20.86	6,232	11,218
								Air dried	6.0	37.9	48.8	7.31	2.37	5.49	66.14	1.48	17.21	6,567	11,821
								Dry coal	....	40.4	51.8	7.78	2.52	5.13	70.35	1.57	12.65	6,985	12,573
								Pure coal	....	43.8	56.2	....	2.73	5.56	76.29	1.70	13.72	7,575	13,635
6803	SE. ¼ SW. ¼	8	12	88	8′	8′	11.7	As received	16.1	29.0	38.6	16.26	.64	5.28	50.42	.88	26.52	4,933	8,880
								Air dried	5.0	32.9	43.7	18.42	.73	4.51	57.09	1.00	18.25	5,587	10,057
								Dry coal	....	34.6	46.0	19.38	.76	4.16	60.10	1.05	14.55	5,880	10,584
								Pure coal	....	42.9	57.1	....	.94	5.16	74.55	1.30	18.05	7,294	13,129
6643	SE. ¼ NE. ¼	18	12	88	12′ 2″	6′ 10″ lower portion of bed.	6.5	As received	13.0	35.7	45.0	6.34	.65	5.78	61.54	1.14	24.55	5,904	10,627
								Air dried	6.9	38.2	48.1	6.78	.70	5.41	65.82	1.22	20.07	6,314	11,365
								Dry coal	....	41.0	51.7	7.28	.75	4.99	70.70	1.31	14.97	6,783	12,209
								Pure coal	....	44.2	55.8	....	.81	5.38	76.25	1.41	16.15	7,315	13,167
5444	SW. ¼ NW. ¼	9	12	89	8′	Upper 7′	5.7	As received	15.8	33.3	47.5	3.44	.58	5.89	62.01	1.10	26.98	5,957	10,723
								Air dried	10.7	35.3	50.3	3.65	.62	5.58	65.76	1.17	23.22	6,317	11,371
								Dry coal	....	39.5	56.4	4.09	.69	4.90	73.64	1.31	15.37	7,075	12,735
								Pure coal	....	41.2	58.8	....	.72	5.11	76.78	1.37	16.02	7,377	13,278
5449	SW. ¼ SE. ¼	5	12	89	15′ 6″	7′ 6″ lower bench.	5.3	As received	14.4	31.8	48.7	5.11	.55	5.82	62.37	.89	25.26	5,997	10,795
								Air dried	9.6	33.6	51.4	5.40	.58	5.52	65.86	.94	21.70	6,333	11,399
								Dry coal	....	37.2	56.8	5.97	.64	4.94	72.82	1.04	14.59	7,002	12,604
								Pure coal	....	39.6	60.4	....	.68	5.25	77.44	1.11	15.52	7,446	13,404
5445	SE. ¼ SE. ¼	6	12	89	14′ 8″	8′ of the upper bench.	4.5	As received	14.3	31.8	48.9	5.00	.46	5.62	60.70	1.02	27.20	5,889	10,600
								Air dried	10.3	33.3	51.2	5.24	.48	5.36	63.56	1.07	24.29	6,167	11,099
								Dry coal	....	37.1	57.1	5.83	.54	4.70	70.82	1.19	16.92	6,871	12,368
								Pure coal	....	39.4	60.6	....	.57	4.99	75.21	1.26	17.97	7,296	13,134
5446	SE. ¼ SE. ¼	6	12	89	14′ 8″	7′ of the upper bench.	6.2	As received	15.2	32.8	48.5	3.51	.60	5.77	59.91	.98	29.23	5,849	10,528
								Air dried	9.6	35.0	51.7	3.74	.64	5.42	63.87	1.04	25.29	6,236	11,224
								Dry coal	....	38.7	57.2	4.14	.71	4.81	70.66	1.16	18.52	6,898	12,416
								Pure coal	....	40.3	59.7	....	.74	5.02	73.71	1.21	19.32	7,196	12,953

5340	SE. ¼	4	17	90	11'+	8'..............	1.9	As received ...	13.6	34.6	43.1	8.69	1.44	5.53	58.79	.89	24.66	5,744	10,339
								Air dried......	11.9	35.2	44.0	8.86	1.47	5.42	59.93	.91	23.41	5,855	10,539
								Dry coal.......	....	40.0	49.9	10.06	1.67	4.65	68.06	1.03	14.53	6,650	11,970
								Pure coal:.....	....	44.5	55.5	....	1.86	5.17	75.67	1.14	16.16	7,394	13,309
5324	NE. ¼ SW. ¼	6	20	88	8'	....	2.3	As received....	19.2	36.5	40.5	3.78	.34	5.74	58.88	1.34	29.92	5,401	9,722
								Air dried......	17.3	37.3	41.5	3.87	.35	5.61	60.27	1.37	28.53	5,528	9,951
								Dry coal.......	....	45.1	50.2	4.68	.42	4.47	72.87	1.66	15.90	6,684	12,031
								Pure coal......	....	47.3	52.7	....	.44	4.69	76.45	1.74	16.68	7,012	12,622
5298	NW. ¼ SW. ¼	12	15	92	7' 9''	2' 1'' from the upper bench.	5.8	As received....	20.7	36.0	33.4	9.90	1.11	5.44	51.84	.72	30.99	4,843	8,717
								Air dried......	15.8	38.2	35.5	10.51	1.18	5.10	55.03	.76	27.42	5,141	9,254
								Dry coal.......	....	45.3	42.2	12.48	1.40	3.96	65.36	.91	15.89	6,106	10,991
								Pure coal......	....	51.8	48.2	....	1.60	4.52	74.68	1.04	18.16	6,977	12,558
5342	NW. ¼ SW. ¼	12	15	92	7' 9''	4' 11'' from the two lower benches.	6.5	As received....	25.0	46.8	20.7	7.51	.39	5.55	51.13	.73	34.69	4,680	8,424
								Air dried......	19.8	50.0	22.2	8.03	.42	5.17	54.68	.78	30.92	5,005	9,010
								Dry coal.......	....	62.4	27.6	10.02	.52	3.70	68.21	.97	16.58	6,243	11,237
								Pure coal......	....	69.3	30.7	....	.58	4.11	75.80	1.08	18.43	6,938	12,488
5448	NE. ¼ NE. ¼	23	13	91	6'+	6'..............	9.8	As received....	24.0	28.5	39.4	8.1	.97	....	....	....	....	4,499	8,098
								Air dried......	15.7	31.6	43.7	9.0	1.08	....	....	....	....	4,988	8,977
								Dry coal.......	....	37.5	51.8	10.7	1.28	....	....	....	....	5,919	10,654
								Pure coal......	....	42.0	58.0	....	1.43	....	....	....	....	6,626	11,927
5447	SW. ¼	24	13	91	16' 5''	6' from bottom of lower bench.	12.8	As received....	26.0	30.1	37.9	6.0	1.01	....	....	....	....	4,641	8,354
								Air dried......	15.2	34.5	43.4	6.9	1.16	....	....	....	....	5,322	9,580
								Dry coal.......	....	40.7	51.1	8.2	1.37	....	....	....	....	6,273	11,291
								Pure coal......	....	44.3	55.7	....	1.49	....	....	....	....	6,832	12,297
5299	SE. ¼ SE. ¼	4	16	92	2' 2''+	2' 2''...........	1.7	As received....	10.3	22.2	57.7	9.83	.87	2.72	67.94	.77	17.87	5,752	10,354
								Air dried......	8.7	22.6	58.7	10.00	.89	2.57	69.12	.78	16.64	5,851	10,533
								Dry coal.......	....	24.8	64.3	10.95	.97	1.76	75.71	.86	9.75	6,410	11,538
								Pure coal......	....	27.8	72.2	....	1.09	1.98	85.02	.96	10.95	7,198	12,957

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term it is used in this report as noted above.

6642. Carbondale mine. Sample from wall of room about 30 feet from main entry.
6644. Stemp Springs mine. Sample taken from wall of irregular room about 10 feet from minor entry.
6803. Linde opening. Sample taken on main entry about 40 feet from entrance.
6643. Lucksinger opening. Sample from breast of main entry.
5444. Martin mine. Sample taken in entry 430 feet from mouth of mine.
5449. Darling mine. Sample taken in entry driven to left 120 feet from main entry and 265 feet from mouth of mine.
5445. Angier mine. Sample taken in main entry of old workings 210 feet from mouth of the mine.
5446. Angier mine. Sample taken in old workings on left 300 feet from main entry and 440 feet from mouth of mine.
5340. Robertson mine. Sample taken from left side of room 50 feet from mouth of mine.
5324. Nebraska mine.
5298. Muddy Bridge opening. Sample on north wall of entry 35 feet from mouth of mine.
5342. Muddy Bridge opening. Sample on north wall of entry 20 feet from mouth of mine.
5448. Prospect. Sample taken from north wall 40 feet from entrance.
5447. Prospect. Sample taken from east wall 145 feet from entrance.
5299. Prospect. Sample taken from south wall 25 feet from entrance.

MESAVERDE COAL.

The Mesaverde formation contains the best coal in the field. Coal from this formation is now being mined in Wyoming at Rock Springs and Superior, and in Colorado in Routt County and from Newcastle to Crested Butte. The Mesaverde coal is probably more easily and economically minable than that of either of the other coal-bearing formations, owing to its prevailing low dips. This advantage may possibly be offset in many places by minor faults of a few feet displacement. The coal, which is bituminous, is very hard, rather brittle, with an almost metallic luster and a tendency to conchoidal fracture. The bedding is obscure and there is little or no cleavage. At the Stemp Springs, Carbondale, and Lucksinger openings there is a well-marked series of rifts or slips in one direction perpendicular to the bedding. In a very few places a less distinct system is present which is perpendicular to the bedding and approximately at right angles to the first system. These rifts, of which advantage is taken in shooting down the coal, dip from 65° to 90° and are not evenly spaced or continuous. Many of them show slickensides, and in the Lucksinger opening a few contain a thin film of pyrite and a very few show one-eighth to one-half inch of crushed coal. The coal is mined and handled with a small percentage of breaking and resists weathering well. A sample from the Lucksinger opening which had laid in an open shed for seven months was black, hard, and firm, with submetallic luster, no cleavage, slight conchoidal fracture, and no signs of weathering beyond a certain amount of peacock coloring. In thoroughly weathered surface exposures the coal breaks into rusty-brown cubes 4 or 5 inches on an edge, and these in turn break into very small cubes with black submetallic faces. The general character of the Mesaverde coal beds is shown in the following sections:

Sections of coal beds in the Mesaverde formation in the Little Snake River field, Wyoming.

No. on Pl. XIII.	Laboratory No.	Location.				Section of coal bed.			Name of mine or character of opening.
		Quarter.	Sec.	T.	R.		Ft.	in.	
		SE. ¼ NW. ¼.	a16	12	87	Sandstone, white.			Surface exposure.
						Coal	1	2	
						Shale, bituminous	2	2	
						Coal, bottom not exposed.			
							3	4+	
		SW. ¼.	a17	12	87	Roof not exposed.			Surface exposure.
						Coal, badly weathered.	6		
						Floor not exposed.			
1	6642	SE. ¼ SW. ¼.	7	13	87	Shale, sandy.			Carbondale mine.
						Coal, good	2	10	
						Fire clay	4		
						Shale.			
							6	10	
		NW. ¼ NW. ¼.	32	13	87	Coal, good	2	10	Surface exposure.

a Colorado.

Sections of coal beds in the Mesaverde formation in the Little Snake River field, Wyoming—Continued.

No. on Pl. XIII.	Laboratory No.	Location.				Section of coal bed.	Ft.	in.	Name of mine or character of opening.
		Quarter.	Sec.	T.	R.				
3	6803	SE. ¼ SW. ¼.	8	12	88	Shale. Coal, hard Shale.	 8 		Linde opening.
4	6643	SE. ¼ NE. ¼.	a18	12	88	Coal, good Shale.	12 	2 	Lucksinger opening.
2	6644	NE. ¼ SW. ¼.	13	13	88	Shale, sandy, slabby. Coal, good Bone.	 2 	 10 	Stemp Springs mine.
		SE. ¼ SE. ¼.	36	13	88	Shale, bituminous, blue to black. Coal, good Shale Coal, good Total	 1 15 2 18	 8 8	Surface exposure.
6	5449	SW. ¼ SE. ¼.	5	12	89	Shale. Coal, good Shale Coal, good Shale Coal. Total	 7 1 7 1 16	 6 2 8	Darling mine.
7	5445 5446	SE. ¼ SE. ¼.	6	12	89	Shale. Coal, good Sandstone Coal, fair Shale. Total	 11 2 1 14	 8 8	Angier mine.
17		NE. ¼ NE. ¼.	8	12	89	Shale. Coal Shale.	 9 		Prospect.
5	5444	SW. ¼ NW. ¼.	9	12	89	Shale. Coal Shale.	 8 		Martin mine or Company bank.
		SW. ¼ SW. ¼.	13	12	89	Shale, bluish Coal, fair Sandstone, calcareous Total	3 5 8 16		Surface exposure.
18		SW. ¼ SE. ¼.	32	13	89	Coal, brown Coal, good Total	1 3 4		Prospect.
		NW. ¼ NE. ¼.	7	14	89	Shale. Coal Shale.	 4 		Surface exposure.
		NW. ¼ NE. ¼.	23	14	89	Shale. Coal Shale.	 3 		Surface exposure.
		SE. ¼ SW. ¼.	32	14	89	Sandstone. Coal, fair Shale.	 6 		Surface exposure.
		NW. ¼ NW. ¼.	33	14	89	Shale. Coal Shale.	 3 		Surface exposure.
		NW. ¼ SW. ¼.	33	14	89	Shale. Coal Shale.	 2 		Surface exposure.
		SE. ¼ NW. ¼.	13	14	90	Shale. Coal Coal.	 2 	 7 	Surface exposure.

a Colorado.

Sections of coal beds in the Mesaverde formation in the Little Snake River field, Wyoming—Continued.

No. on Pl. XIII.	Laboratory No.	Location.				Section of coal bed.	Ft.	in.	Name of mine or character of opening.
		Quarter.	Sec.	T.	R.				
		SE. ¼ NE. ¼.	15	15	90	Coal, fair	2		Surface exposure.
						Shale and sandstone	20		
						Coal	5		
						Shale	15		
						Coal, good	15		
							57		
		NW. ¼ SW. ¼.	22	15	90	Sandstone.			Surface prospect.
						Coal, good, hard	5		
						Shale.			
		NE. ¼ NE. ¼.	18	16	90	Shale.			Surface exposure.
						Coal	4		
						Shale.			
		NW. ¼ NE. ¼.	28	16	90	Shale.			Surface exposure.
						Coal	4	3	
						Shale.			
	5340	SE. ¼.	4	17	90	Sandstone, shaly.			Robertson mine.
						Coal, good	11		
						Bottom not exposed.			

"LARAMIE" COAL.

As stated in a previous paragraph, it was possible to make only a few observations on the coals of the "Laramie" formation in the Little Snake River field, and no samples for analysis were obtained. Where observed, the unweathered coal has a submetallic luster and parts readily along the bedding planes, which are rather prominent. As weathering progresses this tendency to split along the bedding planes increases and vertical joints develop until the coal breaks readily into small plates, with the vertical planes black and lustrous and the horizontal planes yellow or rusty brown.

Sections of coal beds in the "Laramie" formation in the Little Snake River field, Wyoming.

No. on Pl. XIII.	Location.				Section of coal bed.	Ft.	in.	Name of mine or character of opening.
	Quarter.	Sec.	T.	R.				
8	SW. ¼ NE. ¼	15	12	90	Sandstone.			Prospect.
					Coal, good	6	6	
					Shale.			
	SE. ¼ SE. ¼.	15	13	90	Sandstone, massive	15		Surface exposure.
					Shale, gray	2	3	
					Coal	2		
					Shale, gray	1		
					Sandstone, gray, shaly	3		
					Shales, gray and brown	3		
					Coal, brownish	1		
					Shale, bituminous		9	
						28		
	SW. ¼ SW. ¼.	19	18	90	Coal	15+		Surface exposure.
	SE. ¼ SE. ¼.	7	15	91	Sandstone, gray	3		Surface exposure.
					Shale, brown, gypsiferous	1	6	
					Coal	1		
					Shale, brown		10	
					Coal	4		
					Bottom not exposed.			
						10	4	

"UPPER LARAMIE" COAL.

The "Upper Laramie" formation probably contains more coal than any other formation in the field. The coal is of about the same grade as that in the "Laramie," but is of lower calorific power, air slacks much more rapidly, and breaks down more easily in mining and handling than the Mesaverde coal. The nearest point at which it is mined extensively is Hanna, Wyo. The unweathered coal is black in the lowest member and in most of the uppermost member, but in places thin beds of impure coal with a brownish tinge are found near the top of the formation. As a rule the coal is rather light in weight and has a submetallic to resinous luster. Many beds are gypsiferous and a small amount of pyrite is common. It splits readily along the bedding planes and on weathering develops two secondary joint systems approximately at right angles to the bedding and to each other, so that the weathered coal breaks into little shaly blocks, all of whose faces are apt to be coated with a film of selenite or ferrous sulphate.

Sections of coal beds in the basal member[a] of the "Upper Laramie" formation in the Little Snake River field, Wyoming.

Laboratory No.	Location.				Section of coal bed.	Ft.	in.	Name of mine or character of opening.
	Quarter.	Sec.	T.	R.				
5448	NE. ¼ NE. ¼.	23	13	91	Shale, gray.			Prospect.
					Bone		4	
					Coal, dirty	6		
					Bottom not exposed.			
						6	4	
5447	NE. ¼ SW. ¼.	24	13	91	Sandstone, clayey.			Prospect.
					Coal, dirty	3	2	
					Bone		3	
					Coal, dirty		10	
					Bone		2	
					Coal	12		
					Shale, bituminous.			
						16	5	
	SW. ¼ NE. ¼.	25	13	91	Coal	3	8	Prospect.
					Bottom not exposed.			
	SE. ¼ NW. ¼.	25	13	91	Roof not exposed.			Prospect.
					Coal, good	5	2	
					Dirt		2	
					Bottom not exposed.			
						5	4	
	SE. ¼ SW. ¼.	7	17	91	Burned beds.			Surface exposure.
					Coal	2		
					Burned beds, approximately	20		
					Coal, good	4		
						26		
	SW. ¼ SW. ¼.	7	17	91	Shale, brown.			Surface exposure.
					Coal, good	2		
					Shale, brown.			

[a] For section from uppermost member see Bull. U. S. Geol. Survey No. 341, p. 252 ("Creston, 9 miles south of; Coalbank Spring; NE. ¼ NW. ¼ sec. 3, T. 18 N., R. 92 W.")

Sections of coal beds in the basal member of the "Upper Laramie" formation in the Little Snake River field, Wyoming—Continued.

Laboratory No.	Location.				Section of coal bed.			Name of mine or character of opening.
	Quarter.	Sec.	T.	R.		*Ft.*	*in.*	
	SW. ¼ SW. ¼.	33	18	91	Sandstone, shaly.			Surface exposure.
					Shale, bituminous	2		
					Coal		3	
					Shale, bituminous		5	
					Coal	4	6	
					Clay, brown		8	
					Shale, bituminous		2	
					Coal	1	6	
					Clay, sandy, compact.			
						9	6	
5298	NW. ¼ SW. ¼.	12	15	92	Shale, bituminous		6	Muddy Bridge opening.
					Shale, brown		5	
					Coal	2	1	
					Shale, gray		9	
					Coal	2	5	
					Shale		2	
					Coal, slightly dirty	2	4	
						8	8	
5299	SE. ¼ SE. ¼.	4	16	92	Coal, burned	15		Prospect.
					Shale	3		
					Coal	2	2	
					Bottom not exposed.			
						20	2	
	SE. ¼ SE. ¼.	9	16	92	Sandstone, massive.			Surface exposure.
					Shale, bituminous, with thin beds of coal	3		
					Shale, gypsiferous	20		
					Sandstone, brown	1		
					Shale, bituminous	3		
					Coal, gray, shaly	1		
					Shale, gray	10		
					Coal	2		
					Shale, gray	4		
					Coal	14		
					Sandstone, grayish brown	4		
					Sandstone, light brown	1		
					Shale	10		
					Coal	5		
					Shale, gray	1	6	
					Sandstone, white	2		
						81	6	
	SW. ¼ SE. ¼.	10	16	92	Sandstone, light brown.			Surface exposure.
					Coal, good	2		
					Shale, gray	12		
					Coal, good	2	2	
					Shale, gray	2		
					Coal, good	1		
					Sandstone.			
						19	2	

BURNED COAL BEDS.

The thickness and character of many of the coal beds are obscured by burning along the outcrop. The burning is of relatively small extent in the Mesaverde, but much more prevalent in the "Laramie" and "Upper Laramie" coal beds. The most prominent effect is the production in many places of bright-red outcrops, the color being due to the alteration of the iron in the rocks adjacent to the burned bed. Whether or not the neighboring rocks are reddened they are as a rule more or less sintered, the distance to which coloration and sintering extend varying from almost nothing to several feet from the actual seat of burning. A quarter of a mile southeast of Muddy Bridge a small caved drift in the "Laramie" formation exposes about 18 inches of bituminous shale underlain by a few feet of dirty coal. Near by the bituminous shale has been burned, causing baking, reddening, and slumping of the overlying shaly sandstone, but the dirty coal composing the lower part of the bed is apparently not affected. In this connection attention should be called to the fact that sample 5299 in the table on page 206 was taken from a 2-foot bed separated by 3 feet of shale from 15 feet of burned coal. The physical appearance of the bed sampled was not altered by the burning, but the chemical analysis shows decided differences between this sample and the others collected from the same zone—notably increased fuel value, lower air-drying loss, lower volatile matter and higher fixed carbon giving higher fuel ratio, and, in the ultimate analysis, lower hydrogen and oxygen and higher carbon. Thus the coal in close proximity to a burned bed has by alteration become of considerably higher grade than its unaffected neighbors.

COKING.

So far as known the only coking test made on coals in this field was made on the Mesaverde coal at the Stemp Springs property in August, 1907. The chemical composition and physical characteristics show this to be among the very best coals in the region. The coking test was made in a regulation beehive oven 12 feet in diameter and 6 feet high in the arch. The floor was 2 feet thick, with air spaces. Reports of the test state that the fire burned on top and refused to go down, this condition being attributed to inexperienced firing and to the cooling action of the air spaces in the floor. The result was ash on top, unburned coal at the bottom, and some coke in the middle. This coke is stated to have analyzed 87 per cent of fixed carbon, 9 per cent of ash, and 4 per cent of moisture. In contemplation of a test in the near future the oven has been remodeled, with a 3-foot floor without air spaces, and the materials have been laid down for the construction of two new ovens. No report was made on the crushing strength of the coke obtained in the test, nor on the ratio of coal to coke produced.

DEVELOPMENT.

HISTORY AND PRESENT OPERATIONS.[a]

Early openings.—Doubtless the first coal opening in the Little Snake River field was made in 1863 by the Overland Stage Company a short distance east of Sulphur. The coal from this opening was used for blacksmithing and heating at the Sulphur stage station,

[a] For many of the statements regarding the history and development of the field the writers are indebted to Mr. H. F. Angier, Mr. M. W. Dillon, and Mr. John C. Friend.

and small quantities are said to have been shipped for blacksmithing purposes as far east as Denver and as far west as Fort Bridger. After the completion of the Union Pacific Railroad an opening is said to have been made by the United States Government just west of Muddy Creek about 3 miles south of Muddy Bridge, the coal being used in connection with stations on the stage road that ran from Rawlins to the White River Indian Agency, Colo. The first opening made by individual enterprise is reported to have been the Easom mine (NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 8, T. 12 N., R. 89 W.; No. 17[a]), situated between the present locations of the Company bank and the Darling mine. It was opened in 1876 or 1877, but the land was never patented and work was abandoned in the late nineties.

Carbondale mine.—The earliest opening that is still in operation seems to be the Carbondale mine, in the SE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 7, T. 13 N., R. 87 W. (No. 1). Coal was discovered at the present site of the mine in the early eighties by Frank Fernald and Joe Hartenberg, and the mine was opened by George Doane to supply coal for mining operations in the Sierra Madre. Unsuccessful efforts were made to find coal nearer to the point of consumption. In the summer of 1908 the property was producing about 10 tons a day, employing seven men, using drilling machines, and shooting from the solid. The maximum extent of the workings from the outcrop at that time was about 1,300 feet, but the actual depth below the surface is slight throughout. The greater part of the original workings was abandoned in 1904, owing to difficulty with water and to irregularities in the coal bed caused by minor faults, and a new drift was started in March, 1908. The rooms are 12 by 20 feet, with stulls from $1\frac{1}{2}$ to $2\frac{1}{2}$ feet apart. The property is now owned by the United Smelters, Railway and Copper Company.

Stemp Springs mines.—The Stemp Springs mine (NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 13, T. 13 N., R. 88 W.; No. 2) is owned by the Stemp Springs Coal and Power Company, the product being used in mining and smelting operations in the mountains to the east. The main entry is carried 6 feet high in the clear in coal, the rooms and pillars are irregular in size and shape, and stulls are set in the rooms from 3 to 6 feet apart.. The main entry is driven just off the dip, which is about 2° and somewhat irregular.

Lucksinger opening.—The Lucksinger opening (SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 18, T. 12 N., R. 88 W., Colorado; No. 4) has been operated for a number of winters by different persons, supplying coal for domestic use to the ranchmen of the upper Little Snake River valley. The coal has been mined from two large, somewhat irregular, more or less parallel drifts, no rooms being turned and very little timber being used.

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[a] Numbers refer to locations on Plate XIII.

Company bank.—The Company bank (SW. ¼ NW. ¼ sec. 9, T. 12 N., R. 89 W.; No. 5) formerly known as the Martin mine, is owned by the Snake River Coal Company. It was first discovered and opened about 1886 or 1887 by Noah Reader and has since produced about 10,000 tons, the present annual production being about 800 tons. The original entry runs as near the strike of the beds as the escarpment in which the coal bed outcrops will permit. Later entries run in directions successively approaching the north, the earlier entries being allowed to cave as the coal in their vicinity is worked out. The depth along the entries is a little more than 400 feet.

Darling mine.—The Darling mine (SW. ¼ SE. ¼ sec. 5, T. 12 N., R. 89 W.; No. 6), now owned by William Darling, was discovered and opened by Robert Turner and Ira Whiteaker in 1891 and later worked by Robert McIntosh. It has produced about 10,000 tons and is now producing about 800 tons annually. It is developed by an entry running for 265 feet nearly on the strike of the bed, which dips about 8°. From the main entry minor entries are run off to distances of 150 feet or so, and rooms of irregular size are turned from these entries.

Angier mine.—The Angier mine (SE. ¼ SE. ¼ sec. 6, T. 12 N., R. 89 W.; No. 7), on the opposite side of Savery Creek from the Darling property, was discovered and opened by Joseph Wilson in 1890 and is now owned by H. F. Angier. Its total production has been between 10,000 and 12,000 tons; its present annual production is from 800 to 900 tons. The original workings consist of a drift run 400 feet N. 45° W., from which at a depth of 145 feet a second entry runs 700 feet N. 53° W., the coal being worked out in rooms extending between these two entries. These workings are now abandoned, but a somewhat similar system of mining is being followed in the new opening about 100 feet south of the old one.

Dillon mine.—The Dillon mine, opened in 1886 but now abandoned, lies outside of the area especially considered in this paper, in the NE. ¼ NW. ¼ sec. 36, T. 21 N., R. 88 W.,[a] but was for a number of years one of the principal producers in the vicinity of the Little Snake River field, the coal being used in the neighboring town of Rawlins. Two main entries were driven, the earlier one being abandoned, partly because of the quantity of gas encountered. Drifts from the main entries were run at various angles, work being carried to a distance from the outcrop of over 500 feet. The mine was originally owned by M. W. Dillon, who states that it was abandoned in 1900 or 1901 by the people to whom he sold it because minor faults were encountered. The character of the faults may be judged from the following extract from a letter by Mr. Dillon: "The first fault is a downthrow of 4 feet,

[a] Ball, Max W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, Plate XIII.

about 200 feet from the portal; the next is an upthrow of 4 feet, 240 feet from the portal; the next a downthrow of 6 feet, 450 feet from the portal."

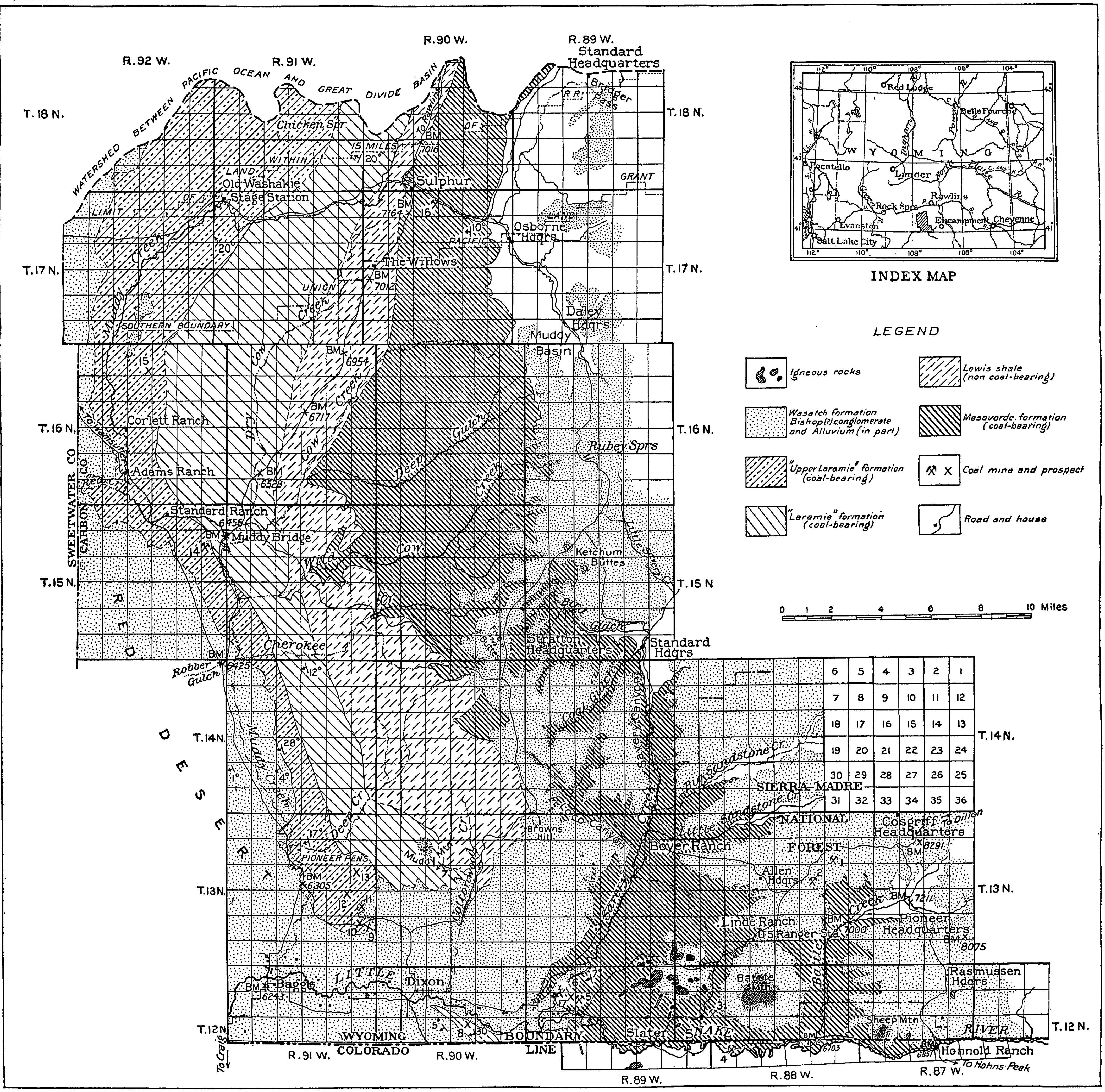
Nebraska mine.—The Nebraska mine (NE. ¼ SW. ¼ sec. 6, T. 20 N., R. 88 W.[a]) lies just outside of the Little Snake River field, in the part of the Great Divide Basin field covered by Ball in 1907. It is the only mine in or adjacent to the Little Snake River field which is in the "Laramie" formation, all the properties described above being in the Mesaverde. Mining is carried on throughout the winter months, the product being used in Rawlins, 7 miles distant. The dip of the bed varies from 12° to 20°. The coal is mined through a main entry, extending approximately down the dip, with entries turned at right angles from 100 to 200 feet apart.

Other openings.—In addition to the mines described above, there are in various parts of the field other openings, some of them supplying coal to one or two ranches in their immediate neighborhoods, others at present entirely abandoned or the scene of desultory prospecting. The Robertson mine (SE. ¼ sec. 4, T. 17 N., R. 90 W.; No. 16), in the Mesaverde, just east of Sulphur, has been worked to a depth of about 100 feet, 50 feet of which is a drift and the remaining 50 feet an irregular chamber. The Linde opening (SE. ¼ SW. ¼ sec. 8, T. 12 N., R. 88 W.; No. 3), also in the Mesaverde, has been worked to a depth of about 40 feet by a single straight, well-timbered drift. The Muddy Bridge opening (NW. ¼ SW. ¼ sec. 12, T. 15 N., R. 92 W.; No. 14), in the "Upper Laramie," is an irregular, practically untimbered opening about 40 feet deep, sloping about 25°. The Corlett opening (SE. ¼ SE. ¼ sec. 4, T. 16 N., R. 92 W.; No. 15), also in the "Upper Laramie," has been carried about 40 feet down a slope of 35°. A few miles northeast of Baggs, in Coal and Cutoff gulches, are a number of openings in the "Upper Laramie" (Nos. 9, 10, 11, and 12), of various depths up to 150 feet or more, none of which are operated at present. No. 10 is an excellently timbered slope dipping 25°, at present nearly full of water. No. 9 is also well timbered and nearly horizontal, but the coal is powdery. No. 11 is a drift approximately 150 feet deep, with coal as roof and no timbering. No. 12 is an irregular opening partly caved. The prospect opposite the Deary ranch (SW. ¼ NE. ¼ sec. 15, T. 12 N., R. 90 W.; No. 8) is in the "Laramie." It is an irregular slope about 30 feet deep, with a small amount of timbering.

FUTURE DEVELOPMENT.

The rapidity with which this field will be developed depends almost entirely on four factors—market, transportation facilities, timber supply, and water supply.

[a] Ball, Max W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, Plate XIII.



MAP OF EASTERN PART OF LITTLE SNAKE RIVER COAL FIELD, WYOMING.

By M. W. Ball and Eugene Stebinger.

MARKET.

The field is unfortunate in being surrounded by producing areas which are more accessible and in having its most available coals farthest from the railroads and from any present market. To the west are the Rock Springs and Uinta County fields, to the east is the Hanna field, and to the south are the Yampa and Grand Hogback fields of Colorado. On the other hand, the demand from the country to the west is so great that the Union Pacific Coal Company has in the last few years ceased shipping its Wyoming coal east, leaving unsupplied a vigorous demand in Omaha and adjacent towns. Denver, although in the vicinity of large coal fields, is a ready market for coal of this grade, and Salt Lake City is using all the coal mined commercially at Rock Springs and most of that in Uinta County, with no apparent danger of overstocking. On the whole, the demand for coal is greater than the supply, and the rapid development of the West is increasing the demand constantly.

The natural local market for the coal of the southern part of the field is in the mining districts in the mountains along the eastern border of the coal-bearing area. On both sides of the crest of the Sierra Madre, just east of the Carbondale and Stemp Springs mines, is the Encampment copper district, to which the coal from those properties is now being hauled. Further development of that district or of any of the prospective mining camps on the headwaters of Little Snake River would call for further development of the coal field. The great need of the smelters in the Encampment vicinity is for coke, and this the coals of the Little Snake River field have not yet been able to supply commercially, but they can supply an excellent steaming coal for power and mining operations.

TRANSPORTATION.

The field has at present no railroad, consequently no coal is produced within the field for consumption outside of it except that hauled by wagon from the Carbondale and Stemp Springs properties to the adjacent mining camps. The nearest railroad is the Union Pacific, about 12 miles to the north of the area especially treated in this paper and some 50 miles from the region of greatest present development. Approximately 50 miles southeast of the area is Steamboat Springs, Colo., the present terminus of the Denver, Northwestern and Pacific Railway, more commonly spoken of as the "Moffat road." It is planned to push this road westward through the Yampa field to Craig, Colo., within 37 miles of Baggs.

The Union Pacific Railroad Company is contemplating a branch from the main line southward to Craig. The starting point of the branch is still uncertain. It may be Rawlins, Creston, or Wamsutter. In any case the road will traverse this field from north to south. A line connecting the field with the "Moffat road" at Steamboat Springs is also discussed, to run through the Hahns Peak region and traverse the upper Little Snake River valley. Still another line which may be constructed is the rumored branch of the Laramie, Hahns Peak and Pacific Railway from Hahns Peak, the road being now under construction some 30 miles west of Laramie.

If a railroad is constructed through the field it will be comparatively easy to reach the coals by spurs. The flat-lying coal beds along Little Snake River from the mouth of Savery Creek upstream would be on any line traversing the valley, and a line from Baggs or Dixon would have a water-level grade. Construction of spurs to some of the coals lying in the higher Mesaverde ridges and plateaus might involve moderate engineering difficulties, but most of them could be developed by tracks laid in the dissecting canyons. No difficulty should be experienced in tapping the coals of the "Laramie" and "Upper Laramie" formations even in the higher parts of the hogback region.

TIMBER SUPPLY.

The fact that most of the coal beds of the field lie under shale roof makes the quality and price of timber an important item in any estimate of mining costs. The cost of timber at the Carbondale mine in the summer of 1908 is reported as about 15 cents to the ton of coal mined. The greater part of the field in Wyoming is devoid of timber, except for a few scattering scrub cedars in the Mesaverde ridges and a few cottonwoods along the river. East of Savery Creek, however, much of the country is well timbered. The Hayden National Forest includes Battle Mountain and extends northward and eastward across the Sierra Madre. The timber in most of the forest is estimated by the Forest Service [a] at less than 2,000 board feet to the acre, although part of it is estimated to carry between 2,000 and 5,000 board feet.

The part of the field in Colorado lies almost entirely within the Routt National Forest and is most of it heavily forested. The timber available in the southeastern part of the field is thus capable of supplying the needs of very extensive mining operations.

WATER SUPPLY.

In general, those streams which head in the formations younger than the Mesaverde are intermittent, and those which head in the Mesaverde or older formations are permanent either throughout their courses or while crossing and for some distance after leaving the older formations. Thus Savery and Battle creeks and their tributaries are permanent streams throughout; Muddy, Cow, Wild Cow,

[a] Sierra Madre folio, Atlas Nat. Forests U. S., U. S. Forest Service.

and Cherokee creeks become intermittent some distance after leaving the Mesaverde; and Dry Cow, Red, and Cottonwood creeks are intermittent throughout. The one younger formation which is strongly water bearing is the Bishop (?) conglomerate, which furnishes much of the water in Savery and Battle creeks and in the headwaters of Muddy Creek. Springs along the base of this formation and in the limestone, where limestone makes up the overlying beds, are rather numerous for the semiarid regions, and the quality of the water is excellent. Another stratigraphic location which shows a tendency to develop springs is the boundary between the Mesaverde formation and the Lewis shale. The springs at this horizon, however, are as a rule rather small and many are highly mineralized, particularly the sulphur springs in the vicinity of Sulphur. In the streams the alkalinity decreases and the quality of the water correspondingly improves as the flow becomes permanent. The water of Little Snake River itself is normally clear and of good quality. The waters of lower Muddy Creek and the lower courses of its tributaries are unfit for either human or boiler use.

So far as was ascertained the only wells in the field are sunk in the alluvium of the stream valleys. The water in these is of uncertain quality. Thus a well 20 feet deep at Muddy Bridge yields good water, but wells from 10 to 40 feet deep at Baggs and Dixon have developed water more alkaline than that in the river. It should be possible to supply small temporary operations by sinking shallow wells in the alluvium of almost any of the main stream valleys, even where the stream itself is intermittent. For deep wells the Mesaverde is the most promising formation in the coal-bearing area. Wells drilled into the westward-dipping part of this formation should yield an abundance of good water. The supply of water to be obtained from wells in the "Laramie" and "Upper Laramie" formations can best be judged by the wells of the Union Pacific Railroad north of the field. At a number of places between Rawlins and Tipton water was obtained at depths of about 500 feet in the "Laramie" and overlying formations, but it was too alkaline to be serviceable. At depths of 1,400 to 1,600 feet alkaline water usable for boiler and domestic purposes is obtained in the "Upper Laramie." In this field wells of that depth in the "Laramie" and "Upper Laramie should yield a plentiful supply of water of about the same grade as that obtained at Riner and Wamsutter. The basal member of the "Upper Laramie" should be the best water-bearing zone of the two formations. The two locations most favorable to the development of artesian water are in the Lewis shale valley at or near the Mesaverde boundary and in the valley formed in places by the middle or clay shale member of the "Upper Laramie," near the top of the lowest member. The two formations to be avoided are the shale immediately east of the Mesaverde and the Lewis shale except near the Mesaverde.

THE SOUTHERN PART OF THE ROCK SPRINGS COAL FIELD, SWEETWATER COUNTY, WYOMING.

By ALFRED R. SCHULTZ.

INTRODUCTION.

This report is a brief discussion of the economic geology of the southern part of the Rock Springs coal field, Wyoming. The survey on which the report is based was made during the summer of 1908 by John L. Rich, B. L. Johnson, George E. Burton, and the writer. A detailed report on the coal of the Rock Springs field will be prepared as soon as time and the work in hand will permit.

The primary object of the investigation was the classification of the public land with respect to its coal content. Economic considerations therefore demanded that the work be based primarily on Land Office subdivisions, and that all coal outcrops, prospects, and geologic data be located with respect to established government corners. In the summer of 1907 similar work was done in the northern part of the Rock Springs field,[a] and in a part of the Great Divide Basin coal field, extending northwestward from the Rawlins dome.[b] The work of the past season was a continuation of that of the preceding year. The mapping of the Rock Springs coal field was completed by the writer, while E. E. Smith completed the mapping of the Great Divide Basin field and closed the gap between the areas mapped in 1907.

The Rock Springs coal field is located in the central part of Sweetwater County, Wyo., on the east side of Green River, in the southern part of the State, the south end of the field being only a few miles north of the Wyoming-Colorado state line. (See Pl. XIV.) It lies in the midst of the great Wyoming desert and occupies the crest of a low structural dome. This eroded dome, with its surrounding rim of Tertiary beds, gives to the field a natural boundary with reference to the outcrop of the coal-bearing rocks. The productive formations, however, underlie much of the surrounding country in the Green

[a] Schultz, A. R., Bull. U. S. Geol. Survey No. 341, 1909, pp. 256–282.
[b] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, pp. 220–242.

River Basin, which includes within its borders the most important coal fields along the Union Pacific Railroad between the Wasatch and Wyoming mountains on the west and the Rocky Mountains on the east.

The Union Pacific is the only railroad crossing this area and nearly all points in the Rock Springs field are readily accessible from the main line. Several projected lines have been surveyed across the north end of the field, but no other line has yet begun active construction. The location of the Union Pacific Railroad places it in a position to control the future development of the field. The grade along its line is moderate, and by short spurs with light grades, similar to those of the Superior and Gunn branches, it will be comparatively easy to reach all points at which mines may be opened to advantage. For all of the southern half of the field the most accessible routes lie along the main tributaries of Bitter Creek—Little Bitter, Killpecker, Salt Wells creeks and their tributaries. Spurs built up any of these valleys would be natural feeders to the trunk line along Bitter Creek.

The southern part of the Rock Springs field is covered by the public-land surveys. Because of an assumed poor survey a considerable tract, approximately 12 townships, was resurveyed by the General Land Office in 1906, and 24 townships were resurveyed by that bureau in 1907. In the part of the field south of the fourth standard parallel few corners could be found, and these do not agree among themselves; hence it is probable that they have not been authoritatively established. In this area it was found necessary to resurvey the townships before the land could be classified. During the summer of 1908 Tps. 15 and 16 N., R. 102 W., were resurveyed by the General Land Office and a detailed topographic map, with a contour interval of 50 feet, was made. The geologic work in these two townships was done by George E. Burton.

Glenn Smith, topographer of the United States Geological Survey, mapped in the summer of 1908 a 15-minute quadrangle in the vicinity of Rock Springs. The mapping of this quadrangle was done on the scale of 1 inch to the mile, the contour interval being 50 feet. Later in the season photographic copies of this base were used in mapping the geology and coal outcrops.

Of the territory outside of the areas of detailed mapping mentioned above, or approximately 10 townships, no maps other than township plats were available for field use. It was therefore necessary to make a topographic map as the geologic work progressed. In such territory all locations were made either (1) by pacing section lines or by making traverse from land corners found by such pacing, or (2) by plane-table station work, supplemented by plane-table traverse, triangulation, and intersection work, checked and tied to land corners.

In areas where no corners could be found plane-table control was used entirely, road and line stadia traverses being made wherever necessary.

Altitudes were carried by stadia, altimeter, Locke level, and aneroid, all being adjusted to the temporary and permanent bench marks along the line of levels run around the dome from Rock Springs north to Steamboat Mountain, thence south to Point of Rocks, Black Buttes, and around the south end of the dome back to Rock Springs. Lines were run one-fourth to one-half mile apart, and the outcrops of all the more important coal beds were traversed and the traverses tied to land corners. The field sheets were made on the scale of 2 inches to the mile, with a contour interval of 50 feet, and will be used in the preparation of the maps to accompany the final report. The maps (Pls. XIV and XV) accompanying the present report have been prepared from the field sheets, and although approximately correct they may differ in minor particulars from the final large-scale maps.

TOPOGRAPHIC FEATURES.

The Rock Springs coal field lies along the eastern margin of the Green River Basin and includes on the northeast a part of the Great Divide Basin. It occupies the major part of the Rock Springs structural dome, which is completely surrounded by Tertiary beds. Within this field there are five distinct topographic districts, each presenting entirely different characteristics from those of its neighbor. Only the most prominent peaks and ridges that encircle the dome rise above the adjacent Tertiary escarpments. The divide between the Green River and Great Divide basins has no topographic identity or distinctness. It lies for the most part several miles east of the dome and is formed in some places of Tertiary rock, in others of Cretaceous rock, and in still others of igneous rock. The divide is irregular, extending across several distinct topographic districts.

The principal topographic features of this field are due to (1) hard, resistant sandstone beds of the Mesaverde formation; (2) hard, resistant limestone and sandstone beds of the nearly horizontal Green River and Wasatch formations; (3) migrating sand; (4) soft beds of the Wasatch formation, Lewis shale, and shale underlying the Mesaverde in the central part of the dome; (5) gravel slopes of the Bishop conglomerate; and (6) igneous rock.

The hard, resistant sandstone of the Mesaverde makes notable concentric ridges or hills that are more or less continuous about the central portion of the dome. These ridges contain the most important coal beds of the field and are in general separated from one another and from areas of equally or more elevated younger rocks by belts of low relief. Two pronounced depressions are carved in the soft shale overlying and underlying the sandstone of the Mesaverde formation. These low valleys are natural routes of travel and afford easy access from the railroad to the more rugged ridges containing the coal. The shale below the Mesaverde gives rise to low relief in the central part of the Rock Springs dome and is the cause for the development of Baxter Basin.

The hard, resistant limestone and sandstone beds of the Green River and Wasatch formations produce notable table-like forms bounded by prominent escarpments of considerable length. In places the harder layers in these beds produce bench after bench in regular succession separated by nearly parallel valleys. In many places the more prominent ridges form bluffs and in parts of the field the beds present characteristic badland topography.

Huge dunes formed by migrating sand constitute the most conspicuous topographic feature in the northern part of the field.

The soft beds of the Wasatch form low depressions along the synclinal trough of the Great Divide Basin and along Killpecker Valley. This formation contains numerous beds of coal, few of which are well exposed, so that their presence over much of the region can only be inferred from a study of sections where it is better exposed. The topographic features in this area are such that the coal beds are readily accessible.

The long, gentle, grass-covered slopes of the hills capped by the Bishop conglomerate form a striking topographic feature and outline in a general way the peneplain that was formed immediately preceding the epoch marked by the deposition of this material.

The igneous rocks in this field rise like landmarks out of the arid plateaus of the Red Desert. The lava forming these rocks flowed from a little group of volcanoes far removed from the centers of igneous activity and spread out on a nearly horizontal surface. The evidence at hand seems to indicate that the surface upon which these lavas flowed is the same as the peneplain referred to above in connection with the Bishop conglomerate. Their nearly concentric cones, needle-like necks, irregular dikes, and table-like sheets afford a striking contrast to the topographic features of the surrounding hills.

The drainage of this area for the most part flows to the Pacific. The main streams are not affected by the Rock Springs dome, which in a way connects the Uinta and Wind River mountain ranges. The most prominent stream in this field is Bitter Creek, which controls the major part of the drainage of the dome. It flows across the central portion of the dome at nearly right angles to the major axis and has carved a broad valley along which the Union Pacific Railroad is constructed. The three largest tributaries of Bitter Creek—

Killpecker, Little Bitter, and Salt Wells creeks—have been shaped indirectly by the fold. On account of the difference in the hardness of the beds these valleys extend in the main along the strike of the beds and are approximately at right angles to Bitter Creek. In some places, as in the valleys of Salt Wells and Black Buttes creeks, the small streams cut across several of the ridges before joining the main stream, and one of the tributaries of Salt Wells Creek cuts three times across a pronounced hogback ridge 1,000 feet in height instead of following the softer shale along the strike of the beds.

At the south end of the dome the streams do not cut directly across the major axis. Red Creek, on the west side, drains southward into Green River after cutting a channel through part of the Uinta uplift. On the east side of the axis Vermilion Creek drains southeastward, paralleling the Uinta uplift through the upper half of its course, and finally cuts directly across part of this uplift and unites with Green River near the south end of Browns Park.

All the streams on the west side of the dome between Red Creek and Jack Morrow Creek not included in the Bitter Creek drainage basin are more or less nearly at right angles to the major axis.

GEOLOGY.

STRUCTURE.

GENERAL STATEMENT.

The structure of the Rock Springs field is comparatively simple. It consists of a huge dome of Cretaceous and Tertiary rocks which rise in the midst of the nearly horizontal rocks of the Green River basin and partly divide the southern portion into two smaller basins, the Bridger Basin on the west and the Red Desert or Washakie Basin on the east. The major north-south axis of the dome is approximately 90 miles long and is located close to the west limb of the anticline. The beds along this limb dip from 5° to 30° W.; those along the east limb dip from 5° to 10° E. The minor east-west axis is approximately 50 miles long, extending across the dome in a direction north of east and south of west, passing north of Aspen Mountain and through a point 4 miles north of Black Buttes, a station on the Union Pacific Railroad. Several small anticlines and synclines are developed upon the main dome, but for the most part they are unimportant. Two of the largest of these cross folds occur near the south end of the dome and are parallel to the minor axis and to the trend of the Uinta uplift. The oldest beds involved in this structure are exposed in the vicinity of Baxter, a station on the Union Pacific Railroad, and outcrop for a distance of about 30 miles along the crest of the dome.

Four coal groups are exposed in this area, and it is believed that another group is concealed by overlap of the youngest or stratigraphically highest coal group. Three of the four groups are more or less continuously exposed and lie somewhat concentrically around the non coal-bearing central part of the dome; the other is exposed only in the northern two-thirds of the east side of the dome. The structural relations of the two lower coal groups (Rock Springs and Almond) are those of two formations that are conformable and outcrop in concentric belts around the central portion of the dome. These two coal groups are separated from each other by white sandstone about 800 feet thick, well exposed at Point of Rocks.

The third or Black Buttes coal group rests conformably on the underlying formation and outcrops in a zone extending along the east side of the dome from T. 23 N., R. 103 W., southward to T. 17 N., R. 101 W. This zone is thought to be concentric with the outcrops of the underlying formations. Although no exposures of it have been seen on the west side of the dome, its beds are believed to be covered there by the Black Rock coal group, which rests in some places upon the beds of the second or Almond coal group and in others upon the white sandstone between the Rock Springs and Almond coal groups, and which in one place (T. 18 N., R. 105 W.) comes into contact with the Rock Springs coal group as a result of faulting. Along the east side of the dome the Black Buttes zone is separated from the Almond zone by a belt of non coal-bearing Lewis shale, which doubtless continues around the dome in the same way as the Black Buttes and Almond coal groups and underlying formations.

The Knobs-Cherokee coal group is not exposed in the Rock Springs dome, but is believed to be present between the Black Buttes and the Black Rock coal groups, probably extending around the dome in a belt that is somewhat concentric with those of the other groups.

The Black Rock coal group lies unconformably upon the Black Buttes and older coal groups and like them outcrops around the dome more or less concentrically with the others. In places this group conceals wholly or in part the underlying group. By far the most pronounced unconformity observed in the field occurs at its base. The Black Rock coal group occupies a large area in the northeastern part of the Rock Springs field and in the Great Divide Basin. The same group contains coal beds in the low synclinal trough between the Rock Springs dome and the Rawlins anticline.[a]

FAULTS.

The general dome or anticlinal structure is somewhat complicated by many normal faults of considerable throw. Here and there the horizontal displacement amounts to 3 miles; the vertical movement is usually less than 100 feet, but in a few localities reaches several

[a] See Bull. U. S. Geol. Survey No. 341, 1909, pp. 220-255.

hundred feet. Near the south end of the dome, in T. 14 N., R. 103 W., along the crest and south limb of a low anticline parallel to the Uinta uplift, is an overthrust fault which has a vertical displacement of 200 feet. The fault plane dips to the south about 20° from the horizontal, indicating that the thrust came from that direction.

Some of the faults extend across the dome, others cut only one limb or part of one limb, and still others extend for only a few hundred feet or a mile or two and then die out. Some of the larger faults have been traced for a distance of more than 20 miles. The general trend of the faults is nearly at right angles to the strike of the rocks or across the axis of the major anticline. In some places, however, the angle of departure is large and the fault parallels the strike more nearly than the dip of the beds. This is well illustrated near the north end of the dome, where the faults cut some of the rocks at right angles to their strike and before dying out continue approximately along the strike of the underlying beds. The position of the larger faults is shown on Plates XIV and XV. In addition to the larger faults readily detected on the surface, numerous small faults are encountered in mine workings. In the Rock Springs coal group, from the Van Dyke coal bed upward, there is at many places a system of characteristic joints or slips that cut the coal at short intervals from floor to roof. These slips incline toward the south, and along many of them there is displacement of one-half inch to a foot or more. As a rule these small faults do not interfere with mining, but rather assist in breaking or parting the coal, thereby making it easier to mine. The larger faults, however, greatly increase the difficulties of mining and tend to retard development work. In regions of much faulting the offsetting of the coal beds may so increase the cost that mining will be abandoned or development work stopped. The exact date of the faulting is not known. It may have occurred at various times during the gradual uplift of the dome after the close of the epoch of Cretaceous deposition. It is believed, however, that most if not all of the faulting is associated with the movements that gave rise to the leucite lava flows and renewed uplift in the Uinta Mountains immediately before the period of deposition of the gravel, which is entirely independent of the faults and folds in the underlying rocks.

STRATIGRAPHY.

OUTLINE OF GEOLOGIC HISTORY.

The beds of coal in the Rock Springs field and the rocks in which they occur form only a small part of the great sedimentary series that was deposited at a time when this part of the continent was largely submerged. The beds were deposited in a nearly horizontal position during the various stages of submergence and emergence under conditions ranging from those of a deep sea to those of shallow water or swamps, in waters that were salt, brackish, or fresh. The oldest rocks exposed in the Rock Springs dome are of Montana age. From the epoch of their deposition until the end of the Cretaceous no profound disturbance or broad orographic movements occurred in this region. There was a gradual change from deep-sea to shallow-water conditions, with oscillations back and forth, giving rise to swampy areas that were favorable for the accumulation of coal beds. From the marine stages of the lower Montana there is a regular succession upward through the brackish-water to the fresh-water stage. The strata, so far as can be seen, are entirely conformable and the series is complete. In late Cretaceous time the horizontal beds deposited in this region became involved in a movement which gave rise to the low anticlinal arch that subsequently developed into the Rock Springs dome. This period of gentle doming or warping was accompanied and succeeded by one of deposition in shallow fresh water, during which a series of beds, conglomeratic at the base and coal bearing throughout, were laid down upon the older marine and brackish-water beds and, in places along the margin of the rising dome, upon the eroded edges of the older rock. In succeeding epochs fresh-water beds in which no coal occurs were deposited to a large degree in lake basins.

After the deposition of the fresh-water beds movements of the earth's crust folded and broke the originally continuous Cretaceous and later sediments, so that it is necessary to study their attitude of superposition in order to determine the relation of the beds to one another. There are also evidences that during great time intervals deposits were not formed or that if laid down they were subsequently removed, leaving little or no record of their existence. Particularly is this true of post-Cretaceous time. After the fresh-water beds had been laid down there was a long epoch of erosion in which the entire region was reduced to a peneplain or nearly level surface. This was succeeded by mild volcanic activity, during which the leucite lava flows north and west of Rock Springs were poured out on a planed off, nearly level surface, formed by the truncation of the underlying rocks. This volcanic activity culminated in or accompanied orographic movements that resulted in rapid erosion and the deposition of an extensive gravel sheet over the entire region from the Uinta Mountains northward to Bitter Creek. This gravel sheet is independent of the folds and faults in the underlying rocks, which are beveled across entirely irrespective of either hardness or structure. From this gravel-covered plain the present topographic features have been carved in late Quaternary time, almost solely by erosion.

DESCRIPTION OF FORMATIONS.

The investigations of the Rock Springs field have shown that the subdivisions mapped by King and Powell can not be applied to the sequence of rocks in this region. A large collection of fossils obtained by members of this party and studied by F. H. Knowlton and T. W. Stanton indicates that the several formations have the geologic time values indicated in the accompanying table. In this table the general character and succession of the Cretaceous and Tertiary rocks, together with their economic importance, are set forth. As nearly all the rocks exposed in the Rock Springs dome are closely related to the coal-bearing rocks, the entire stratigraphic section is here presented.

Geologic formations of the Rock Springs field.

System.	Series or group.	Formation.	Economic designation.	Thickness (feet).	Description.	Economic value.
(?)	Post-Eocene.	Igneous.	Leucite lava.	0 to 350	Dikes, flows, volcanic necks, and agglomerate.	Potash niter occurs in some of these rocks.
		Bishop conglomerate.	Gravel.	0 to 200	Waterworn and subangular pebbles and bowlders, many of them from 1 to 6 feet in diameter, embedded in finer gravel and sand.	**Good water horizon.** Supplies many of the springs in southern part of field.
~~	~~~~	Unconformity.	~~~~	~~~~	~~~~	~~~~
Tertiary.	Eocene series.	Green River formation.		0 to 630	Massive, irregularly bedded sandstone; white, yellow, and brown shaly sandstone; some limestone and interbedded shale.	
		Unconformity.	~~~~	~~~~	~~~~	~~~~
				0 to 950	Thin-bedded shale, sandstone, and limestones (some of which are oolitic); some dark-colored bituminous shale.	Contains traces of oil in bituminous shale. In places rock seems to have been burned in consequence of presence of oil.
		Unconformity.	~~~~	~~~~	~~~~	~~~~
		Wasatch formation.		0 to 800	Variegated clay, shale, and sandstone, in places slightly conglomeratic; produces highly colored escarpment of Laney Rim and Cathedral Bluffs.	
				100 to 275	Thin fissile shale and sandstone; pronounced oolitic limestone, in places 20 to 50 feet thick near base; also other oolitic and concretionary beds locally resembling huge oyster shells scattered on sursurface.	

Geologic formations of the Rock Springs field—Continued.

System.	Series or group.	Formation.	Economic designation.	Thickness (feet).	Description.	Economic value.
Tertiary.	Eocene series.	Wasatch formation.	Black Rock coal group.	1,000 to 3,500	Alternating layers of white, yellow, and brown sandstones, and gray, drab, and carbonaceous shales, with coal beds and conglomerate containing granite and quartzite pebbles. Numerous bands of white concretionary sandstone, weathering in irregular shapes. Basal sandstone is conglomeratic. Sandstone hardens locally and weathers into forms resembling large log or spherical concretions. Large cross-bedded reddish sandstone forms badland topography in Red Creek valley and Fire Hole Basin.	**Coal bearing.** Many thin beds of coal and at least one bed 25 feet thick occurs in this group. No large mines opened on this coal. Prospects opened in these beds at many places around the dome.
		Unconformity.				
		"Upper Laramie" formation.	Knobs-Cherokee coal group.	6,000 to 9,400	Alternating layers of soft yellowish brown and white sandstones and drab, brown, and black shales. Not exposed in the Rock Springs dome.	**Coal bearing.** Several beds of workable coal occur in the upper portion near Cherokee and in the lower portion near Knobs. Regarding Cherokee and overlying coal beds see logs of Wamsutter wells, T. 20 N., R. 94 W., page 125.
		Unconformity.				
Cretaceous.	Montana group.	"Laramie" formation.	Black Buttes coal group.	1,500	Massive basal bed of white and yellow sandstone showing traces of conglomerate in places; forms prominent scarp; overlain by various sandstone, clay, and coal beds. Fossils abound in places. Exposed only in the northern part of the east side of the dome and here only lower part is visible. On west side of Rawlins dome this formation is 3,900 feet thick.	**Coal bearing.** Mines once worked on these beds near Hallville and Black Buttes station. New mine opened in 1907 south of Black Buttes. Prospects at various points. May yield artesian water.
		Lewis shale.		750	Dark-gray, drab, and black shales, highly gypsiferous, with some soft shaly sandstone and large concretions; some lenticular beds of white sandstone near base; produces topography of low relief.	Possible source of clay Natural routes of travel. Not known to be coal bearing.
		Mesaverde formation.	Almond coal group.	700 to 950	Soft white and brown sandstones, sandy shale, and clay, with numerous beds of coal and bituminous shale.	**Coal bearing.** Many coal beds. Numerous prospects throughout the field. Coal from these beds has been mined at Rock Springs and Point of Rocks.

Geologic formations of the Rock Springs field—Continued.

System.	Series or group.	Formation.	Economic designation.	Thickness (feet).	Description.	Economic value.
Cretaceous.	Montana group.	Mesaverde formation.		800 to 1,000	Massive white and yellowish sandstone. Upper third conglomeratic, with fine black and gray quartz pebbles. Sandstone forms pronounced escarpments and hogback ridges, giving rise to the "white wall."	**Water bearing.** Yields artesian water in parts of field. Flowing wells at Point of Rocks. Wells northwest of Superior. Water will probably be encountered in these beds back from the outcrop all around the Rock Springs dome.
			Rock Springs coal group.	600 to 1,400	White to yellow sandstone, interbedded shale and clay, with several coal beds. The heaviest beds of sandstone are grouped near the base of the formation. Total aggregate thickness of coal in this group about 90 feet.	**Coal bearing.** Many large coal beds and numerous smaller beds. Best coal in the Rock Springs field. Important mines at Rock Springs, Sweetwater, Blairtown, Gunn, and Superior. Many prospects and drifts opened. Artesian-water zone. Flowing wells at Superior and Rock Springs.
				1,200 to 1,800	Drab, yellow, and brown sandstones and interbedded shale and shaly sandstone with little or no bituminous matter. Massive sandstones are grouped near top of formation, giving rise to the "golden wall."	**Water bearing.** Important artesian-water zone. This formation will probably supply water outside of the ridges and escarpments surrounding Baxter Basin.
				1,000	Black and drab shales, very soft and friable. Shaly sandstones and arenaceous shale, in places highly gypsiferous. Much of it very friable, producing low benches and ridges.	Possible source of clay. Considerable gypsum. In places some sulphur.

IGNEOUS ROCKS.

In the north half of the dome numerous intrusive and extrusive masses have been forced up through the Cretaceous and Tertiary rocks and cap these rocks in several localities. The exposures of leucite range from talus-covered hills, isolated volcanic necks, and associated dikes to lava flows with cones, intruded sheets, and dikes. Many of the lava sheets present abrupt walls from 50 to 100 feet in height. Some of the lava flows and volcanic necks lie along fault lines through which the molten mass may have found an outlet. In other localities the lava seems to have forced its way through the rocks without causing any disturbance. The sedimentary beds lie practically horizontal around the igneous masses, which contain many fragmentary inclusions of the country rocks. Although the lavas have cut many coal beds and rocks of the coal-bearing formations, in no place were the coal and igneous rock seen in actual contact. Coal samples Nos. 5597 and 5599 [a] were collected from two prospect pits in sec. 10, T. 21 N., R. 102 W., a few rods below the overlying lava sheets and about a mile from several volcanic cones, but showed no apparent difference in physical or chemical properties from coals lying at a distance from the igneous rock. The exact age of these leucite flows has not been definitely determined. They are positively later than the Green River formation and may be considerably later. From the best evidence at hand it is believed that a period of mild volcanic activity followed the peneplanation mentioned in the outline of the geologic history.

NON COAL-BEARING ROCKS.

In the Rock Springs field there are several zones of non coal-bearing rocks below, between, and above the coal groups. Below the Mesaverde formation is an unnamed dark-gray to black shale of Montana age, which occupies the central part of the dome in Baxter Basin. This is the oldest rock exposed in the field. Above this shale and below the Rock Springs coal group occur sandy shale and sandstone, which form the lower beds of the Mesaverde formation. The upper of these beds gives rise to the main scarp surrounding Baxter Basin, often referred to as the "golden wall."

Between the Rock Springs and Almond coal groups is a massive white sandstone, well exposed at Point of Rocks, which contains here and there traces of bituminous matter and beds of coal from 2 to 18 inches thick. It is not, however, coal bearing in a commercial sense. The upper third is more compact and conglomeratic than the lower portion. This sandstone gives rise to the main scarp surrounding the Rock Springs coal zone, often referred to as the "white wall." In parts of the field this escarpment is from 200 to 500 feet high.

Between the Almond and Black Buttes coal groups is a mass of soft gray and drab shales, highly gypsiferous, which on weathering give rise to regions of low relief that furnish excellent natural routes for travel across the field. No trace of coal has been found in these beds.

Overlying the Black Rock coal group are four groups of beds which are not known to be coal bearing in this region. The lower two belong to the Wasatch formation, and the upper two to the Green River formation. The beds immediately overlying the Black Rock coal group consist of fissile shale, conglomerate, oolitic limestone, shale, clay, and sandstone. Some of the greenish-white shale of these beds is very fissile and closely resembles the shale in the lower

[a] Bull. U. S. Geol. Survey No. 341, 1909, p. 272.

part of the Green River formation. The second group of beds consists of red or varicolored conglomeratic sandstone, shale, and clay, which are well exposed in Laney Rim and Cathedral Bluffs, southwest of Wamsutter. The third group of beds belongs to the Green River formation and consists of white and green fissile shales, limestone, and sandstone similar to those so characteristic of the lower part of the Green River formation in other parts of the Green River Basin. At the south end of the dome, outside of the territory here described, traces of coal were found near the base of these beds, but throughout most of the field no coal was seen in them. The fourth group of beds also belongs to the Green River formation and consists of massive, irregularly bedded sandstone, sandy limestone, and shale that are well exposed north of Wilkins, a station on the Union Pacific Railroad, a few miles west of Rock Springs, and in the vicinity of the town of Green River. The same beds are present in small outliers on the east side of the dome in the vicinity of Pine Butte.

Overlying all these beds and obscuring many of them is a mantle of slightly indurated gravel (Bishop conglomerate) that extended originally over the entire region south of Rock Springs to the north flank of the Uinta Mountains. This material has been dissected by the streams until only remnants are left. The largest of these extends southward from Aspen Mountain to Miller Mountain (Tabor Plateau) and westward between the headwaters of Sage and Little Bitter creeks. Two other remnants of considerable size are found on Little Mountain (Quien Hornet of the Powell Survey) and on Pine Mountain (Bishop Mountain of the Powell Survey). The first is separated from Miller Mountain by the valley of Sage Creek and the second lies about 10 miles southeast of Miller Mountain. At many other localities small areas are capped by similar sheets of gravel lying at accordant elevations, which once formed parts of the sheet that mantled this entire region.

In this report all the non coal-bearing rocks are considered collectively and mapped in two patterns irrespective of their stratigraphic relations. All the beds above the coal groups are shown in stipple; those below and between the coal groups are shown in a parallel ruled pattern.

COAL-BEARING ROCKS.

GENERAL STATEMENT.

The oldest coal-bearing rocks exposed in this field are of Montana age. The Frontier formation [a] of the Colorado group, which contains the high-grade Kemmerer coals of Uinta County, although not outcropping in this area, is believed to be present and to contain workable beds of coal. It is also believed that along the axis of the

[a] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, p. 226. Schultz, A. R., Bull. U. S. Geol. Survey No. 316, 1907, pp. 212-241. Veatch, A. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 331-353.

dome in the vicinity of Baxter station these coals may lie near enough to the surface to be mined some day, but at present no borings have penetrated to a sufficient depth to reveal them, and the depth at which they may occur and even their existence are somewhat problematical.

The Mesaverde formation consists of four distinct members, two of which are coal bearing. The lowest member consists chiefly of sandstone, shaly sandstone, and shale, all of which are barren of coal and show no indications of carbonaceous matter. The two coal-bearing members of the Mesaverde are separated from each other by massive white sandstone 800 to 900 feet thick. The lower one of the Mesaverde is known as the Rock Springs coal group and the upper as the Almond coal group. The Almond coal group is overlain by the Lewis shale, and the remaining coal-bearing rocks exposed in the Rock Springs field are of post-Montana age. Above the Lewis shale, the upper formation of the Montana group, in the western part of the area are two groups of coal beds separated from each other by an unconformity of considerable magnitude. For convenience in the following discussion the lower has been called the Black Buttes coal group and the upper the Black Rock coal group. The unconformity between them may in places escape observation. The lower group of these post-Montana coal beds is of "Laramie" age; the upper group belongs to the Wasatch formation, and is therefore of Tertiary age. In the region to the east there occurs still another coal group at the base of the Tertiary, called undifferentiated Tertiary by Smith[a] in his report on the coal field of the Great Divide Basin. This group contains the coal beds at Knobs and Cherokee and in this paper it will be referred to as the Knobs-Cherokee coal group, or "Upper Laramie" formation. According to the paleobotanical evidence it is of Fort Union age and is the same as the "Upper Laramie" of central Carbon County, described by Veatch,[b] and the "Upper Laramie" of the Little Snake River field, described by Ball on pages 186 to 213 of this bulletin. It is exposed on the west side of the Rawlins dome, but does not appear at the surface in the Rock Springs dome, the entire formation being concealed by overlap of the Black Rock coal group.

ROCK SPRINGS COAL GROUP.

The Rock Springs coal group is the most important in this region and the one containing the highest-grade coal. Its lower portion consists of heavy beds of ridge-making, coal-bearing sandstone and the remainder of brown, yellow, and white sandstone, shale, clay, and interbedded coal. It contains at least twelve coal beds ranging from 2 to 10 feet in thickness and many other beds less than 2 feet

[a] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, pp. 233, 234.
[b] Veatch, A. C., Bull. U. S. Geol. Survey No. 316, 1907, pp. 244-260.

thick. The total aggregate of coal beds over 2 feet thick in the Rock Springs coal group in the vicinity of Superior is more than 80 feet, and in the vicinity of Rock Springs it is more than 90 feet. These beds occur somewhat irregularly throughout the group, but are fairly persistent along the strike. They have been prospected all the way from Aspen Mountain northward to Rock Springs and Superior and on the east side of the dome to Black Butte Mountain. South of Superior the coal beds are somewhat thinner and the number of beds is not so great as between Superior and Rock Springs, and therefore very little prospecting has been done in that area. South of a line drawn through the southwest corner of T. 16 N., R. 104 W., and the southeast corner of T. 18 N., R. 102 W., the group is not known to be coal bearing. In part of this area the exposures are poor. Some coal beds may be present, but none were seen. The rocks here appear to be a continuation of the beds that were laid down under conditions similar to those which existed during the deposition of the "golden wall" in the northern and southern parts of the field. The coal is, however, of high grade and additional mines are certain to be opened in the near future at other points along the outcrop from Rock Springs to Aspen Mountain. Mines are in operation on upper beds of this coal group at Sweetwater, Rock Springs, and Superior. At Gunn and Van Dyke the coal beds near the base of the group (the Van Dyke coal beds) are being mined. New mines were to be opened in 1908 along Killpecker Valley, north of Rock Springs, but owing to the money stringency work was greatly delayed and some of it temporarily abandoned.

The area underlain by the Rock Springs coal group was mapped in detail and the locations of mines, prospect pits, and the coal outcrops were determined by a stadia survey. The locations of the outcrops of the more important coal beds as well as the formation contacts are shown on Plate XV. The general character and thickness of the coal beds in the Rock Springs coal group are shown in the following sections taken at various points along the outcrop:

Sections of coal beds in the Rock Springs coal group in the southern part of the Rock Springs field, Wyoming.[a]

Location.				Section of coal bed.			Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*	Quarter.	Sec.	T.	R.		*Ft.*	*in.*
NE. ¼ NE. ¼.	14	17	105	Shale, brown	20		SE. ¼ SW. ¼.	14	17	105	Sandstone, white	3	
				Coal	3	8					Coal	3	4
				Shale, brown		6					Shale, brown		6
				Sandstone, white	10						Sandstone, white.		
					34	2						6	10

[a] For sections of these beds in the northern part of the Rock Springs field see Bull. U. S. Geol. Survey No. 341, 1909, p. 262.

Sections of coal beds in the Rock Springs coal group in the southern part of the Rock Springs field, Wyoming—Continued.

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*
SW. ¼ NW. ¼.	24	17	105	Shale, sandy	6	
				Coal	3	10
				Shale, brown	1	
				Sandstone, white	8	
					18	10
SW. ¼ SW. ¼.	1	18	105	Coal	1	
				Shale		½
				Coal	4	
					5	½
SE. ¼ SE. ¼.	2	18	105	Shale.		
				Coal	7	
				Shale.		
SW. ¼ SE. ¼.	12	18	105	Shale.		
				Coal	5	5½
				Sandstone.		
SW. ¼ SE. ¼.	22	18	105	Coal		10
				Shale		¼
				Coal	4	
					4	10¼
NW. ¼ NE. ¼.	34	18	105	Coal	3	3
				Shale		2
				Coal		6
					3	11
NW. ¼ NW. ¼.	25	19	105	Shale.		
				Coal	11	
				Sandstone.		
NE. ¼ NW. ¼.	25	19	105	Shale.		
				Coal	7	
				Shale.		
NE. ¼ NW. ¼.	25	19	105	Shale.		
				Coal	2	10
				Shale	1	5
				Coal		9
				Sandstone.		
					5	
SW. ¼ SW. ¼.	26	19	105	Clay.		
				Coal		6
				Shale, yellow		1
				Coal	1	4
				Shale, yellow		3
				Coal	1	2
				Shale, dark		1
				Coal		9
				Shale, yellow		1½
				Coal	2	2
				Shale.		
					6	5½
NW. ¼ SW. ¼.	26	19	105	Shale.		
				Coal	1	10
				Bone		7
				Coal	1	8
				Shale.		
					4	1
SW. ¼ SW. ¼.	26	19	105	Shale.		
				Coal	7	8
				Shale.		
NW. ¼ SW. ¼.	30	19	105	Shale.		
				Coal	2	9
				Sandstone.		
SE. ¼ NE. ¼.	30	19	105	Coal		6
				Shale, sandy	1	
				Coal	3	10
				Shale.		
					5	4
NW. ¼ NE. ¼.	35	19	105	Shale.		
				Coal	1	3
				Shale		8
				Coal	2	4
				Bone		6
				Coal	4	11
				Sandstone.		
					9	8
NE. ¼ NE. ¼.	6	19	104	Coal	1	8
				Shale		3
				Coal	3	8
					5	7
NW. ¼ NE. ¼.	7	19	104	Coal	1	6
				Shale	1	
				Coal	2	
					4	6
SE. ¼ SW. ¼.	18	19	104	Coal	3	
				Shale	2	7
				Coal	3	
					8	7
NW. ¼ SW. ¼.	5	20	104	Coal	3	
				Shale	2	
				Coal	7	8
					12	8
SW. ¼ NW. ¼.	8	20	104	Coal	5	1
				Bone	1	
				Coal	1	3
					7	4
SW. ¼ SE. ¼.	8	20	104	Coal	10	
SW. ¼ SW. ¼.	17	20	104	Coal	1	3
				Shale		3
				Coal	3	6
					5	
SE. ¼ SE. ¼.	29	20	104	Coal	5	
				Sandstone		5
				Coal	3	3
					8	8
SE. ¼ SE. ¼.	30	20	104	Coal	2	6
				Bone		9
				Coal	11	
					14	3

ALMOND COAL GROUP.

The Almond coal group is of second importance in the field. Its coals are not so good as those of the Rock Springs coal group and up to the present time have been little developed. The group consists of beds of carbonaceous shale, clay, and brown and gray sandstones, with numerous beds of coal in the lower half of the formation. Several coal beds from 2 to 8 feet thick have been prospected in various parts of the field. Unlike the Rock Springs coal group the Almond is known to be coal bearing around the entire dome. Mines were opened in these beds just east of Almond or Point of Rocks, in T. 20 N., R. 101 W., when the Union Pacific Railroad was first built. They were soon abandoned, however, and not reopened until the summer of 1907. The old No. 6 mine at Rock Springs (sec. 22, T. 19 N., R. 105 W.) was opened in these beds in 1882, operated for a short time, and abandoned in 1886, as the coal was found to be inferior to that obtained from the Rock Springs coal group. The aggregate of coal beds over 2 feet thick in the Almond coal group is from 15 to 30 feet and the beds occur chiefly in the lower half of the formation. The total thickness of the Almond coal group is exposed only on the east side of the dome. Throughout the remainder of the region the upper part is concealed by the overlap of the Black Rock coal group, and on the southwest flank of the dome the whole of the Almond coal group is covered by overlap of these same beds. In the area from T. 18 N., R. 105 W., to T. 14 N., R. 104 W., no exposures of the Almond coal group were seen. It is present, however, beneath the Black Rock beds and is believed to be coal bearing. The following sections, which are a few of the numerous measurements made at various points along the outcrop, show the character and thickness of these beds:

Sections of coal beds in the Almond coal group in the southern part of the Rock Springs field, Wyoming.[a]

Location.				Section of coal bed.	Location.				Section of coal bed.
Quarter.	Sec.	T.	R.		Quarter.	Sec.	T.	R.	
SW. ¼ SW. ¼.	5	14	102	Shale. *Ft.* *in.* Coal....... 7 11 Shale.	SW. ¼ SW. ¼.	10	14	102	*Ft.* *in.* Shale. Coal....... 3 6 Shale.
SW. ¼ SW. ¼.	6	14	102	Shale. Coal....... 3 4 Shale....... 1 Coal....... 4 Shale. 8 4	NW. ¼ NW. ¼.	13	14	103	Shale. Coal....... 1 6 Bone....... 1 Coal....... 2 6 5
NE. ¼ NE. ¼.	8	14	102	Shale. Coal....... 7 Shale.					

[a] For sections of these beds in the northern part of the Rock Springs field see Bull. U. S. Geol. Survey No. 341, 1909, p. 263.

Sections of coal beds in the Almond coal group in the southern part of the Rock Springs field, Wyoming—Continued.

Quarter.	Sec.	T.	R.	Section of coal bed.	Ft.	in.
NE. ¼ NE. ¼.	28	14	103	Shale.		
				Coal.......	1	9
				Shale........	2	
				Coal.......	1	3
					5	
NE. ¼ NE. ¼.	30	14	103	Shale.		
				Coal.......	3	
				Shale........	6	
				Coal.......	2	
					11	
SW. ¼ NW. ¼.	30	14	103	Shale........	3	
				Coal.......	6	6
				Shale and sandstone....	6	
				Coal.......	5	
					20	6
SE. ¼ NE. ¼.	25	14	104	Clay, sandy.		
				Coal.......	6	6
				Shale, brown.		
S. ½ SW. ¼.	31	15	101	Coal.......	3	4
				Shale........	30	
				Coal.......	6	9
				Shale........	5	
				Coal.......	1	8
				Shale........	10	
					56	9
SW. ¼ SW. ¼.	4	15	102	Shale, brown	6	
				Coal.......	2	6
				Shale, brown	1	
				Sandstone, white.		
					9	6
NW. ¼ SW. ¼.	17	15	102	Shale, brown	15	
				Coal.......	4	
				Shale.......	1	6
					20	6
NW. ¼ NW. ¼.	28	15	102	Shale, brown	4	
				Coal.......	3	6
				Shale, brown.		
					7	6
SE. ¼ NW. ¼.	3	16	102	Shale, sandy	4	
				Coal.......	4	6
				Shale, brown	3	
				Sandstone...	2	
				Coal.......	2	
					15	6
NW. ¼ NE. ¼.	10	16	102	Shale, brown	4	
				Coal.......	5	
				Shale, brown	2	
					11	

Quarter.	Sec.	T.	R.	Section of coal bed.	Ft.	in.
SW. ¼ SW. ¼.	33	16	102	Shale, brown	2	
				Coal.......	4	
				Shale, sandy...		6
				Coal.......	4	
				Shale, brown	2	
					12	6
SE. ¼ SE. ¼.	8	17	101	Coal.......	4	10
SE. ¼ SE. ¼.	8	17	101	Coal.......	3	10
SE. ¼ SE. ¼.	8	17	101	Coal.......	4	10
NW. ¼ SW. ¼.	9	17	101	Coal.......	4	10
NW. ¼ SW. ¼.	9	17	101	Coal.......	3	10
NE. ¼ SW. ¼.	17	17	101	Coal.......	5	1
NE. ¼ SW. ¼.	17	17	101	Coal.......	3	8
SE. ¼ NW. ¼.	6	18	100	Shale.		
				Coal.......	3	
				Sandstone		1
				Coal.......	1	8
				Shale.		
					4	9
NE. ¼ NW. ¼.	6	18	100	Shale.		
				Coal.......	2	
				Shale.....	1	
				Coal.......	3	2
				Shale.		
					6	2
NW. ¼ NW. ¼.	10	18	100	Coal.......	2	4
				Coal, bony	1	3
					3	7
NE. ¼ SE. ¼.	10	19	105	Shale.		
				Coal.......	1	
				Clay.......		½
				Coal.......	4	
				Shale.		
					5	½
SE. ¼ NW. ¼.	14	19	105	Shale, drab.		
				Shale, carbonaceous...	1	9
				Coal.......	1	6
				Shale, carbonaceous ...	2	
				Coal.......	1	
				Shale, carbonaceous ...	3	
				Coal.......	1	
					10	3

Sections of coal beds in the Almond coal group in the southern part of the Rock Springs field, Wyoming—Continued.

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*
NE. ¼ SE. ¼.	22	19	105	Sandstone, yellow.		
				Shale	1	6
				Coal	1	2
				Bone		6
				Coal	2	1
				Shale	1	
				Coal	1	6
				Coal, bony		5
				Coal	1	11
				Shale		6
				Sandstone, yellow.		
					10	7
NW. ¼ SE. ¼.	1	20	105	Shale, brown	2	
				Coal	3	6
				Shale, brown	3	
				Sandstone, brown	2	6
				Shale, brown	2	
				Coal	4	
				Shale, brown	2	
					19	
NW. ¼ SE. ¼.	35	20	105	Shale.		
				Coal	4	
				Shale.		
NW. ¼ NE. ¼.	12	20	105	Shale	3	
				Coal	4	
				Shale and sandstone	7	6
				Coal	1	6
				Shale	2	
				Coal	2	6
				Shale	3	
					23	6
SW. ¼ NE. ¼.	13	20	105	Sandstone	2	
				Shale, brown	1	
				Coal	5	
				Shale, brown	6	
					14	
SE. ¼ SE. ¼.	24	20	105	Shale, brown	4	
				Coal	5	
				Shale, brown	2	
					11	
SE. ¼ SE. ¼.	25	20	105	Shale, brown	2	
				Coal	5	6
				Shale, brown	6	
					13	6

BLACK BUTTES COAL GROUP.

Along the east side of the dome the Black Buttes coal group, so far as known, lies conformably upon the marine Lewis shale. The basal member of the group consists of a massive bed of yellowish-white sandstone, in places over 100 feet thick, and is not known to be coal bearing. This member, resting upon the soft, friable Lewis shale, forms steep hills and cliffs along the contact. The rocks above it consist of variant sandstone, clay, and coal beds that lie exposed in the low hills and ridges east of the main scarp. The Black Buttes coal group is exposed only in the northern two-thirds of the east side of the dome and nowhere in the Rock Springs field does the entire group outcrop. The upper portion is concealed by overlap of the Black Rock coal group. In the southern part of the field, the Black Buttes coal group is exposed only for a distance of 12 miles southwest of Black Buttes. On the south and west sides of the dome this group is concealed and the Black Rock coal group rests unconformably in turn upon Lewis shale, the Almond coal group, and the white sandstone like that at Point of Rocks, lying between the Almond and Rock Springs coal groups, and at one place (in T. 15 N., R. 105 W.) upon the Rock Springs coal group. Considerable prospecting has been done at various places along this coal zone and good beds of coal are exposed. Near Black Buttes station the Union Pacific Railroad

Company opened a mine in 1868 which was worked for a time and then abandoned. The old Hall mine,[a] 2 miles south of Hallville station, after being worked a few years was abandoned, as the coal was not so good as that mined at Rock Springs. During the summer of 1907 a mine was opened in these beds 1½ miles southwest of Black Buttes station and coal from it was placed on the market in 1908.

The following sections taken along the outcrop illustrate the thickness and character of the coal beds in the Black Buttes coal group:

Sections of coal beds in the Black Buttes coal group in the southern part of the Rock Springs field, Wyoming.[b]

Location.				Section of coal bed.
Quarter.	Sec.	T.	R.	*Ft. in.*
SW.¼SW.¼.	1	17	101	Coal........ 5 2
NE.¼NW.¼.	12	17	101	Coal........ 5 2
NE.¼NW.¼.	14	17	101	Coal........ 4 10
SE.¼ SW.¼.	14	17	101	Coal........ 5 4
NE.¼ NE.¼.	22	17	101	Sandstone, brown.... 12 Coal........ 5 2 Shale. 17 2
SE.¼NE.¼.	23	17	101	Coal........ 4 10
NE.¼ SE.¼.	4	18	100	Coal........ 4 Bone....... 1 Coal........ 3 6 7 7
NW.¼NW.¼.	6	18	100	Coal....... 6 8 Bone....... ½ Coal....... 2 8 8½
SE.¼NE.¼.	9	18	100	Coal....... 1 9 Bone....... 3 Coal....... 5 Bone....... 2 Coal....... 5 1 9 6
SE.¼NE.¼.	9	18	100	Coal....... 5
SW.¼SW.¼.	10	18	100	Shale........ 4 Coal....... 2 Shale...... 3 Coal....... 2 Shale...... 3 Coal....... 3 Shale........ 4 Coal....... 1 5 6 10
SE.¼NW.¼.	16	18	100	*Ft. in.* Shale. Coal...... 1 Sandstone and shale 15 Coal...... 8 24
NE.¼NE.¼.	20	18	100	Shale and sandstone. Coal...... 6 6 Shale and sandstone 78 Coal...... 4 6 Shale and sandstone 13 8 Coal...... 2 2 Shale. 104 10
NE.¼NE.¼.	20	18	100	Coal...... 2 Shale..... ¼ Coal...... 3 6 Shale..... 1 Coal...... 10 6 5¼
NE.¼NE.¼.	20	18	100	Coal...... 6 Bone...... ½ Coal...... 4 Shale..... ¼ Coal...... 3 5 Bone...... ½ Coal...... 1 1 5 5¼
SW.¼NW.¼	29	18	100	Shale...... 5 Coal...... 3 4 Shale....... 7 10 Coal...... 3 Shale..... 2 Coal...... 2 Shale....... 9 Sandstone... 10 Coal...... 5 8 36 10

[a] For a description of these mines see Bull. U. S. Geol. Survey No. 341, 1909, pp. 276-277.
[b] For sections of these beds in the northern part of the field see Bull. U. S. Geol. Survey No. 341, 1909, p. 264.

Sections of coal beds in the Black Buttes coal group in the southern part of the Rock Springs field, Wyoming—Continued.

Location.				Section of coal bed.
Quarter.	Sec.	T.	R.	
SW. ¼ NE. ¼.	20	18	100	*Ft. in.* Shale. Coal...... 1 Shale..... ¼ Coal...... 4 2 Shale. 5 2¼
NE. ¼ SE. ¼.	30	18	100	Shale. Coal...... 3 2 Shale..... ¼ Coal...... 3 10 Shale..... 6 Coal...... 1 8 Shale. 9 2¼
SE. ¼ SE. ¼.	30	18	100	Shale. Coal...... 5 Shale..... ¼ Coal...... 1 10 Shale..... 6 Coal...... 1 4 Shale. 8 8¼

Location.				Section of coal bed.
Quarter.	Sec.	T.	R.	
SW. ¼ SE. ¼.	30	18	100	*Ft. in.* Shale. Coal...... 3 4 Shale..... ¼ Coal...... 4 Shale..... 5 Coal...... 1 10 Shale. 9 7¼
SW. ¼ NE. ¼.	31	18	100	Coal...... 6 8
NW. ¼ NE. ¼.	31	18	100	Shale. Coal...... 3 6 Shale..... ¼ Coal...... 4 4 7 10¼
NW. ¼ NE. ¼.	31	18	100	Shale. Coal...... 5 6 Shale..... ¼ Coal...... 1 10 7 4¼

KNOBS-CHEROKEE COAL GROUP.

In the eastern part of this region the Knobs-Cherokee coal group or "Upper Laramie" formation is separated from the "Laramie" formation by an unconformity. The base of the group consists of non coal-bearing beds composed of soft shale and brown conglomeratic sandstone, probably constituting the base of the Tertiary system. In other places this coal group is apparently conformable with the "Laramie." In part of the Great Divide Basin it is coal bearing in both the lower and upper portions. Coal beds in the Knobs-Cherokee coal group are present on the west side of the Rawlins dome and probably occur along the east side of the Rock Springs dome. They are, however, concealed by the overlap of the Black Rock coal beds. At best the location or even the presence of the base of these beds along the east side of the Rock Springs dome can only be inferred. For further information the reader is referred to Bulletin 341.[a]

At Cherokee Siding, in sec. 10, T. 20 N., R. 91 W., a prospect slope was driven down on a dip of 7° to a distance of 75 feet. At the old Fillmore station, in sec. 31, T. 21 N., R. 90 W., in an artesian well drilled by the Union Pacific Railroad Company, a 20-foot bed of coal was reported at a depth of 220 feet, a 10-foot bed at 270 feet, and a 15-foot bed at 320 feet. At Wamsutter, in sec. 34, T. 20 N., R. 94 W.,

[a] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, pp. 233-234.

several artesian wells were drilled by the Union Pacific Railroad Company to supply water for the railroad. In well No. 2 three beds passed through between 1,045 and 1,145 feet are considered as belonging to the same horizon as the four Cherokee coal beds described in T. 20 N., R. 91 W. The exact base of the Wasatch can not be determined from the Wamsutter well records, but from a careful consideration of the facts noted in the field and the relation of the coal beds that outcrop just north of Wamsutter and Latham it is believed that all the coal beds mentioned in the drill record below a depth of 150 feet belong to the Knobs-Cherokee coal group or "Upper Laramie" formation.

Record of Union Pacific Railroad wells at Wamsutter.

WELL NO. 2.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	75	75	Strata, hard	3	528
Shale and small beds of coal	15	90	Shale, gray	32	560
Shale	5	95	Sandstone	20	580
Sandstone	15	110	Shale, gray	80	660
Shale, black and gray	40	150	Sandstone	20	680
Coal	5	155	Shale, black	35	715
Shale	65	220	Sandstone	15	730
Coal	5	225	Shale, black	5	735
Shale, gray	10	235	Sandstone, hard	5	740
Strata, hard	2	237	Shale	55	795
Shale	23	260	Sandstone, soft	35	830
Sandstone	25	285	Shale	102	932
Shale, gray and brown	195	480	Sandstone	28	960
Sandstone	15	495	Shale	85	1,045
Coal	5	500	Coal	7	1,052
Shale	25	525	Shale, black and gray	33	1,085

WELL NO. 3.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil or surface deposit	140	140	Rock, light gray	9	280
Sandstone, brown, very soft	20	160	Rock, very hard	2	282
Coal, small bed	5	165	Shale, light gray	58	340
Shale, light colored	35	200	Rock, dark brown	5	345
Sandstone, brown, very hard	1	201	Coal	5	350
Shale, light colored	14	215	Rock, dark brown	10	360
Chalk, cream colored, and soapstone	20	235	Shale, light gray, somewhat gritty	60	420
Coal	5	240	Rock, dark brown, hard and tough	15	435
Shale, light gray	18	258	Coal	15	450
Rock, hard	1	259	Sandstone, brown	35	485
Rock, soft, chalklike	11	270	Coal	5	490
Coal	1	271	Shale	235	725

The thickness of these beds at Wamsutter is probably 9,400 feet, and this is believed to be the entire thickness of the formation, as this place is very near the synclinal axis between the Rawlins and Rock Springs uplifts. For a description of sections along the outcrop of this formation illustrating the character and thickness of the coal beds, the reader is referred to the reports on the Great Divide Basin coal field [a] and the western part of the Little Snake River coal field.[b]

BLACK ROCK COAL GROUP.

The Black Rock coal group is thought to be of Fort Union age, but in this region the beds as a whole constitute the lowest member of the Wasatch formation, which here consists of three separate and distinct units. At the base of the coal group is a thin band of conglomerate, ranging in thickness from 2 to 6 feet near the central part of the dome and increasing in thickness northward. The pebbles are very small, consisting mostly of quartz, although in many places pebbles of other materials are present. This conglomerate marks an unconformable contact between this coal group and the Black Buttes coal group. Lithologically this coal group resembles the upper part of the Black Buttes coal group, but is on the whole whiter and more conglomeratic. The sandstone and shale, however, are more highly colored and more poorly cemented and contain a large number of spherical and irregular concretions. Slag due to the burning of coal beds was observed at several places in this field, but as a rule it is of very small extent compared with the material affected by the burning.

The Black Rock coal group consists of two members. The lower member is made up of light-gray sandy shale, with beds of much darker sandstone. The sandstone is medium grained, brown, and cross-bedded. Many of the beds of sandstone are concretionary and chip into small conchoidal fragments, resembling chert chips, and do not form pronounced ledges. The beds are rich in fossils and are the source of the best plant collections made in this field.

The lower portion of the upper member consists of massive brown sandstone interbedded with light and dark shales. The middle and upper portions of the member are predominantly shaly and have a rather decided greenish tinge. In the upper part of the member occurs a somewhat harder sandy shale which is one of the ledges of a well-marked scarp in this part of the field. In this ledge are found numerous plants which are pronounced by F. H. Knowlton to be of Fort Union age. Thin layers of sandstone with abundant gastropods are found in ledges of the scarp and a few feet below are several thin bands of low-grade bituminous coal.

According to the blueprints of the Union Pacific Railroad Company a well was drilled in these beds at Table Rock to a depth of 1,402 feet. The only record available states that the well was drilled in 1881 and gives the strata passed through to a depth of 550 feet. At a depth of 435 feet the record shows coal 15 feet thick. As no description of the beds at a greater depth than 550 feet is available,

[a] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, pp. 233-234.
[b] Ball, M. W., Idem, pp. 252-253.

nothing further can be said regarding the coal beds that are supposed to occur in the Black Rock coal group in this part of the field. Wells were drilled by the Union Pacific Railroad Company at Red Desert, in sec. 6, T. 19 N., R. 95 W., and Bitter Creek, in sec. 10, T. 18 N., R. 99 W. The Red Desert well was drilled to a depth of 1,115 feet and Bitter Creek well to 696 feet. No coal was reported in either well; but at a depth of 546 feet in the Bitter Creek well the record gives 9 feet of rich petroleum shale. The wells were drilled by churn drills, and it is possible that the coal may have escaped notice or was not recorded in the logs. It does not seem probable that all the coal beds are thin or absent at so short a distance back from the outcrop on the east side of the Rock Springs dome.

The lower half of the Black Rock coal group is richly coal bearing, some of the coal beds having a thickness of 25 feet. The coal beds on the east side of the dome lie nearly horizontal; those on the west side dip from 5° to 25° W. Not a few outcrops of coal beds in this group are concealed by a large amount of burned material. At various places throughout the field coal is burning along the outcrop at the present time. Coal for local ranch use is being mined at Hootén's prospect in sec. 24, T. 23 N., R. 104 W., and at the Menkinney mine in sec. 13, T. 15 N., R. 105 W., and to a less degree at some of the other prospects in this group.

The eastern boundary of this coal zone is described in the reports on the Great Divide Basin coal field, and the Little Snake River coal field already cited.[a] The same coal group spreads over a large territory in the southeastern part of the Rock Springs field, occupying a considerable area in the Vermilion Creek basin. Coals are known to outcrop in many parts of this basin in the southern part of Wyoming and the northern part of Colorado, but as this part of the field has not been mapped definite statements can not be made regarding them. Coal has been mined in a prospect on Canyon Creek, in sec. 7 or 8, T. 12 N., R. 101 W. The coal clearly belongs to the Black Rock coal group and its character is the same as that of the coal found in this group around the Rock Springs dome. E. E. Smith collected a sample of coal at this prospect, the analysis of which (No. 6795) is incorporated with those of the Black Rock coals in the table of analyses. The Black Rock coal group also extends southward across the state line into Colorado and lies exposed in the low synclinal trough between the south end of the Rock Springs dome and the north flank of the Uinta uplift. In a rapid trip across these beds from the end of the Rock Springs dome southwestward to Red Creek canyon it was observed that the Black Rock coal group extends southward, resting in T. 12 N., R. 105 W., on the white sandstone between the Almond and Rock Springs coal groups or on the Almond coal group.

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[a] Bull. U. S. Geol. Survey No. 341, 1909 pp. 220-242, 243-255.

The following representative sections taken along the outcrop of the coal beds at various places around the dome illustrate their thickness and character:

Sections of coal beds in the Black Rock coal group in the southern part of the Rock Springs field, Wyoming.[a]

Location: Quarter.	Sec.	T.	R.	Section of coal bed.	Ft.	in.
NE. ¼ SW. ¼.	11	13	104	Coal	4	
SW. ¼ SW. ¼.	5	14	101	Shale, brown		
				Coal	9	
				Shale, brown.		
NE. ¼ NW. ¼	13	14	102	Coal	7	
NE. ¼ NW. ¼.	20	14	102	Sandstone	6	
				Shale	1	6
				Coal	3	6
				Shale.		
					11	
SE. ¼ NE. ¼.	17	14	105	Coal	1	6
NW. ¼ NW. ¼.	22	14	105	Coal	3	
SW. ¼ NW. ¼.	21	15	102	Shale, brown	2	
				Coal	2	6
				Shale, brown	1	
				Sandstone, white.		
					5	6
NE. ¼ NE. ¼.	34	15	102	Shale, brown	2	
				Coal	2	6
				Shale, brown.		
					4	6
NW. ¼ SW. ¼.	13	15	105	Shale, blue.		
				Coal	2	6
				Clay		1
				Coal	2	2
				Shale, black.		
					4	9
NE. ¼ SW. ¼.	1	16	102	Sandstone, brown	10	
				Shale, brown	3	
				Coal	9	6
				Shale, brown	1	6
				Sandstone, red	2	6
				Shale, brown	2	
				Coal, bony	1	6
				Sandstone, brown	1	6
				Coal		8
				Shale, brown	15	
					47	2
NW. ¼ SE. ¼.	14	16	102	Sandstone, red	4	
				Shale, brown	6	
				Coal	7	6
				Shale, brown	2	
					19	6
NE. ¼ NW. ¼.	23	16	102	Sandstone, red	2	
				Shale, brown	6	
				Coal	7	
				Shale, brown	2	
					17	
SW. ¼ NE. ¼.	24	16	102	Shale, sandy	6	
				Coal	2	6
				Shale, brown	3	
					11	6
NE. ¼ NE. ¼.	6	16	105	Coal		8
				Bone		1
				Coal	2	
				Bone		1
				Coal	1	
				Sandstone		2
				Coal		10
				Bone		1
				Coal		9
					5	8
SW. ¼ NW. ¼.	6	16	105	Coal		10
				Bone		1
				Coal		4
				Bone		½
				Coal	3	1
					4	4½
SW. ¼ NE. ¼.	8	16	105	Coal	1	6
				Bone		1
				Coal	2	
				Bone		2
				Coal	1	1
					4	10
NW. ¼ SW. ¼.	16	16	105	Coal	1	8
				Bone		1
				Coal	1	9
				Bone		1½
				Coal	1	4
					4	11½
SE. ¼ SE. ¼.	17	16	105	Coal	1	1
				Bone		½
				Coal		4
				Bone		1
				Coal	1	2
				Bone		½
				Coal	1	11
					4	8
NW. ¼ NW. ¼.	17	16	105	Coal	1	6
				Bone		1
				Coal	2	7
					4	2

[a] For sections of these beds in the northern part of the Rock Springs field see Bull. U. S. Geol. Survey No. 341, 1909, p. 265.

Sections of coal beds in the Black Rock coal group in the southern part of the Rock Springs field, Wyoming—Continued.

Location: Quarter.	Sec.	T.	R.	Section of coal bed.	Ft.	in.
SW. ¼ NE. ¼.	10	16	106	Coal.......	3	
SE. ¼ SE. ¼.	13	17	101	Shale.		
				Coal.......		4
				Shale......		6
				Coal........	4	
				Shale.		
					4	10
SW. ¼ NE. ¼.	5	17	105	Coal.......		6
				Bone......		1
				Coal.......	1	6
					2	1
SW. ¼ NE. ¼.	29	17	105	Coal.......	1	4
				Bone......		2
				Coal.......	2	4
				Bone......		3
				Coal.......	1	2
				Sandstone		3
				Coal.......		6
				Bone......	1	
				Coal.......		8
					7	8
NE. ¼ SE. ¼.	30	17	105	Coal.......	1	2
				Bone......		1
				Coal.......	2	3
				Sandstone.		2
				Coal.......	1	1
					4	9
SW. ¼ NW. ¼.	20	18	98	Coal.......		4
				Shale......		4
				Coal.......		3½
				Shale.		
						11½
NE. ¼ SW. ¼.	29	18	98	Coal.......		4
				Shale......		4
				Coal.......	1	
				Shale.		
					1	8
NE. ¼ SW. ¼.	18	18	99	Shale.		
				Coal.......		4
				Shale......	1	4
				Coal.......	1	6
				Shale.		
					3	2
SW. ¼ NW. ¼.	18	18	99	Shale.		
				Coal.......		4
				Shale......	1	2
				Coal.......	1	6
				Shale.		
					3	
SE. ¼ SE. ¼.	11	18	100	Shale........		3
				Coal.......	2	6
					2	9
SE. ¼ SW. ¼.	21	18	100	Shale........	4	7
				Coal.......		2
				Shale......		1
				Coal.......	11	
					15	10
NW. ¼ NE. ¼.	23	18	100	Coal........	1	
				Shale.......		2
				Coal........	2	3
				Shale........	1	1
					4	6
NE. ¼ NE. ¼.	31	18	100	Coal........	2	3
				Shale.......	1	8
				Coal........		8
				Shale.......		4
				Coal........	6	5
					11	4
NW. ¼ NW. ¼.	34	18	100	Shale.		
				Coal........	3	6
				Bone.........		6
				Shale.		
					4	
NE. ¼ SE. ¼.	4	18	105	Coal........	2	7
				Bone.......		1
				Coal........	3	8
				Bone.......		2
				Coal........		8
				Bone.......		2
				Coal........	1	1
					8	5
SW. ¼ SE. ¼.	20	18	105	Coal........	2	
				Sandstone..		1
				Coal........	2	8
					4	9
SE. ¼ SW. ¼.	21	18	105	Coal........		10
				Bone.......		1
				Coal........	2	9
				Sandstone..		2
				Coal........		8
				Bone.......		1
				Coal........		8
					5	3
NW. ¼ SW. ¼.	32	18	105	Coal........		8
				Bone.......		1
				Coal........	2	6
					3	3
SW. ¼ SE. ¼.	10	19	105	Coal........	3	10
				Bone.......		2
				Coal........		7
				Bone.......		1
				Coal........	2	
					6	8
SE. ¼ SE. ¼.	13	23	104	Shale.........	2	
				Coal........	7	10
					9	10
SE. ¼ NE. ¼.	24	23	104	Shale.........	5	
				Coal........		10
				Shale.......		2
				Coal........	8	
				Shale.		
					14	

THE COAL.

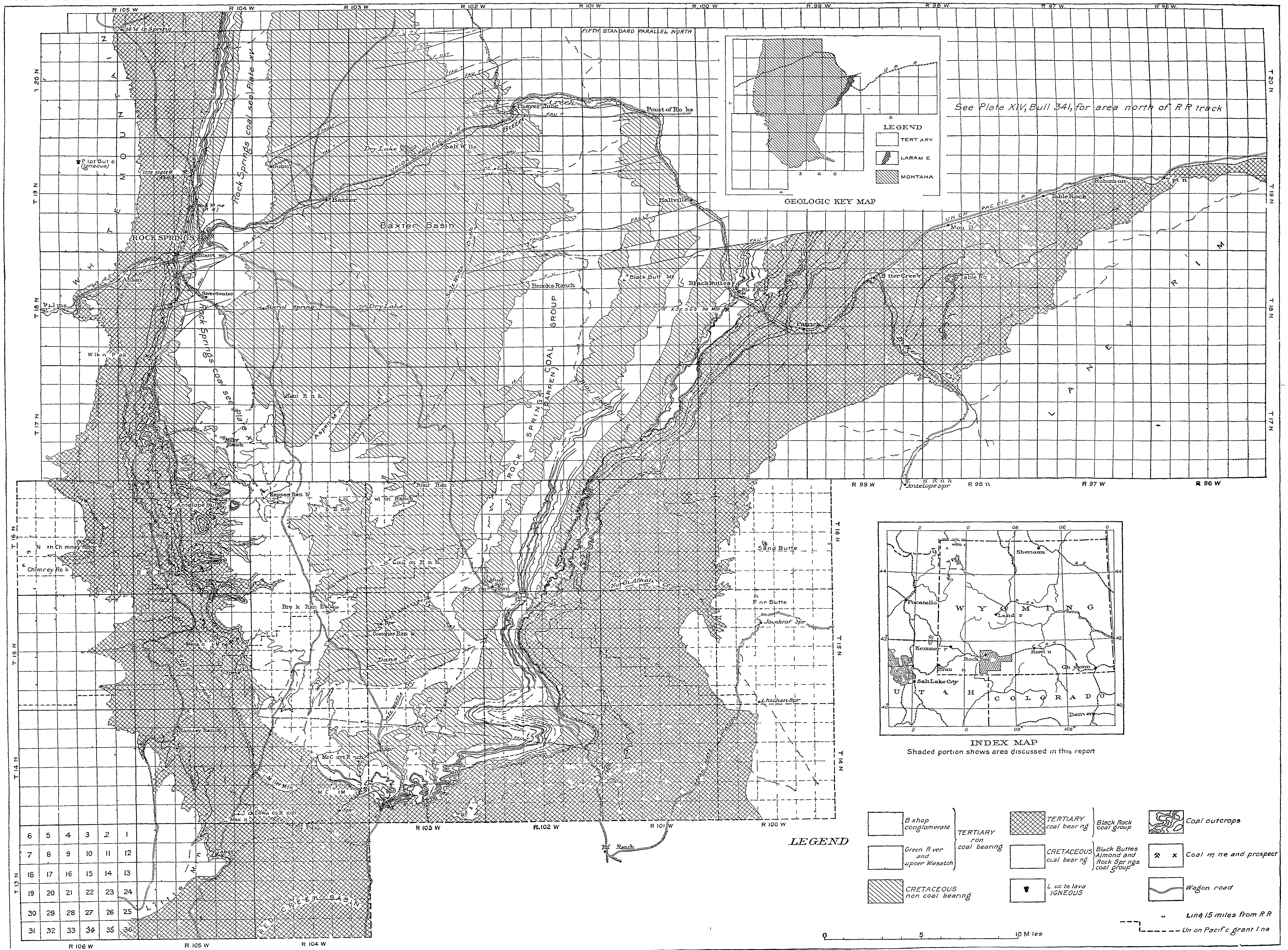
PHYSICAL PROPERTIES.

The Rock Springs coal is jet black as it comes from the mine, has a bright or even glassy luster, and in places shows iridescent colors. The structure of the bedding planes is as a rule well preserved, but jointing is not strongly developed. The coal is dense in texture and somewhat brittle. The streak ranges in color from brownish black to black. Many slickensided surfaces are present in this coal, as well as numerous faults. Considerable deposits of salts occur on the faces of the coal and on the sandstone along the entries in the mines. The coal on exposure to the air remains firm and compact and stands shipping without breaking down. On burning it produces no clinker and leaves a small bulk of red-white or reddish ash. Samples taken from surface prospects and placed in air-tight cans soon lose their bright luster and the surface becomes covered with a velvety-brown coating, which is probably due to the alteration of the weathered coal. The chief impurities of the coal are sulphur balls and small lenses of pyrite that are scattered somewhat irregularly through the bed.

The higher coals are also distinctly black, with a bright luster as they come from the mine. They show more traces of iron stain than the Rock Springs coal and contain considerable gypsum and salt flakes in the joints or bedding planes. On exposure to the air they alter more readily than the lower coals, lose their bright luster, and become a dull black. As they break down cracks form along and perpendicular to the bedding planes, producing somewhat regular blocks instead of the irregular pieces resulting from conchoidal fracture. These coals somewhat resemble the Adaville coal of Uinta County, but they seem to be affected less on exposure to the air and their fractures and joints are more regular and quite different from the conchoidal fracture of the Adaville coal.

CHEMICAL PROPERTIES.

On account of the slight amount of development work done in the southern part of the field it was not possible to obtain many representative samples of the coal for chemical analysis. Eleven samples were taken, but only one of these (No. 6672) was obtained from a fresh face of coal in an operating mine. Most of the samples were collected near weathered surfaces, from old abandoned prospects, and the coals were probably more or less altered. Most of the prospects from which samples were taken have been opened sufficiently to pass through the weathered zone near the surface, but deterioration in these places is in part due to the action of air on the walls of the coal in the prospect pit since the opening was made. Besides the eleven samples above mentioned, fifteen additional



MAP OF SOUTHERN PART OF ROCK SPRINGS COAL FIELD, WYOMING

By A R Schultz

samples were collected to show the various stages of weathering or the depth to which weathering affects the chemical composition of the coal. Five samples were collected from the Rock Springs coal at the Gunn mine; five from the Almond coal at the mine east of Point of Rocks, and five from the Black Buttes coal southwest of Black Buttes. These are described in the next paper in this bulletin (pp. 282–296).

Representative samples of coal were collected from the four coal groups wherever good coal could be obtained and were sent in air-tight cans to the chemical laboratory of the fuel-testing plant at Pittsburg, Pa., for analysis.[a]

In order that the results from the samples collected might be entirely comparable, all sampling was done in accordance with the general plan adopted by the fuel-testing plant.[b]

The accompanying table gives the result of analysis of (1) samples as received in the laboratory, containing all the moisture that is present in the coal in the mine; (2) air-dried coal, after part of the moisture that is easily separated has been expelled; (3) dry coal, after the moisture has all been eliminated, and (4) pure coal, after the moisture and ash have been eliminated. The analyses are grouped according to the calorific values, the coal having the highest British thermal unit value in the air-dried sample heading the list for each of the four groups.

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[a] For analyses of coal sampled in the northern part of the Rock Springs field in 1907 see Bull U. S. Geol. Survey No. 341, 1909, pp. 270-273.

[b] Bull. U. S. Geol. Survey No. 341, 1909, pp. 12-13.

Analyses of coal samples from the Rock Springs coal field, Wyoming.

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

ROCK SPRINGS COAL GROUP, LOWER PART OF MESAVERDE FORMATION.

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6772	NW. ¼	2	18	105	5′ 4″	5′ 4″	7.1	As received	11.5	36.8	50.1	1.62	0.75	5.94	68.29	1.16	22.24	6,791	12,224
	NW. ¼							Air dried	4.7	39.7	53.9	1.74	.81	5.54	73.51	1.25	17.15	7,310	13,158
								Dry coal	....	41.6	56.6	1.83	.85	5.27	77.16	1.31	13.58	7,673	13,811
								Pure coal	....	42.4	57.6		.87	5.37	78.60	1.33	13.83	7,816	14,069
7091	NW. ¼	8	19	104	5′ 10″	5′ 10″	12.4	As received	15.7	33.5	48.4	2.39	.93	6.11	63.11	1.30	26.16	6,191	11,144
	SE. ¼							Air dried	3.8	38.2	55.3	2.73	1.06	5.40	72.04	1.48	17.29	7,069	12,721
								Dry coal	....	39.8	57.4	2.84	1.10	5.17	74.87	1.54	14.48	7,345	13,221
								Pure coal	....	40.9	59.1	....	1.13	5.32	77.06	1.58	14.91	7,559	13,606
7089	NW. ¼	8	19	104	5′ 10″	5′ 10″	9.1	As received	13.5	34.9	49.4	2.24	.95	5.76	64.33	1.21	25.51	6,365	11,455
	SE. ¼							Air dried	4.8	38.4	54.3	2.46	1.05	5.23	70.77	1.33	19.16	7,002	12,604
								Dry coal	....	40.3	57.1	2.59	1.10	4.93	74.31	1.40	15.67	7,352	13,234
								Pure coal	....	41.4	58.6	....	1.13	5.06	76.29	1.44	16.08	7,548	13,586
6796	NW. ¼	24	17	105	3′ 6″	3′ 6″	9.2	As received	12.8	34.8	49.9	2.49	.76	5.84	64.78	1.30	24.83	6,312	11,362
	NW. ¼							Air dried	4.0	38.3	55.0	2.74	.84	5.31	71.34	1.43	18.34	6,952	12,514
								Dry coal	....	39.9	57.2	2.85	.87	5.07	74.27	1.49	15.45	7,237	13,027
								Pure coal	....	41.1	58.9	....	.90	5.22	76.45	1.53	15.90	7,449	13,408
7092	NW. ¼	8	19	104	5′ 10″	5′ 10″	11.5	As received	15.9	33.3	47.1	3.73	1.10	5.99	61.76	1.29	26.13	6,044	11,879
	SE. ¼							Air dried	5.0	37.6	53.2	4.22	1.24	5.33	69.78	1.46	17.97	6,829	12,292
								Dry coal	....	39.5	56.1	4.44	1.31	5.02	73.44	1.53	14.26	7,187	12,937
								Pure coal	....	41.4	58.6	....	1.37	5.25	76.85	1.60	14.93	7,521	13,538
6799	NE. ¼	14	17	105	3′ 6″	3′ 6″	8.3	As received	13.1	35.6	45.6	5.72	1.40	5.94	62.85	1.23	22.86	6,173	11,111
	NE. ¼							Air dried	5.2	38.8	49.8	6.24	1.53	5.47	68.54	1.34	16.88	6,732	12,118
								Dry coal	....	40.9	52.5	6.58	1.61	5.16	72.32	1.42	12.91	7,103	12,785
								Pure coal	....	43.8	56.2	....	1.72	5.52	77.41	1.52	13.83	7,603	13,685
8534	NW. ¼	8	19	104	5′ 10″	5′ 10″	9.4	As received	17.6	31.1	47.5	3.80	1.13	6.24	60.36	1.30	27.17	5,982	10,768
	SE. ¼							Air dried	9.1	34.3	52.4	4.19	1.25	5.74	66.62	1.44	20.76	6,603	11,885
								Dry coal	....	37.7	57.7	4.61	1.37	5.19	73.26	1.58	13.99	7,260	13,068
								Pure coal	....	39.6	60.4	....	1.44	5.44	76.80	1.66	14.66	7,611	13,700

7090	NW. ¼ SE. ¼	8	19	104	5′ 10″	5′ 10″	17.3	As received....	23.3	31.9	41.5	3.27	.53	5.53	50.17	1.04	39.46	4,500	8,100
								Air dried......	7.2	38.6	50.2	3.95	.64	4.36	60.66	1.26	29.13	5,441	9,794
								Dry coal......	....	41.6	54.1	4.26	.69	3.83	65.41	1.36	24.45	5,867	10,561
								Pure coal......	....	43.5	56.5	....	.72	4.00	68.32	1.42	25.54	6,128	11,030
6791	SE. ¼ SW. ¼	14	17	105	4′ 0″	4′ 0″	18.4	As received....	24.2	32.1	40.0	3.70	.49	5.57	49.19	1.07	39.98	4,384	7,891
								Air dried......	7.1	39.4	49.0	4.54	.60	4.32	60.28	1.31	28.95	5,372	9,670
								Dry coal......	....	42.4	52.7	4.88	.64	3.80	64.90	1.41	24.37	5,784	10,411
								Pure coal......	....	44.6	55.4	....	.67	3.99	68.23	1.48	25.63	6,081	10,946
ALMOND COAL GROUP, UPPER PART OF MESAVERDE FORMATION.																			
7087	SW. ¼ SW. ¼	26	20	101	7′ 2″	7′ 2″	12.0	As received....	16.9	28.4	51.3	3.40	0.55	5.75	60.61	1.24	28.45	5 785	10,413
								Air dried......	5.6	32.2	58.3	3.86	.62	5.02	68.88	1.41	20.21	6 575	11,835
								Dry coal......	....	34.1	61.8	4.09	.66	4.66	72.96	1.49	16.14	6,963	12,533
								Pure coal......	....	35.6	64.4	....	.69	4.86	76.07	1.55	16.83	7,260	13,068
7102	SW. ¼ SW. ¼	26	20	101	7′ 2″	7′ 2″	13.6	As received....	18.8	29.5	48.2	3.52	.55	5.90	58.97	1.21	29.85	5,619	10,114
								Air dried......	6.0	34.1	55.8	4.07	.64	5.08	68.25	1.40	20.56	6,504	11,707
								Dry coal......	....	36.3	59.4	4.34	.68	4.69	72.65	1.49	16.15	6,923	12,461
								Pure coal......	....	37.9	62.1	....	.71	4.90	75.95	1.56	16.88	7,237	13,027
7094	SW. ¼ SW. ¼	26	20	101	7′ 2″	7′ 2″	12.4	As received....	17.9	29.5	49.3	3.27	.50	5.87	59.46	1.24	29.66	5,678	10,220
								Air dried......	6.3	33.7	56.3	3.73	.57	5.13	67.87	1.41	21.29	6,482	11,668
								Dry coal......	....	35.9	60.1	3.98	.61	4.73	72.44	1.51	16.73	6,918	12,452
								Pure coal......	....	37.4	62.6	....	.64	4.93	75.44	1.57	17.42	7,204	12,967
6773	NE. ¼ SE. ¼	22	19	105	8′ 4″	8′ 4″	9.1	As received....	14.9	32.9	47.8	4.42	.40	5.46	61.09	1.20	27.43	5,779	10,402
								Air dried......	6.4	36.2	52.5	4.86	.44	4.90	67.21	1.32	21.27	6,358	11,444
								Dry coal......	....	38.7	56.1	5.19	.47	4.47	71.79	1.41	16.67	6,791	12,224
								Pure coal......	....	40.8	59.2	....	.50	4.71	75.72	1.49	17.58	7,162	12,892
6797	NE. ¼ NE. ¼	25	14	104	6′ 6″	6′ 6″	15.0	As received....	18.6	29.7	48.1	3.55	.41	5.38	57.24	1.28	32.14	5,365	9,657
								Air dried......	4.3	34.9	56.6	4.18	.48	4.37	67.34	1.50	22.13	6,312	11,362
								Dry coal......	....	36.5	59.1	4.36	.50	4.07	70.33	1.57	19.17	6,592	11,866
								Pure coal......	....	38.2	61.8	....	.52	4.26	73.54	1.64	20.04	6,893	12,407
7095	SW. ¼ SW. ¼	26	20	101	7′ 2″	7′ 2″	8.6	As received....	14.0	31.1	50.8	4.09	.56	5.38	60.29	1.26	28.42	5,653	10,175
								Air dried......	5.9	34.0	55.6	4.48	.61	4.84	65.93	1.38	22.73	6,185	11,133
								Dry coal......	....	36.2	59.1	4.75	.65	4.45	70.07	1.46	18.62	6,570	11,826
								Pure coal......	....	38.0	62.0	....	.68	4.67	73.56	1.53	19.56	6,897	12,415
6775	NE. ¼ SE. ¼	10	19	105	4′ 6″	4′ 6″	13.7	As received....	21.0	31.3	40.1	7.60	.79	5.38	49.55	1.04	35.64	4,556	8,201
								Air dried......	8.5	36.3	46.4	8.81	.91	4.47	57.42	1.20	27.19	5,279	9,502
								Dry coal......	....	39.7	50.7	9.62	1.00	3.86	62.72	1.32	21.48	5,767	10,381
								Pure coal......	....	43.9	56.1	....	1.11	4.27	69.39	1.46	23.77	6,381	11,486
7088	SW. ¼ SW. ¼	26	20	101	6′ 4″	6′ 4″	7.5	As received....	14.3	33.2	47.1	5.44	.74	4.69	54.16	1.35	33.62	4,630	8,334
								Air dried......	7.3	35.9	50.9	5.88	.81	4.17	58.55	1.46	29.13	5,005	9,009
								Dry coal......	....	38.8	54.9	6.34	.87	3.63	63.17	1.57	24.42	5,400	9,720
								Pure coal......	....	41.4	58.6	....	.93	3.88	67.45	1.68	26.06	5,766	10,379

Analyses of coal samples from the Rock Springs coal field, Wyoming—Continued.

BLACK BUTTES COAL GROUP, "LARAMIE" FORMATION.

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
7093	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	15.6	As received	20.8	28.4	47.1	3.73	0.36	5.98	57.11	1.06	31.76	5,507	9,913
								Air dried	6.1	33.6	55.9	4.42	.43	5.03	67.66	1.26	21.20	6,526	11,747
								Dry coal	....	35.8	59.5	4.71	.45	4.63	72.08	1.34	16.79	6,950	12,510
								Pure coal	....	37.6	62.4	....	.47	4.86	75.64	1.41	17.62	7,293	13,127
7097	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	13.1	As received	18.7	29.2	48.4	3.73	.44	5.79	58.45	1.41	30.18	5,582	10,047
								Air dried	6.4	33.7	55.6	4.29	.51	4.98	67.26	1.62	21.34	6,423	11,561
								Dry coal	....	35.9	59.5	4.59	.54	4.56	71.89	1.73	16.69	6,865	12,357
								Pure coal	....	37.7	62.3	....	.57	4.78	75.34	1.81	17.50	7,195	12,951
7096	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	14.5	As received	19.5	28.2	47.9	4.40	.37	5.89	57.34	1.40	30.60	5,465	9,837
								Air dried	5.9	33.0	56.0	5.15	.43	5.01	67.07	1.64	20.70	6,392	11,506
								Dry coal	....	35.0	59.5	5.47	.46	4.62	71.27	1.74	16.44	6,792	12,226
								Pure coal	....	37.1	62.9	....	.49	4.89	75.40	1.84	17.38	7,185	12,933
7170	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	7.9	As received	18.9	28.9	48.1	4.13	.43	5.82	59.20	1.43	28.99	5,607	10,093
								Air dried	11.9	31.4	52.2	4.48	.47	5.36	64.28	1.55	23.86	6,088	10,958
								Dry coal	....	35.7	59.2	5.09	.53	4.59	72.97	1.76	15.06	6,911	12,440
								Pure coal	....	37.6	62.4	....	.56	4.84	76.88	1.85	15.87	7,281	13,106
7103	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	13.1	As received	17.2	30.3	48.3	4.23	.35	5.36	56.22	1.51	32.33	5,216	9,389
								Air dried	4.7	34.9	55.5	4.87	.40	4.49	64.69	1.74	23.81	6,002	10,804
								Dry coal	....	36.6	58.3	5.11	.42	4.17	67.91	1.82	20.57	6,301	11,342
								Pure coal	....	38.6	61.4	....	.44	4.39	71.57	1.92	21.68	6,641	11,954

BLACK ROCK COAL GROUP, WASATCH FORMATION.

6794	NW.¼ SW.¼	13	15	105	4′ 8″	4′ 8″	4.5	As received	8.1	38.8	42.5	10.64	1.01	5.59	61.70	1.33	19.73	6,181	11,126
								Air dried	3.8	40.6	44.5	11.14	1.06	5.33	64.61	1.39	16.47	6,472	11,650
								Dry coal		42.2	46.2	11.58	1.10	5.10	67.12	1.45	13.65	6,724	12,103
								Pure coal		47.7	52.3		1.24	5.77	75.91	1.64	15.44	7,605	13,689
6774	SW.¼ SE.¼	10	19	105	6′ 8″	6′ 5″	8.4	As received	13.4	36.3	41.8	8.48	.83	5.90	59.84	1.15	23.80	5,813	10,463
								Air dried	5.4	39.6	45.7	9.26	.91	5.43	65.33	1.25	17.82	6,346	11,423
								Dry coal		41.9	48.3	9.79	.96	5.09	69.07	1.33	13.76	6,710	12,078
								Pure coal		46.4	53.6		1.06	5.64	76.57	1.47	15.26	7,438	13,388
6795			12	101	7′ 1″	6′ 9″	7.4	As received	12.4	39.2	36.9	11.53	5.44	5.42	55.78	1.54	20.29	5,626	10,127
								Air dried	5.4	42.3	39.8	12.45	5.88	4.97	60.24	1.66	14.80	6,076	10,937
								Dry coal		44.7	42.1	13.17	6.21	4.61	63.70	1.76	10.55	6,424	11,563
								Pure coal		51.5	48.5		7.15	5.31	73.36	2.03	12.15	7,399	13,318
6771	NE.¼ SE.¼	4	18	105			11.2	As received	19.8	35.7	37.8	6.70	.67	5.11	48.14	1.33	38.05	4,349	7,828
								As dried	9.7	40.2	42.6	7.54	.76	4.36	54.21	1.50	31.63	4,898	8,816
								Dry coal		44.5	47.1	8.36	.84	3.63	60.05	1.66	25.46	5,425	9,765
								Pure coal		48.6	51.4		.92	3.96	65.53	1.81	27.78	5,920	10,656

Samples of coal from the Rock Springs coal field, Wyoming.

Laboratory No.	Name of mine.	Sampling point.	Condition of sample.	Sampler.
6772	Wyoming Coal and Coke Co.	Second entry south. 20 feet north of fault.	Dry, unaltered	B. L. Johnson.
8534	Gunn-Quealy	1,100 feet from mouth	Dry, unaltered	H. E. Lewis.
7091	Gunn-Quealy	800 feet down slope	Dry, unaltered	J. L. Rich.
7089	Gunn-Quealy	80 feet down slope	Weathered	J. L. Rich.
6796	Millor	40 feet from entrance	Dry, unaltered	R. O. Bartholomew.
7092	Gunn-Quealy	150 feet from surface	Dry, unaltered	J. L. Rich.
6799	Kent	75 feet from opening, south entry.	Dry, unaltered	R. O. Bartholomew.
7090	Gunn-Quealy	10 feet down slope	Dry, badly weathered.	J. L. Rich.
6791	Kappes	40 feet from entrance	Slightly weathered	R. O. Bartholomew.
7087	Rock Springs-Wyoming Coal Co.	300 feet in from opening.	Dry, unaltered	B. L. Johnson.
7102	Rock Springs-Wyoming Coal Co.	1,000 feet in from opening.	Dry, unaltered	B. L. Johnson.
7094	Rock Springs-Wyoming Coal Co.	500 feet in from opening.	Dry, unaltered	B. L. Johnson.
6773	Old No. 6	300 feet west of opening.	Dry, weathered	B. L. Johnson.
6797	McCourt	30 feet from opening	Slightly weathered	J. L. Rich.
7095	Rock Springs-Wyoming Coal Co.	150 feet in from opening.	Dry, unaltered	B. L. Johnson.
6775	Prospect	100 feet down slope	Dry, unaltered	J. L. Rich.
7088	Rock Springs-Wyoming Coal Co.	50 feet from opening	Dry	B. L. Johnson.
7093	Rock Springs-Gibraltar Coal Co.	355 feet from opening down dip.	Dry, unaltered	B. L. Johnson.
7097	Rock Springs-Gibraltar Coal Co.	150 feet from opening down dip.	Dry, unaltered	B. L. Johnson.
7096	Rock Springs-Gibraltar Coal Co.	225 feet from opening down dip.	Dry, unaltered	B. L. Johnson.
7170	Rock Springs-Gibraltar Coal Co.	100 feet from opening down dip.	Dry, unaltered	B. L. Johnson.
7103	Rock Springs-Gibraltar Coal Co.	50 feet from opening down dip.	Weathered	B. L. Johnson.
6794	Menkinney	30 feet from opening	Dry, unaltered	A. R. Schultz.
6774	Interstate	54 feet west by 40 feet south of opening.	Dry, unaltered	B. L. Johnson.
6795	Canyon Creek prospect.	50 feet from opening	Slightly weathered	E. E. Smith.
6771	Prospect	50 feet from opening	Dry, slightly weathered.	B. L. Johnson.

BURNING OF OUTCROP.

In the western coal fields many coal beds have been burned along their outcrop, and in a few places the burning is going on at the present time. The extent of the burning is in general inversely proportional to the value of the coal.

In the Rock Springs field the amount of burning is relatively small in the Rock Springs and Almond coal groups and a little more prominent in each of the other coal groups, being most pronounced in the Black Rock. Considering the amount of burning that has been going on, the slag accumulations are small and unimportant, as the coal burns without leaving much clinker. In some places the effect on the adjacent rocks can be seen several feet from the actual seat of the burning; in other places rocks a very short distance away are not affected. The physical appearance of the coal bed near the burning or burned bed does not seem to be altered by the burning. On the other hand, the chemical analyses usually show decided differences between coal from the immediate vicinity of the burned or burning bed and similar coals collected from the same group at more remote distances. The coal taken near a burned area has become of considerably higher grade than the unaffected coal, having as a rule a higher British thermal unit value, lower air-drying loss, low volatile matter and high fixed carbon, and, in the ultimate analysis, high carbon and low hydrogen and oxygen. In this connection a comparison of analysis No. 5299 [a] with Nos. 5298, 5432, 5448, and 5447, representing the same group of coals, is interesting.

QUALITY OF COAL.

The lower coals of the Rock Springs coal group stand shipment well and do not slack on exposure to the air. They belong in the bituminous, noncoking class of coals. The coal of the Almond coal group is physically and chemically more closely related to the coals of the Black Buttes, Knobs-Cherokee, and Black Rock coal groups than to the Rock Springs coal. The chief difference is that all the coals above the Rock Springs coal group have more moisture and are lighter in weight than those of the Rock Springs and slack considerably on exposure to the air. These coals fall in the lowest grade of bituminous or the highest grade of subbituminous coals. As a rule they are better than the Adaville and Evanston coals of southern Uinta County. The coals of the Rock Springs field have a low sulphur content which ranges from 0.30 to 5.88 per cent, but is usually less than 1 per cent, averaging 0.84 per cent for the entire 85 samples collected. The coal beds in the four coal groups (Rock Springs, Almond, Black Buttes, and Black Rock) give comparatively clean coal and have a low content of ash, ranging from 1.51 to 17.41 per cent and averaging 5.43 per cent for the 85 samples collected.

The following table may be considered as representing the average condition of the coal in the five groups of coal beds. The table shows the relative values of these coals with respect to ash, sulphur, carbon, and fixed carbon. The Black Rock coals have the greatest amount of ash and sulphur, and in this respect as well as in their carbon content are only a little poorer than the Knobs-Cherokee coals. The Rock Springs and Black Buttes coals carry nearly the same amount of impurity and carbon.

[a] Ball, M. W., Bull. U. S. Geol. Survey No. 341, 1909, p. 251.

Values of air-dried coal in the various coal groups in the Rock Springs coal field.

Coal group.	Number of samples.	Range.	Ash.	Sulphur.	Carbon.	Fixed carbon.
Black Rock	10	Maximum	17.41	5.88	65.33	52.78
		Minimum	4.94	.30	43.16	28.17
		Average	9.10	1.46	58.85	42.95
Knobs-Cherokee[a]	7	Maximum	10.51	1.18	69.12	58.68
		Minimum	1.70	.15	54.14	22.15
		Average	7.96	.80	59.11	41.18
Black Buttes	10	Maximum	5.15	.40	67.66	55.96
		Minimum	4.29	.64	62.52	47.94
		Average	4.58	.50	65.14	53.40
Almond	20	Maximum	11.74	.98	68.88	59.77
		Minimum	3.73	.32	52.94	41.97
		Average	6.27	.58	61.70	50.50
Rock Springs	45	Maximum	15.80	1.53	73.51	55.38
		Minimum	1.51	.36	44.75	34.98
		Average	4.41	.89	64.12	49.77

[a] Smith, E. E. The eastern part of the Great Divide Basin coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, p. 238. Ball, M. W., The western part of the Little Snake River coal field, Wyoming: Idem, p. 251. This coal group is not exposed in the Rock Springs dome, but is believed to be present.

As pointed out by David White,[a] ash and oxygen are of nearly equal weight as impurities in coal with respect to heat efficiencies. On arranging the values of the samples obtained in the Rock Springs field according to the ratio C ÷ (O + ash) it is found that these values have approximately the same order as the efficiencies determined calorimetrically. Although the order differs slightly from that of the British thermal unit values, the difference is small, the variation in thermal units being for the greater number of samples less than 100 and in few exceeding 500. Many of these samples were considerably weathered and it is remarkable that these ratios should correspond so closely with the determined British thermal unit values. From these analyses it appears that the ratio C ÷ (O + ash) furnishes a fairly satisfactory basis for grouping coals according to their heat efficiencies.

COMPARATIVE VALUES.

The coals of the Rock Springs coal group occur in the same geologic formation (the Mesaverde) as the bituminous coals of the Yampa, Danforth Hills, and Grand Hogback fields of Colorado and the Book Cliffs field of Utah, and compare favorably with those coals. They are not so good as the Kemmerer coals[b] (of Benton age) in Uinta County, Wyo., which show a tendency to coke and have a high heat efficiency.

Rock Springs coal bed No. 7 was tested by the United States fuel-testing plant at St. Louis in 1906 for producer-gas and coking properties.[c] Two mine samples and one car sample of coal were

[a] The effect of oxygen in coal: Bull. U. S. Geol. Survey No. 382, 1909.

[b] Schultz, A. R., Bull. U. S. Geol. Survey No. 316, 1907, pp. 219-222. Veatch, A. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 336-337.

[c] See "Wyoming No. 5," Bull. U. S. Geol. Survey No. 332, 1908, pp. 286-287.

taken for chemical analysis. The analyses, together with the results of the producer-gas and coking tests, are given here for the purpose of comparison. Samples 3164 and 3165 were taken in the mine 5,200 and 7,000 feet north of the foot of the slope, and the coal bed at these places measured, respectively, 7 feet 6 inches and 7 feet 2 inches in thickness.

Analyses of Rock Springs coal as received from bed No. 7, Rock Springs, Wyo.

	Mine samples.		Car sample.
Laboratory No	3164	3165	3213
Air-drying loss	4.00	4.40	6.00
Proximate:			
Moisture	12.41	13.10	11.64
Volatile matter	36.57	34.97	36.37
Fixed carbon	48.50	48.59	48.58
Ash	2.52	3.34	3.41
Sulphur	.80	1.04	.81
Ultimate:			
Hydrogen	......	......	5.72
Carbon	......	......	66.08
Nitrogen	......	......	1.43
Oxygen	......	......	22.55
Calorific value (as received):			
Calories	6,622	......	6,538
British thermal units	11,920	......	11,768

Producer-gas test of Rock Springs coal (run-of-mine) from bed No. 7, Rock Springs.

COAL CONSUMED IN PRODUCER PER HORSEPOWER PER HOUR (POUNDS).

	Coal as fired.	Dry coal.	Combustible.
Per electrical horsepower:			
Commercially available	1.72	1.52	1.46
Developed at switchboard	1.60	1.42	1.38
Per brake horsepower:			
Commercially available	1.46	1.29	1.24
Developed at engine	1.36	1.21	1.16

ANALYSES.

COAL.		GAS.	
Moisture	11.44	Carbon dioxide (CO_2)	10.1
Volatile matter	36.37	Carbon monoxide (CO)	20.4
Fixed carbon	48.49	Hydrogen (H_2)	18.2
Ash	3.70	Methane (CH_4)	2.6
Sulphur	.91	Nitrogen (N_2)	48.3
		Ethylene (C_2H_4)	.4

Duration of test, fifty hours. Average electrical horsepower, 194.5. Average British thermal units per cubic foot of gas, 168. Total coal fired, 15,600 pounds.

Coking test of Rock Springs coal from bed No. 7, Rock Springs, Wyo.

Size as used: Raw, finely crushed. Duration of test, thirty-nine hours. Coal charged, 8,000 pounds. Coke produced, none. Analysis of coal: Moisture, 11.09; volatile matter, 34.53; fixed carbon, 50.50; ash, 3.88; sulphur, 0.84.

The Rock Springs coal as a locomotive fuel or steam coal has few superiors in the West. It burns under a forced draft without heavy sparking and is a quick steamer, leaving only a small quantity of ash. Although the coals of the Almond, Black Buttes, and Black Rocks coal groups have been mined and prospected very little in the past, the future no doubt will see extensive mining on all these coal beds. During the summers of 1907 and 1908 two mines were opened on coal beds of the Almond and Black Buttes groups and coal is now being shipped from them. The coal from these beds is no doubt much like the "Upper Laramie" coals of the Hanna field, and there is no apparent reason why it should not serve as well as most of the Carbon County, Sheridan (Wyo.), and Montana coals, which are at present extensively and satisfactorily used for firing locomotives on the Union Pacific and Burlington railroads. Although the coal is very light for such work, it has proved very successful when used under natural draft for heating purposes and a large trade in it has been developed.

HISTORY OF DEVELOPMENT.

PROSPECTING AND MINING.

Coal was discovered in Wyoming prior to 1834 on Belle Fourche River, but the first coal mine was opened at Coal Bank Hollow, near Rock Creek crossing, in Carbon County, where the Denver and Salt Lake stage company utilized the coal for fuel and blacksmithing purposes. Mining on a commercial scale, however, did not begin until the construction of the Union Pacific Railroad across Wyoming in 1867, 1868, and 1869. Prospecting for coal along the route of this road commenced in 1867, and coal was opened at Carbon, Point of Rocks, and Rock Springs early in 1868. The Carbon mines in 1868 produced the first Wyoming coal used by the railroad company. During August of that year the production amounted to 650 tons. A few months later the Rock Springs and Point of Rocks mines were ready for operation. The total coal production of Wyoming in 1868 was 6,925 short tons. The output for 1869 was as follows:

Coal production in Wyoming, 1869.[a]

	Tons.
Carbon	30,428
Rock Springs	16,903
Point of Rocks	5,426
Evanston (Almy)	4,439
Other localities	990
	58,186

The above figures are slightly different from those generally reported and given in the "Mineral resources of the United States"—49,382

[a] Raymond, R. W., Mineral resources west of the Rocky Mountains, 1872, pp. 370–371.

tons. This discrepancy arises mainly from the fact that the product of the Point of Rocks mine and 2,473 tons mined by the Rocky Mountain Coal and Iron Company at Evanston are generally omitted from the reports. In forty-one years coal mining has developed into the leading industry in Wyoming, with an annual production of over 6,000,000 tons, valued at approximately $10,000,000, of which one-third comes from the Rock Springs field. The rapid construction of railways and the ever-increasing demand for fuel in this and adjoining States will make coal mining Wyoming's greatest enterprise for many years to come.

From the completion of the Union Pacific Railroad in 1869 to the construction of the Superior branch up Horsethief Canyon in 1906 all the mining camps in the Rock Springs field, except the Sweetwater camp south of Rock Springs, were opened along the railroad in Bitter Creek valley at distances of less than a mile from the main line. Although the entire Rock Springs field has been fairly well prospected, thus far only four districts—Rock Springs, Superior, Point of Rocks, and Black Buttes—are producing coal. All the mining camps within these four districts are less than 10 miles from the main line of the Union Pacific Railroad.

ROCK SPRINGS DISTRICT.

DESCRIPTION OF COAL BEDS AND OUTLINE OF DEVELOPMENT.

The Rock Springs district is by far the oldest, largest, and best developed in the field. It includes all the coal-bearing beds north and south of Bitter Creek valley on the west side of the dome in the vicinity of Rock Springs, or that part of Little Bitter Creek and Killpecker valleys whose source of supply and transportation centers about Rock Springs. Within this district have been opened seven mining camps—Rock Springs, Sweetwater, Blairtown, No. 6, Interstate, Van Dyke, and Gunn—most of which are still in active operation. In each of these camps, except the No. 6 and Interstate, there is one or more active operating mines at the present time. Of the four coal groups exposed in the Rock Springs dome, three (Rock Springs, Almond, and Black Rock) are exposed in the Rock Springs district. Mines have been opened on coal beds in each of these groups, but at present only the mines working on the coal beds in the Rock Springs coal group are in active operation. Several coal beds occur in the Black Rock and Almond coal groups in the Rock Springs district (see Pl. XIV), but thus far none of these beds have been profitably mined.

The total number of coal beds in the Rock Springs coal group has not been determined. Twenty beds that range in thickness from 2 to 12 feet are known; and it is certain that there are many beds less than 2 feet thick. One section taken across this group shows 37 distinct coal beds. That the number and thickness of the coal beds differ considerably at different points along the bed is equally certain. On being traced along the outcrop many of the larger beds are seen to become thinner and many of the thin beds to become thicker and workable. On the whole, the coal beds of this group are fairly persistent and regular. Of the large number of beds exposed in the hills on either side of Bitter Creek in the vicinity of Rock Springs, only five of the best have thus far been considered large enough to be worked.

Owing to the general practice of numbering mines according to the sequence in which they are opened by the company and later naming each coal bed after some prominent mine upon it, the designations of the Rock Springs coal beds, though in numerals, give no information regarding the stratigraphic order in which they occur.

All the mines in the Rock Springs district are located in Tps. 18 and 19 N., Rs. 104 and 105 W. The Sweetwater mine No. 1, in sec. 14, T. 18 N., R. 105 W., is the southernmost and the Gunn mine, in sec. 8, T. 19 N., R. 104 W., is the northernmost of the productive mines in this district. East-west lines drawn through the extreme north and south workings of these two mines would be only 7 miles apart. All the workings of the other mines in the district lie between these two, in a belt less than 5 miles wide. The five coal beds of the Rock Springs coal group on which mines have been opened in this district, together with their respective mines, are given in the following table in their proper stratigraphic sequence:

Stratigraphic position and thickness of five of the most important coal beds in the Rock Springs coal group and mines which have been opened on each bed.

Local name of coal bed.	Thickness. (feet).	Location of mouth of mine.				Name of mine.	Year opened.	Remarks.
		Quarter.	Sec.	T.	R.			
No. 5	6	SW. ¼ SW. ¼	26	19	105	Union Pacific Coal Co.'s old mine No. 5	1879	Abandoned 1885.
Interval	209							
No. 3	5–8	NW. ¼ SE. ¼	26	19	105	Union Pacific Coal Co.'s mine No. 3	1873	Worked out 1895.
		SW. ¼ SW. ¼	26	19	105	Union Pacific Coal Co.'s mine No. 5	1885	Abandoned 1890.
		NW. ¼ NW. ¼	8	18	105	Wyoming Coal and Coke Co.'s mine	1907	Operating.
Interval	224							
No. 1	7–12	NE. ¼ NE. ¼	35	19	105	Union Pacific Coal Co.'s mine No. 1	1868	Do.
		NW. ¼ SE. ¼	35	19	105	Union Pacific Coal Co.'s mine No. 2	1871	Abandoned 1883.
		NW. ¼ NW. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 4	1884	Worked out 1895.
		SW. ¼ NE. ¼	8	18	105	Rock Springs Coal Co.'s mine No. 1		Abandoned.
Interval	256							
No. 7	4–10	NE. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 7	1888	Operating.
		NW. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 8	1889	Do.
		NE. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 9	1890	Do.
		NW. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 10	1900	Do.
		SW. ¼ NE. ¼	14	18	105	Central Coal and Coke Co.'s mine No. 1	1887	Do.
		NE. ¼ SW. ¼	36	19	105	Central Coal and Coke Co.'s mine No. 2	1889	Do.
			12	18	105	Central Coal and Coke Co.'s mine No. 3		Worked out 1907.
			2	18	105	Central Coal and Coke Co.'s mine No. 4		Do.
			11	18	105	Central Coal and Coke Co.'s mine No. 5	1907	Operating as part Central Coal and Coke Co.'s mine No. 1.
		SW. ¼ NW. ¼	1	18	105	Ludvigson mine		Abandoned.
Interval	207							
H, or Upper Van Dyke	2–6	NW. ¼ SE. ¼	8	19	104	Gunn-Quealy Coal Co.'s mine A	1907	Operating.
Interval	40–100							
Van Dyke	3–5	NW. ¼ SE. ¼	30	19	104	Van Dyke Coal Co. (now part of Central Coal and Coke Co.).	1870	Reopened 1887; closed 1895; reopened 1909.
		NW. ¼ SE. ¼	8	19	104	Gunn-Quealy Coal Co.'s mine B	1907	Operating.

That the five coal beds mentioned above are by no means the only ones in the Rock Springs coal group is best brought out by the following section, furnished to the writer by the Union Pacific Coal Company:

Section of the Rock Springs coal group in the Rock Springs district, showing the stratigraphic succession of the various coal beds as determined by the Union Pacific Coal Company.

Order of coal beds.	Local name of coal bed.	Distance from top of group to base of coal bed.		Section of beds.			Thickness of coal.		Distance from base of coal bed to base of next underlying coal bed.	
		Ft.	*in.*		*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
1	....	7		Shale	1		2	6	7	
				Coal, shaly	1					
				Clay	2	6				
				Coal	1					
				Clay	1					
				Coal		6				
2	....	30	3	Clay	2	6	1	9	23	3
				Shale	11	6				
				Sandstone	6					
				Coal, bony	1					
				Shale	1	6				
				Coal		9				
3	No. 5	67		Shale	3	9	7		36	9
				Sandstone	20					
				Coal	1					
				Clay	3					
				Coal	1					
				Shale	3					
				Clay and coal	5					
4	....	178	6	Sandstone	18		8	6	111	6
				Shale	2					
				Sandstone	69					
				Shale	5					
				Sandstone	9					
				Clay and coal	7					
				Coal, shaly	1	6				
5	....	217		Clay	7	6	13		38	6
				Sandstone	18					
				Clay and coal	13					
6	....	227		Sandstone	8		2		10	
				Clay and coal	2					
7	No. 3	248		Sandstone	6		13		21	
				Shale	2					
				Coal	7	6				
				Coal and clay	5	6				
8	....	265		Sandstone	6		2		17	
				Clay	4					
				Sandstone	5					
				Coal		10				
				Clay and coal	1	2				
9	....	278	6	Sandstone	4		1	6	13	6
				Shale	2					
				Sandstone	6					
				Clay and coal	1	6				
10	....	414		Sandstone	7	6	1		135	6
				Shale	7					
				Sandstone	12					
				Clay	11					
				Sandstone	97					
				Coal and clay	1					

Section of the Rock Springs coal group in the Rock Springs district, showing the stratigraphic succession of the various coal beds as determined by the Union Pacific Coal Company—Continued.

Order of coal beds.	Local name of coal bed.	Distance from top of group to base of coal bed.		Section of beds.			Thickness of coal.		Distance from base of coal bed to base of next underlying coal bed.	
		Ft.	*in.*		*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
11	No. 1	481	6	Shale Sandstone Shale Sandstone Shale (fossils) Coal	6 12 18 17 5 9	 6	9	6	67	6
12	....	577		Clay Sandstone Shale Coal	1 88 4 2	6 	2		95	6
13	....	605		Clay Sandstone Shale Coal	 9 17 1	6 6 	1		28	
14	....	650		Clay Shale Sandstone Shale (fossils) Coal Clay and coal	 14 6 22 1 1	6 6 	2		45	
15	....	689		Sandstone Shale Sandstone Shale Sandstone Shale Clay and coal	6 7 3 4 6 12 1		1		39	
16	....	713		Sandstone Coal	22 1	6 6	1	6	24	
17	No. 7	743		Clay Sandstone Shale Sandstone Shale Coal Shale Coal	3 6 4 5 3 1 2 5	 6 6	7		30	
18	A	805	9	Clay Sandstone, white Coal	3 58 1	 6 3	1	3	62	9
19	{ B { C	} 825	9	Sandstone and shale Coal Shale Coal	15 2 1	11 4 3 6	1	10	20	
20	D	855	10	Sandstone Coal	27 2	2½ 10½	2	10½	30	1
21	E	899	10½	Sandstone, white, and shale Coal Shale Coal Shale Coal	38 1 1 2 	9 5 10½	3	10½	44	½
22	F	915	6½	Sandstone, red, hard Coal	12 2	9 11	2	11	15	8
23	G	932	½	Sandstone Coal	16 	 6		6	16	6

Section of the Rock Springs coal group in the Rock Springs district, showing the stratigraphic succession of the various coal beds as determined by the Union Pacific Coal Company—Continued.

Order of coal beds.	Local name of coal bed.	Distance from top of group to base of coal bed.	Section of beds.		Thickness of coal.	Distance from base of coal bed to base of next underlying coal bed.
		Ft. in.		*Ft. in.*	*Ft. in.*	*Ft. in.*
24	H or Upper Van Dyke	951 8½	Sandstone Coal	17 4 2 4	2 4	19 8
25	I	963 11	Shale Coal	10 7½ 1 7	1 7	12 2½
26	J	993 2	Sandstone, yellow Coal	28 7 8	8	29 3
27	K	1,007 8	Sandstone, yellow Coal	12 2 6	2 6	14 6
28	L	1,030 5	Sandstone, white Coal	20 9 2	2	22 9
29	Van Dyke	1,055 9	Not recorded Coal Clay Coal	20 6 7 5 3 10	4 5	25 4
30	M	1,124 9	Not recorded Coal Shale Coal	66 7 1 2 11 4	1 6	69
31	N	1,133 9	Not recorded Coal	8 8 4	4	9
32	O	1,146 11	Not recorded Coal	12 8 6	6	13 2
33	P	1,156 1	Not recorded Coal	9 1 1	1	9 2
34	Q	1,180	Not recorded Coal Shale Coal Shale Coal	22 6 2 3 2 5 5	9	23 11
35	R	1,211 4	Sandstone, yellow, and shale Coal	30 1 1 3	1 3	31 4
36	S	1,259 2	Sandstone, white Coal	47 10	10	47 10
37	T	1,275 8	Not recorded Coal	14 3 2 3	2 3	16 6
			Shale. Sandstone, massive, white; base of Rock Springs coal group.			
			Total coal		110 6	

Of the five coal beds thus far opened, Nos. 1 and 7 have produced by far the largest amount of coal, and nearly as many mines have been opened on No. 7 as on all the other beds together. On the Van Dyke bed two mines have been opened, one at Van Dyke and the other at Gunn. This bed as opened at the old Van Dyke workings averaged about 4 feet in thickness, and as a rule it is not less than 3 feet 8 inches nor more than 4 feet 2 inches thick. Overlying the Van Dyke bed is a group of beds which increase in size toward the north. About a mile north of the Van Dyke main entry there are openings upon three of these beds, two of them showing but 2 or 3 feet of coal, the third 4 feet 2 inches of very clean and bright coal. Still farther north, in sec. 8, T. 19 N., R. 104 W., on the western slope of Baxter Basin, two of the beds are at least 6 feet thick, a third about 4 feet, and several others smaller. In this section the Gunn-Quealy Coal Company opened its A and B mines, presumably on the lower and upper Van Dyke coal beds, respectively. Two of the larger coal beds have been opened about three-fourths of a mile farther north, where they are nearly 7 feet thick. These two beds are 40 feet apart and at least 200 feet lower than bed No. 7, which outcrops at the upper edge of the bluff forming the side of the basin.

Bed No. 7 has produced more coal than any other bed in the Rock Springs district, and, as shown by the description of the various camps, most of the producing mines are located on it. The coal bed shows considerable variation in thickness, but it is not over 10 feet thick in that part of the district opened by mine workings. It is, however, remarkable in maintaining a workable thickness of clean coal, and this more than counterbalances its small size.

The Central Coal and Coke Company's No. 1 mine is the most southerly large opening on this bed. It is situated in Sweetwater Valley and the main entry begins near the center of sec. 14, T. 18 N., R. 105 W. The bed here is from 7 feet to 7 feet 6 inches thick, is without partings, and has an average dip of 7° to 8° N. 85° W. A stratum of impure clay only a few inches thick lies immediately below the coal, and below that is a firm, massive gray sandstone. Above the coal there is 10 feet of clay shale, and above that a reddish sandstone that is also very persistent.

A mile northeast of the Central Coal and Coke Company's No. 1 mine there are a series of shallow cuts on bed No. 7 that show 7 feet or so of clear coal. About 2 feet from the roof there are two thin seams of clay, 2½ inches apart, each of which is from a quarter to half an inch thick. This double clay parting is uncommon, but a single parting of this character is generally present, the Central Coal and Coke Company's No. 1 mine being the only one that does not show it. The distance of this parting from the roof is about 2 feet, no matter what the thickness of the bed. Another peculiarity is the presence above the coal of a thin band consisting of alternate streaks of clayey matter and coal. This layer is from 2 to 5 inches thick, and when exposed to the air it soon scales down. Displacement along slips is well shown in one of the cuts referred to above. The two clay streaks show four small faults in a space of 20 inches.

The downthrow of these faults is (1) to south, 2 inches; (2) to south, 4 inches; (3) to north, 1 inch; (4) to south, 3½ inches. The inclination of the fault planes varies from 40° to 65° from the horizontal.

Along the outcrop of bed No. 7 toward Rock Springs the gray sandstone floor is in places very prominent and outcrops beyond the coal as a bare platform. Near the center of sec. 12, T. 18 N., R. 105 W. there are two faults approximately 700 feet apart. The movement of the block between these two faults was downward; the amount of displacement was not ascertained. Another displacement in bed No. 7 appears farther north, about 800 feet south of the west quarter corner of sec. 1, T. 18 N., R. 105 W. Here the bed is cut by a fault with a downthrow to the north of about 100 feet. This fault appears to have a general course of S. 60° W. and passes in this direction across the SE. ¼ sec. 2, T. 18 N., R. 105 W. Along the line of outcrop, not more than 1,400 feet north of the abovementioned corner, there is another fault with a displacement in the same direction probably amounting to 150 feet. This fault has a direction of about S. 75° W., and consequently diverges toward the west from the fault just described. It also passes into sec. 2. A peculiar feature of this fault is that it is lost to sight in the flat not far to the west, but along its general course, near the center of sec. 2, a fault is observed just north of the Klegg opening on bed No. 1, with an upthrow to the north of no great amount. Continuing on the same course, the fault is found to have a displacement of nearly 100 feet, with an upthrow to the north, as plainly shown on the outcrop of bed No. 3. The Wyoming Coal and Coke Company's mine, lying immediately north of this fault, shows no other serious displacement in that direction, and the continuous outcrop of the sandstone floor of bed No. 3 for some distance to the south indicates no disturbance in that direction. Consequently it appears either that the displacement shown on the outcrop of bed No. 7 makes a great change in its general course or that it rapidly decreases toward the west to a point where there is no displacement and then shows an increasing throw in the opposite direction. An apparent greater dip of the strata on the south side of this fault might perhaps help to explain the phenomenon. The same results might be obtained by a slight distortion of the block between the two faults.

In an opening on bed No. 7, known as the Ludvigson mine or prospect, between the two faults just described, the bed contains 6 feet of coal of excellent quality. The clay parting, 2 feet from the roof, is about a quarter of an inch thick.

The next opening toward the north on bed No. 7 is in sec. 36, T. 19 N., R. 105 W., where the Central Coal and Coke Company has opened its No. 2 mine. The bed, as exposed in the two strike entries, shows

5 feet of clear coal, broken only by the usual parting above mentioned. The dip is from 7° to 9°, but the strike has swung a little to the west (N. 10° to 20° E.). The roof and floor are of the usual character. The bed appears to have reached its minimum thickness of 4 feet 6 inches in this mine. The coal as a rule is very clean and pure. The normal clay parting is present. Near the eastern limit of the mine the streak of dirty coal and clay already referred to thickens and encroaches upon the upper bench of the coal. Other bands of carbonaceous clay appear lower down, but above the parting, and the entire upper 20 inches is worthless, in places leaving less than 3 feet of coal for mining. The poor coal is apparently confined to a narrow belt running in a northerly direction. Owing to the deep gulches in this section the outcrop is irregular and has never been accurately located. After crossing the main gulch near the center of the section it passes up a lateral ravine and, returning, swings in a bold curve across a high hill into the valley of Bitter Creek, on the north side of which the Union Pacific Coal Company's mines Nos. 7, 8, 9, and 10 are located.

North of Bitter Creek the Union Pacific Coal Company's mine No. 8 is a shaft about west of the No. 7 main entry. The coal appears to be of excellent quality in the workings and the bed is about 4 feet 8 inches thick.

North of mine No. 7, which extends nearly to the north end of T. 19 N., R. 105 W., several prospect entries have been excavated on the bed. Thus in the NW. ¼ sec. 20, T. 19 N., R. 104 W., an entry 175 feet in length shows the bed to contain about 8 feet of coal, as shown in the following section:

Section in entry in NW. ¼ sec. 20, T. 19 N., R. 104 W.

	Ft.	in.
Sandstone, hard, rusty.		
Shale, light, with siliceous band	9±	
Shale, dark	2	
Coal	2	4
Clay		⅓
Coal	3	1½
Shale, carbonaceous		5
Coal	2	
Clay, carbonaceous		6
Sandstone, massive, gray.		
Coal bed	7	10⅚

The coal is clear and bright and appears equal in every respect to that mined farther south. Another entry on the same bed starts near the top of the hills facing Baxter Basin in the SE. ¼ sec. 8 of the same township. Though the entry is over 200 feet in length it attains no great depth beneath the surface, and the coal shows the softening due to surface action in some of the streaks between the slips. The bed contains 7 feet 6 inches of coal. The clay parting is about 2 feet from the top. There is no carbonaceous shale near the bottom, as noted in sec. 20. The dip is about 10° and the strike has swung back to almost due north.

Bed No. 7, as well as many of the others, has been traced for several miles north, and prospects have been opened on it and other beds. (For locations see Pls. XIV and XV.) It can not be stated with certainty that the bed No. 7 at Rock Springs is the same as bed No. 7 at Superior, although the Superior beds were correlated and named from the Rock Springs coal beds. A comparison of the two sections of the Rock Springs coal group will show the relation between them.

Although the first coal mined at Rock Springs was taken from bed No. 1, the mines on it are closer together and less prospecting has been done along its outcrop than on bed No. 7, so that at present it is not so well understood. It is apparent, however, that although the coal in bed No. 1 attains a maximum thickness greater than that of bed No. 7 the former bed is by no means so regular as the latter and apparently contains neither the area nor the quantity of coal that bed No. 7 contains. The most southerly mine opened on bed No. 1 is the old Blair mine, sometimes known as the Rock Springs Coal Company's mine No. 1, at present owned in part by the Wyoming Coal and Coke Company. Next north is the now abandoned Union Pacific Coal Company's mine No. 2, then the Union Pacific Coal Company's Nos. 1 and 4, the latter being the most northerly on this bed. At present all these mines except the Wyoming Coal and Coke Company's mine and the Union Pacific Coal Company's mine No. 1 are abandoned.

South of the old Blair mine there are several openings. The Klegg entry to the southeast, directly south of the fault from Rock Springs Coal Company's mine No. 1, shows 10 feet of coal. Another opening on the east side of Sweetwater Valley shows 9 feet of coal and one to the west about 4 feet 6 inches. Bed No. 1 has been traced for miles northward from Rock Springs, but no extensive workings have been opened on it north of that city.

Bed No. 3 has been only a little developed. Three mines are located on it and show coal of good grade of from 6 feet to 7 feet 6 inches in thickness. Two of these mines have been abandoned and the third is just being opened.

Very little prospecting has been done, and only one mine has been opened on bed No. 5, consequently little can be said regarding it. At the place the mine was opened the coal was found to be slaty and the mine was therefore soon abandoned, but the indications along the outcrop suggest that this bed ought to furnish good coal in parts of the district.

ROCK SPRINGS CAMP.

The Rock Springs mining camp was the first one opened in the Rock Springs district. Several companies have operated here, and two are still active. Some of the mines, as the Blair mine and those of the Rock Springs, Excelsior, and Peacock coal companies, have shut down; others, as those of the Sweetwater Coal Mining Company, the Youngs mine, and the Klegg mine, have been consolidated with those of larger companies and are still producing. Mines in this camp have been opened on four beds of the Rock Springs coal group, Nos. 7, 1, 3, and 5. At present the only companies operating in the camp are the Union Pacific Coal Company and the Central Coal and Coke Company.

The Union Pacific Coal Company has opened mines Nos. 1, 2, 3, 4, old No. 5, 5, 7, 8, 9, and 10. Of these mines Nos. 7, 8, 9, and 10 were opened on bed No. 7; Nos. 1, 2, and 4 on bed No. 1; Nos. 3 and 5 on bed No. 3, and old No. 5 on bed No. 5. At present this company is working only beds Nos. 1 and 7. Mine No. 1 is working bed No. 1, and mines Nos. 7, 8, 9, and 10 are working bed No. 7. The Central Coal and Coke Company is working at present in this camp only bed No. 7, on which is located its No. 2 mine.

Union Pacific Coal Company's mine No. 1.—The Union Pacific Coal Company's mine No. 1 was opened in 1868 and is still producing. It is operated by a 7,500-foot double-track slope on the dip of the coal, which is about 5° at the outcrop, but steepens to 23° near the bottom of the slope. The direction of the dip and slope is a little north of west. Entries extend along the strike on either side, with rooms driven to the rise, parallel to the slope.

A peculiarity developed at many places in the workings of mine No. 1, but also common to the other mines on the same bed, consists of the so-called rock slips or horsebacks. These are long, slim wedges of white sandstone which protrude into the coal, usually from the floor. They have commonly a polished surface on one side and a rough surface to which the coal adheres on the other. Some of them extend only a few inches from the floor; others almost or quite to the roof of the bed. They are very narrow, being at most only a few feet wide at the base, and gradually wedge out. Longitudinally many of them extend for many yards. There appears to be no regularity in the direction in which they run or the frequency of their occurrence. The coal is of the normal quality, even where it is in direct contact with the pure sandstone.

The roof of this mine is usually shale and the floor brown or white sandstone. In all the lower entries 20 inches or 2 feet of coal is left for a roof. The section in this part of the mine is as follows:

Section of coal bed in mine No. 1 of the Union Pacific Coal Company at Rock Springs.

	Ft.	in.
Shale (roof).		
Coal (not mined in lower entries)	1	10
Coal, bony		9
Coal, good (mined and sampled)	7–8	
Sandstone (floor).		

A number of faults are present in this mine, which is in part bounded on the east and southeast by two faults, each with a maximum displacement between 65 and 70 feet and a downthrow toward the mine. These two faults probably intersect a short distance southeast of the mouth of the main slope. The one to the southeast separates the mine from the old Union Pacific mine No. 2, the other separates it from Union Pacific mine No. 4. The latter fault has been struck at several points, but the displacement has been determined at only one place, where it is 65 feet. Several other small faults and many slickensides are encountered in the eastern part of Union Pacific mine No. 1.

At a point nearly 3,500 feet from the mouth of the main slope a fault was encountered having an upthrow to the west of about 70 feet. Its general direction is northeast by north. The same fault in the main slope of mine No. 5 has a displacement of only 17 feet, and it seems to have died out farther to the northeast. In other words, the displacement of this fault decreases more than 50 feet in a horizontal distance of less than 1,000 feet. The coal bed contains 10 feet of clean coal west of this fault. The slope, which has an average inclination of 10° to 12°, was gradually flattened to half pitch and was so continued until the coal was again entered beyond the fault. There are a few minor faults and a considerable number of slickensides throughout the mine.

Union Pacific Coal Company's mine No. 2.—The Union Pacific Coal Company's mine No. 2, approximately half a mile south of the mouth of No. 1, was opened in 1871 on the same bed as No. 1, and operated until 1883, when it was abandoned because it contained too much water and on account of the numerous faults in this region. Faults of considerable magnitude bound this mine on the north and south. The fault between mines Nos. 1 and 2 has a general southwesterly direction and a maximum downthrow of about 70 feet toward the northeast. Approximately 30 acres of coal was mined. The bed contains some bone and dirty coal in the western and southwestern portions of the workings; however, as the lower entries in mine No. 1, less than a mile to the west, are driven more than half a mile farther south than the south end of mine No. 2, the bands of shale do not appear to interfere with mining and are not persistent.

Union Pacific Coal Company's mine No. 4.—Mine No. 4 lies to the northeast of No. 1. The slopes of the two mines are nearly a mile apart and opened on the same bed. The slope of No. 4, approximately half a mile northeast of mine No. 3, was driven parallel to the slope of No. 3 for a distance of 3,500 feet. Nine entries were turned off the slope on the south side and seven on the north. This mine was opened in 1884 and worked until 1895, when it was abandoned, as it ran into dirty coal on the north and all the good coal appeared to be worked out. The slope of No. 4 passes a little to the northeast of the true dip, which is locally about N. 65° W. Consequently the slopes of mines Nos. 1 and 4 diverge at a wide angle.

The coal bed in this mine contains two partings. The upper one is very persistent, though only 1 or 2 inches thick. It is a yellowish-white fine-grained argillaceous sandstone. The lower parting is the ordinary highly carbonaceous shale or so-called slate. It is not so persistent as the upper one, although present at many places. It disappears in the southwesterly workings and thickens toward the northeast. These partings are peculiar and well worthy of description. Below the burned zone which marks the outcrop, good coal is mined from both sides of the slope and shows only the yellow band about 2½ feet from the top. The lower levels ultimately strike bands of shale, at first a great distance from the slope, then nearer to it, until finally the shale shows in the face of the slope itself. The most prominent band is developed about 3 feet from the floor of the bed. Then other bands appear higher up and the yellow band changes to carbonaceous shale and thickens. Finally the lower band changes into sandstone and abruptly thickens by the raising of its upper surface until it replaces the entire upper portion of the bed. So rapidly is the change accomplished that the upper bench disappears within a distance of only a few yards beyond the point where the sandstone first begins. One entry that has been driven for 80 yards beyond this point shows 3 feet of coal on the bottom, continuing with great regularity, but with no sign of the upper portion of the bed; nor does a drill hole 8 feet deep show other than pure sandstone. At the face of the slope there is 2 feet of bony coal which has to be thrown out in mining, but the sandstone is not present. The entries to the south near the face of the slope pass out of this bony area within a short distance and the bed assumes its normal condition. In this direction all the development, both in this mine and in No. 1, tends to show that there is a very large area of excellent coal. Although the mine had a large supply of coal it was a one-sided mine below 2,500 feet from the surface—that is to say, all of the coal had to come from the southwest side of the mine below that depth on the slope. As soon as the southwesterly workings of the mine struck the fault that divides it from No. 1 and all the good coal was taken out the mine was abandoned.

Union Pacific Coal Company's mine No. 3.—The Union Pacific mine No. 3 was opened in 1873 and continued in operation until 1895, when it was abandoned because of a fire in the mine, which lasted for several years. It is reported that the mine was nearly worked out and for that reason was not reopened. The mine was opened on bed No. 3 and the slope was driven for a distance of about 4,000 feet N. 20° W., or a little northeast of the true dip. Twenty-four entries, twelve on each side, were turned off from the main slope and driven north and south for a distance of more than a mile. The face or breast of the mine extends for a distance of 2¼ miles, or from mine No. 5, with which it was connected, to the north end of sec. 23, T. 19 N., R. 105 W. Mine No. 3 exposes from 6 feet 6 inches to 7 feet 6 inches of clean homogeneous coal, and in the block of ground between slopes No. 3 and No. 5 the coal preserves the same character. The coal rests upon a bed of fire clay more than 1 foot thick, under which there is a bed of coal about 14 inches thick. Over the large bed there is first a clay shale, then sandstone. On the north side of the slope a band of shale appears about 2 feet from the floor of the coal. It changes to sandstone farther northeast and there only the bench above it is mined. In some places where the sandstone first appears the upper bench narrows to such an extent that rooms are not turned off, but 200 feet beyond this bench widens and affords from 4 feet 6 inches to 5 feet 6 inches of good coal. As in mine No. 4, this shale zone is far from the slope at the surface and rapidly approaches it with depth, so that it soon reaches the face. In other words, the edge of the bony area runs about halfway between the dip and the strike of the bed. The levels from a point near the face of the slope southwestward show 7 feet 6 inches of clean coal. The north entries strike a fault that seems to correspond to the one between mines Nos. 1 and 4. It has a displacement of 8 to 12 feet. Although its course is approximately north and south, it is very irregular. This indicates a dying out of the fault toward the north.

Union Pacific Coal Company's old mine No. 5.—Old mine No. 5 of the Union Pacific Coal Company was opened on bed No. 5 in 1879 and was abandoned in 1885, after approximately 20 acres of coal had been mined. The coal was mined through a slope from the surface. As soon as the mine was well opened it was learned that bed No. 5 contained too much shale to be of value and the mine was therefore abandoned. It is the only attempt made to open this bed in the Rock Springs field. A fault was encountered on the north side of this mine that is presumably the same as the one mentioned in the description of mine No. 5 below. The same fault is present in mine No. 1, which is on a bed 414 feet stratigraphically lower than bed No. 5.

Union Pacific Coal Company's mine No. 5.—The mouth of Union Pacific mine No. 5 is less than half a mile southwest of No. 3, with which it is connected, and is just east of the mouth of old mine No. 5. The mine was opened in 1885, operated until all the good coal was worked out, and then used as a part of No. 3 mine until 1890, when it was abandoned. There is but little to say regarding mine No. 5 that has not been covered in the description of mine No. 3. Both of these mines were opened on bed No. 3. Mine No. 5 was worked through a shaft, with a slope from the point where it struck coal bed No. 3. The slope was driven down the dip, approximately parallel to the slope of Union Pacific mine No. 1. The shaft of mine No. 5 is approximately 600 feet north and the face of the slope 900 feet north of the No. 1 slope. Twelve entries were turned off from the main slope, six toward the south and six toward the north. The north entries were driven only a short distance, as there is another area to the southwest of the mine in which a heavy band of shale appears near the center of the bed. This belt runs nearly at right angles to the stratum of sandstone near the bottom of the bed, as shown in the northerly workings of mine No. 3. A small fault cuts across the slope at the mouth of No. 5 entry. The strike is N. 80° E. and the block on the north side of the fault was moved upward about 6 feet.

Union Pacific Coal Company's mine No. 7.—Union Pacific mine No. 7 was opened in 1888 on coal bed No. 7 and was the first mine operated by this company on this bed. The mine was opened by means of a 1,300-foot entry driven on the strike. From this entry diagonal slopes run to the rise and entries are driven to each side. The entries have been pushed northward and northeastward for a distance of 4 to 5 miles, or nearly to the north township line. One entry extends into sec. 6, T. 19 N., R. 104 W. The entire underground workings of this mine are connected with mines Nos. 8, 9, and 10 in such a way that they are practically all part of one big mine, although they have separate slopes and entries. They are ventilated as if they were one mine and they are all made to drain to the pump of No. 10, which is the lowest on the dip. A fault was encountered near the north quarter corner of sec. 7, T. 19 N., R. 104 W. The bed south of the fault has moved up 12 feet. Several smaller faults and many slickensides were observed in the mine, but these do not interfere with mining.

Union Pacific Coal Company's mine No. 8.—Mine No. 8, which is connected with Nos. 7, 9, and 10, was opened in 1889 and is still in active operation. It is worked through a triple-compartment vertical shaft 180 feet deep. The coal is not screened or assorted. A single-track entry 14,000 feet long connects the lower ends of four single-track slopes with the shaft. Entries are driven on each side of the slopes and rooms are turned off parallel to the slopes.

The greatest pitch in the mine is about 7°, but varies from 5° to 7°. The coal near the shaft is 4 feet 6 inches thick, but farther down in the mine it is 7 or 8 feet thick and it averages from 7 feet 4 inches to 7 feet 7 inches. A layer of soft black shale 2 feet thick occurs just above the coal all through the mine. About 2 feet below the top of the coal bed, or approximately 5 feet 5 inches above the bottom, there is a thin shale parting which persists throughout the mine. It is in few places more than an inch thick. It keeps a uniform distance from the top of the coal bed, any increase in the thickness of the bed being added to the lower bench. The coal is very clean and needs no assorting after leaving the mine. Considerable pyrite was observed near the shale and the pyrite near the base of the coal occurs in little, thin plates. Below the coal bed there is 6 feet or more of brown shale containing in places a little coal. Below this is a sandstone layer. The roof of the mine is a bluish to chocolate-colored shale locally carrying fossils. Where fossils are present the roof is not so good as elsewhere. In mining, a thin layer of coal is left to form the roof, as it is better than the shale, which is liable to flake off.

The dip (5° to 7°) remains nearly constant throughout the mine. The strike, which is a little east of north at the shaft, gradually swings toward the west, till at the end of the mine it is a little west of north.

Union Pacific Coal Company's mine No. 9.—Union Pacific mine No. 9 was opened in 1890. The mouth of this mine lies 200 feet southeast of No. 7. It is the eastern part of the big mine formed by the connection of Nos. 9, 7, 8, and 10, which lie in the order named from east to west along the north side of Bitter Creek valley. This mine is worked very much like No. 8, except that the main entry is reached by an 800-foot slope instead of a vertical shaft. The main entry is 12,700 feet long, and the coal is brought to it through three slopes driven to the rise. The entries of No. 9 are not driven so far north as those of No. 7, which they parallel, but they have entered the S. ½ sec. 7, T. 19 N., R. 104 W. The method of work and operation is the same as in mines Nos. 7 and 8.

Union Pacific Coal Company's mine No. 10.—Mine No. 10 was opened by the Union Pacific Coal Company in 1900 and is still in active operation. It is the westernmost member of the big mine represented by Nos. 10, 9, 8, and 7, which produces nearly 1,500,000 tons of coal annually. The mouth of No. 10 mine lies approximately 600 feet west of No. 8 shaft. A rock slope with a grade of 15° reaches the coal at 1,200 feet and extends 1,500 feet in the coal at a 5° dip.

A fault was encountered in this mine near the mouth of the second entry. Its strike is a little east of north, but in going northward it swings toward the west, and where it cuts No. 3 and No. 4 entries the strike is nearly due north. Where the fault cuts No. 5 entry, 900 feet from the slope, it has a displacement of only 7 feet. An area of poor coal was encountered in the NW. ¼ sec. 24, T. 19 N., R. 105 W., as shown by openings in entries Nos. 4, 5, 6, and 7. The main slope ran into dirty coal and was abandoned. Entry No. 7 encountered this zone at 900 feet; entry No. 6 entered it 1,500 feet from the slope and was abandoned; entry No. 5 encountered the poor coal at several places 1,600 to 8,000 feet from the slope and is not worked at the present time.

Central Coal and Coke Company's mine No. 2.—The Central Coal and Coke Company's mine No. 2 was opened in 1888, on bed No. 7. The mouth of the mine lies about 1¼ miles south of the shaft of the Union Pacific Coal Company's mine No. 8. A slope is driven down the dip approximately 2,700 feet and entries are turned off toward the north and south. Most of the mine workings lie in the north and west halves of sec. 36, T. 19 N., R. 105 W.

In the southern part of the mine the coal is 6 feet 6 inches thick, in the northern part 4 feet 8 inches. On the north side a layer of bone from 4 to 8 inches thick is associated with the coal, but it pinches out before reaching the south side. Overlying the coal bed is 3 feet of shale, and on top of this is a 20-foot bed of gray sandstone. Twenty inches below the top of the coal bed is a shale parting three-eighths of an inch thick. A considerable number of slickensides and a few faults were observed in this mine. The largest fault lies in the SW. ¼ sec. 36, and cuts the entries approximately at right angles. Farther west the strike changes and the fault passes into sec. 35 with a trend a little south of west.

SWEETWATER CAMP.

The Sweetwater camp is the southernmost camp in the Rock Springs district. At present only the Central Coal and Coke Company is operating in this camp. This company is working bed No. 7, and has thus far worked four mines—Nos. 1, 3, 4, and 5. Mines Nos. 1, 3, and 4 were practically worked out in 1907. What little coal remains will be taken out through No. 5 slope. All these mines were combined in the fall of 1907 and are considered as part of the Central Coal and Coke Company's mine No. 1. The camp is reached by a spur built up Sweetwater Valley from Blairtown, on the Union Pacific main line.

Central Coal and Coke Company's No. 1 mine.—Mine No. 1 of this company was opened by Mark Hopkins in 1888 at Hopkinsville. Its mouth is a little northeast of the center of sec. 14, T. 18 N., R. 105 W.

Shortly after the mine was opened it was sold to the Sweetwater Coal Mining Company and the name of the village was changed from Hopkinsville to Sweetwater.

The coal in this mine is from 7 feet to 7 feet 6 inches thick, with neither bone nor parting. A stratum of impure clay only a few inches thick immediately underlies the coal and below this there is a firm, massive gray sandstone. Above the coal there is 10 feet of clay shale overlain by a reddish sandstone that is very persistent. The dip in the mine averages from 7° to 8° N. 85° W. A system of joints or slips commonly present in the Rock Springs coal is very prominent in this mine. In many places they part the coal from roof to floor every few feet. They are without doubt closely related genetically with the movements that produced the faults in the coal-bearing rocks. These slips run 5° to 20° south of the dip and are generally inclined toward the south. The faces present every peculiarity of faults, and along many of them there is an actual displacement of 1 to 4 inches. The fissures showing such a displacement usually pass into the roof of the bed, but where no displacement is observed this is not the case.

Central Coal and Coke Company's mine No. 3.—Mine No. 3 of the Central Coal and Coke Company lies in the NW. ¼ sec. 12, T. 18 N., R. 105 W. It is opened by a slope to the main entry, with slopes to the rise. This mine was nearly worked out in 1907 and has since been worked only in order to open mine No. 5, in sec. 11, north of the fault. The coal bed (No. 7) in mine No. 3 is about 5 feet 2½ inches thick[a] where it was sampled in slope entry No. 5, but runs from 4 to 8 feet in the mine. The clay parting is one-fourth inch thick and 7¼ inches below the top of the coal. The coal is very similar to that mined by the same company in mine No. 4. Twenty feet above bed No. 7 lies another bed from 4 to 12 inches thick, but thus far no attention has been given to this upper bed.

At the back air course of entry No. 5 is a fault with a downthrow of 20 feet on the north side. South of the fault the coal is from 7 to 8 feet thick and north of the fault it is from 4 to 6 feet thick. Many slickensides and minor faults similar to those in mine No. 1 were noticed throughout the mine.

Central Coal and Coke Company's mine No. 4.—The Central Coal and Coke Company's mine No. 4 was nearly worked out in the fall of 1907. It lies north of No. 1 and west of No. 3, in the SE. ¼ SE. ¼ sec. 2, T. 18 N., R. 105 W. It was opened on bed No. 7 by a slope of 6½° about 1,700 feet long. A fault is present 1,300 feet below the mouth of the slope. The coal in this mine is 6 feet 3 inches to 7 feet thick, with a ½-inch shale parting 2 feet 3 inches below the top of the

[a] In Bulletin 341, p. 270, the coal bed was erroneously reported to be 12 feet thick in this mine

coal bed. The dip of the bed is about 5½° SW. and the strike about N. 5° W. On top of the coal bed lies an 8-foot layer of shale. This is hard, dark, and very fossiliferous. Above the shale is a gray sandstone; in places the dark shale is missing and this sandstone forms the roof of the coal. Below the coal is a massive bed of gray sandstone approximately 20 feet thick. No attempt is made to separate the shale parting from the coal. The mine is dry and only along the fault above mentioned was water observed. In the lower workings in the northwestern part of the mine a small spring was encountered near the fault. Many slickensides and minor faults occur in the mine, the conditions in this respect being very similar to those in mines Nos. 1 and 3. As measured on the parting the displacement ranges from a few tenths of an inch to several feet. The coal usually breaks along these walls or slips, and this breaking facilitates mining. The slickenside planes can be traced readily into the roof, but do not show displacement. Some sulphur balls are present in the coal, but most of the sulphur occurs near the base of the coal bed in the form of lenses. In addition some sulphur is disseminated through the coal.

Central Coal and Coke Company's mine No. 5.—The Central Coal and Coke Company's mine No. 5 was opened in 1907. It lies north and east of mine No. 1. A new slope was being driven in the fall of 1907. It was the intention of the manager, in order to shorten the haul, to combine all that was left of Nos. 1, 3, and 4 as soon as new entries were connected, about December 1, 1907. The coal in mine No. 5 in dip room No. 2 off back entry No. 5 is 7 feet 9⅝ inches thick. No shale parting occurs in this bed northeast of the workings in mine No. 1. The roof is shale and the floor is gray sandstone, as in mines Nos. 3 and 4. At the fault along the north side of mine No. 1 and south of No. 5 the coal on the north side is 3 feet 3 inches thinner than on the south side of the fault, where it is nearly 8 feet thick. The downthrow amounts to about 20 feet on the north side.

The Central Coal and Coke Company's mines Nos. 1, 3, 4, and 5, although opened separately and spoken of as separate mines, constitute in fact one large mine, resembling in this regard the Union Pacific Coal Company's mines Nos. 7, 8, 9, and 10. All the mines are on bed No. 7, and the necessity of opening separate mines or changing the method of mining is due to the displacements caused by the numerous faults in this locality. As soon as mine No. 1 encountered the big fault on the north the entire workings had to be readjusted. Nearly all of the available coal in Nos. 1, 3, and 4 has been taken out. What remains of these mines and the new workings called "No. 5" are at present known as parts of Central Coal and Coke Company's No. 1 mine.

BLAIRTOWN CAMP.

The Blairtown camp lies about a mile south of Rock Springs, and has been the scene of coal mining for many years. The date of opening of this camp is usually given as 1869, although a few prospects were opened before that year. The Rock Springs Coal Company's mine No. 1, or the old Blair mine, was the first to begin operation and started in 1869. P. J. Quealy reopened this mine on bed No. 1 just north of the fault passing through the northern part of secs. 1 and 2. He also opened a small mine on the same bed south of the fault. These two mines lie south of the Union Pacific Coal Company's mines Nos. 1, 2, and 4 on the same bed, described under "Rock Springs camp." In May, 1907, another mine was opened on bed No. 3, a short distance west of the Rock Springs Coal Company's mine No. 1. Beds Nos. 1 and 3 are the only ones on which mines are operating in the Blairtown camp.

Rock Springs Coal Company's mine No. 1.—The Rock Springs Coal Company's mine No. 1 is situated in the NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 2, T. 18 N., R. 105 W. It is said to have been first opened in 1869. Archibald Blair owned the property and opened the prospect as well as the mine. Work continued for a time and then the mine was shut down. Later the old Blair mine was leased to P. J. Quealy, who worked it for some time. Part of this mine, as well as the E. $\frac{1}{2}$ sec. 2, became the property of the Rock Springs Coal Company, which reopened the mine in 1887 and produced 47,300 tons of coal in 1888. It was abandoned in 1903. The old Blair mine was opened on bed No. 1 just north of the fault above described. The original opening, known as the "Quealy mine or prospect," was opened on the same bed a few feet south of the fault by P. J. Quealy while operating the leased Blair mine. Both mines were worked by the Rock Springs Coal Company. The coal from the Quealy mine was run down an incline and loaded into cars at the Blair mine. When operations at the Blair mine were suspended the Quealy mine was also shut down.

In 1902 Matthew Muir reopened the Quealy mine by driving a new entry near the base of Quealy's workings, so as to save haulage. The new entry is a few rods west of the Quealy opening. The mine lies between two faults, one at the north, the other on the south, the distance between them being about 750 feet. The coal has been mined 1,200 feet down the dip. This property is at present owned by the Central Coal and Coke Company, and the mine is leased to Matthew Muir, who employs two miners. The coal is hauled to the mouth of the mine by horse, transported by wagon to Rock Springs, and sold locally or shipped with the Central Coal and Coke Company's coal. Practically all the coal taken out of this mine is used in Rock Springs for domestic purposes. Another opening, known as the "Young mine," was made in 1883 on the same bed a short distance to the north by George Young. The mine was worked for a short time by the Excelsior Coal Company and then abandoned because the coal was dirty and pinched out. The coal in the Blair mine is about 11 feet thick and in all the upper workings of the mine is perfectly clean. Bands of shale are encountered in the southwestern workings. They occur, however, near the base of the coal and 7 feet of clean coal lies above them. Union Pacific mine No. 2, now abandoned, also showed bony coal on this bed in the western and southwestern portions of its workings. It seems probable that there is here an area or zone containing bands of shale in this part of the bed and that both of these mines encountered it.

Wyoming Coal and Coke Company's mine.—In April, 1907, the Wyoming Coal and Coke Company opened a mine on bed No. 3 north of the fault described above as passing south of the old Blair mine. The south entries were worked only to the fault. Matthew Muir had previously opened a small mine on this bed a few rods south of the Wyoming opening and a few rods north of the fault contact. He leased the mine from Mr. Blair and worked it for a few years, until he encountered water. The new slope opened by the Wyoming Coal Company was driven down the dip of the coal bed, here about 12°. In September, 1909, the slope was down 1,600 feet. About 730 feet down a fault was encountered, which brings bed No. 1 up on the west into alignment with bed No. 3 east of the fault. Before striking bed No. 1 the slope passed through 90 feet of rock. Bed No. 3 was 4 feet 8 inches thick; bed No. 1 on the other side of the fault was 11 feet thick, mostly clean coal, with a few shale partings in the upper portion. In 1909 the company sunk a double-compartment shaft about 300 feet southeast of the mouth of No. 3 slope. The shaft was sunk 139 feet to a point where it struck bed No. 1. From the base of this shaft an entry was driven to the end of the old slope in Rock Springs Coal Company's mine No. 1, commonly known as the "Blair mine." The Wyoming Coal Company purchased the NW. ¼ sec. 2 from Mr. Blair and will extend and complete the workings of the old Blair mine as soon as the present entry connects with the Blair slope. In September, 1909, there was still 400 feet to open up. About 226 feet from the shaft, or 140 feet west of the end of the Blair slope, a small fault was encountered with the downthrow on the east. This is probably the same as the fault seen at the surface on the hill point just northeast of the mine, with a displacement of about 5 feet. A drill hole was sunk at the base of the shaft through bed No. 7, which was found to be 7 feet 6 inches thick. It is reported that the company intends to sink a shaft to bed No. 7, possibly to the Van Dyke bed, and to mine all these coals. The coal in bed No. 1 south of the old Blair slope is dirty throughout the lower part, having two or three shale partings nearly a foot thick. The upper 5 feet 6 inches is clean coal. West of the fault bed No. 1 is clean coal and has only a few partings in the upper part. Thus far most of the work has been confined to entries, which have been pushed forward as fast as possible, but little room work being done.

No. 6 CAMP.

No. 6 is the only camp on the west side of the Rock Springs dome where a mine has been opened on a coal bed in the Almond coal group. This camp was opened in 1882 by the Union Pacific Coal Company in sec. 22, T. 19 N., R. 105 W. The mine was known as the Union Pacific Coal Company's No. 6 and is often referred to as old No. 6 mine. The following section shows the condition of the coal bed:

Section of coal bed at old No. 6 mine.

	Ft.	in.
Sandstone, soft yellow.		
Shale	1	6
Coal	1	2
Bone		6
Coal	2	1
Shale	1	6
Coal	1	6
Coal, bony		5
Coal	1	11
Shale		6
Sandstone, soft, yellow.		
Total coal bed	9	1

Overlying the coal is about 18 inches of moderately soft chocolate-colored gypsiferous shale containing numerous fossils, apparently of the same species as those found at other points along the outcrop of the Almond coal group.

The mine was operated until 1886 and then abandoned, because the quality of the coal was such that it could not compete with the Rock Springs coal. A short prospect was opened on a 12-foot bed of coal west of and a little higher than bed No. 6, but no extensive work was done on it.

INTERSTATE CAMP.

The Interstate camp lies about 1½ miles north of No. 6 and is the only camp on the west side of the Rock Springs dome in this district where a mine has been opened in a coal bed belonging to the Black Rock coal group. This mine was opened in April, 1889, at the south center of sec. 10, T. 19 N., R. 105 W. Work was continued for a year and abandoned in 1890 on account of the poor quality of the coal, which could not be shipped without slacking. The small amount of coal that was mined was hauled to market in wagons or to the spur of the Union Pacific Railroad near old No. 6 mine. The coal is of about the same grade as that in No. 6 mine and would have no better market.

VAN DYKE CAMP.

The Van Dyke camp lies 2 miles east of Rock Springs and was the first camp where the lower coal beds of the Rock Springs coal group were mined. The Van Dyke mine, opened by Hall & Cotton in 1870, is located in the SW. ¼ sec. 30, T. 19 N., R. 104 W. The mine was soon abandoned, but was reopened by the Van Dyke Coal Company in 1888, when it produced approximately 20,280 tons.

The coal bed averages 4 feet in thickness. It shows little variation, being as a rule not less than 3 feet 8 inches nor more than 4 feet 2 inches thick. The roof of the bed is clay, which stands well so long as there is a current of dry air to carry away exuding moisture. Where it is not thus exposed it scales down in thick, heavy slabs. The floor is likewise clay, which is somewhat arenaceous a few feet below the coal. The dip of the bed where measured is from $3\frac{1}{2}°$ to 5° nearly due west. The coal is clean, showing no shale partings.

Between the Van Dyke mine and bed No. 7 on an east-west line there do not appear to be any beds of coal large enough to work, but there is a group of thin beds lying nearer the Van Dyke than bed No. 7, which increases in size toward the north. About a mile north of the Van Dyke main entry openings have been made on three of these beds, two of them showing only 2 or 3 feet of coal and the third 4 feet 2 inches of clean and bright-looking coal. Farther north, in sec. 8, T. 19 N., R. 104 W., on the western slope of Baxter Basin, the beds are thicker, so that two of them are at least 6 feet thick, a third about 4 feet, and several others smaller. In this section the Gunn-Quealy Coal Company opened its A and B mines, presumably on the lower and upper Van Dyke coal beds, respectively. Two of the larger coal beds have been opened about three-fourths of a mile farther north and are there nearly 7 feet thick. These beds are 40 feet apart and at least 200 feet lower than bed No. 7, which outcrops at the upper edge of the bluff forming the side of the basin.

The Van Dyke mine was again abandoned in 1895, as the thin coal did not yield enough to pay the expense of operation. Since then the property has passed to the Central Coal and Coke Company, which reopened the mine in the fall of 1909 and made preparations to extend the mine workings to much greater depths.

GUNN CAMP.

The Gunn camp lies in sec. 8, T. 19 N., R. 104 W., about $4\frac{1}{2}$ miles northeast of Rock Springs, on the western edge of Baxter Basin. At this place P. J. Quealy and George Gunn, representatives of the Gunn-Quealy Coal Company, opened mines in order to develop the two beds which have been known throughout this district as the Van Dyke coal beds and which up to that time had been mined in a small way only in the Van Dyke camp, about 3 miles southwest of Gunn. In July, 1907, work was commenced on a spur from the Union Pacific main line near Baxter to the mine, and in September of the same year development of the mine was begun. The first shipment of coal was made in May, 1908.

The Van Dyke coal beds lie near the base of the Rock Springs coal group, and the lower bed, on which mine A is located, is probably the same bed as the Van Dyke, on which the Van Dyke mine was located. The mouths of the mines are about 4½ miles northeast of Rock Springs. Mine A is opened on the lower Van Dyke bed and mine B, 40 feet stratigraphically above mine A, is on the upper Van Dyke bed. Regarding the mines at the Gunn camp Superintendent H. E. Lewis makes the following statement:

The coal pitches at this point about 9½° W. 8° S.; the upper bed averages a little more than 6 feet thick. The lower bed runs about 4 feet 9 inches thick, being thicker toward the north. The lower mine, or A, is 400 feet deep, with three entries turned off. The upper mine, or B, is 1,200 feet deep, with eight entries turned to the north and south. The upper mine, B, struck water level at the sixth level, or 900 feet below the surface, yielding about 200 gallons per twenty-four hours.

OTHER OPENINGS.

Many other prospects and entries have been opened on the Black Rock, Almond, and Rock Springs coal beds in the Rock Springs district. The most important are the Ludvigson mine, in the SW. ¼ NW. ¼ sec. 1, T. 18 N., R. 105 W., on bed No. 7, and the Carleson mine, in the SW. ¼ NW. ¼ sec. 6, T. 18 N., R. 104 W., on one of the coal beds near the base of the Rock Springs coal group. Very little coal has been taken from these mines, most of it coming from the entries. The Ludvigson mine was opened between two large faults and occupies the territory between the Central Coal and Coke Company's mine No. 2 at Rock Springs and the same company's mine No. 1 at Sweetwater. Most of the other openings were made primarily for prospecting purposes, with no intention of developing mines at those particular places.

POINT OF ROCKS DISTRICT.

The Point of Rocks district includes all the coal-bearing beds on the east side of the Rock Springs dome in the vicinity of Point of Rocks, or that part of the field north of Hallville, which is drained by Ninemile, Tenmile, and Twelvemile creeks—the area whose natural source of supply and transportation centers around Point of Rocks. Although this was one of the first districts to be opened in the Rock Springs field, very little mining has been done in it. Thus far only one camp, a mile east of Point of Rocks station, has been opened in the district. The Wyoming Coal and Mining Company, which had a contract to supply coal to the Union Pacific Railroad Company, opened a mine on a coal bed of the Almond coal group at this place as early as 1868. The main drift at this mine was driven northward at right angles to the dip of the beds, which is nearly due east. The mine was in operation until December, 1869, and was then abandoned, owing to the poor quality of the coal, as the same company was obtaining coal of a better grade at Rock Springs. The total production of the mine for that early period was 7,256 tons.

During the summer of 1907 the Rock Springs and Wyoming Coal Company reopened this mine and built a new spur from the main line to it, and in the latter part of the year began shipping coal. In the hill at this place five coal beds occur within a vertical distance of 80 feet. The lowest is approximately 100 feet above the bed of Bitter Creek. The new company opened two beds in 1907. The upper bed is 6 feet 4 inches thick and the lower 5 feet 1 inch thick. In 1908 the lower bed, which had been opened in 1868 and cleaned out in 1907 in preparation for new work, was abandoned owing to the large amount of impurities which make the coal inferior to that of the upper bed. The poor quality of this coal may be due in part to its weathered condition near the face of the old openings, as it is well known that coal of this type deteriorates rapidly when exposed to the air.

The upper bed varies slightly in thickness and was found to be 7 feet thick at the face of the mine in October, 1908. The yield of this mine in the fall of 1908 averaged 150 to 200 tons a day. There is a large amount of moisture in the coal, so that the company has considerable difficulty in disposing of the slack. At the mine the dip of the bed is about 6 per cent. The main entry, over 1,000 feet in length, is being driven on the level or in places with a little up grade in order to facilitate handling the loaded cars.

BLACK BUTTES DISTRICT.

The Black Buttes district lies on the east side of the Rock Springs dome and includes all the coal-bearing beds from the Point of Rocks district southward to Black Buttes Creek, or all the territory in this part of the Rock Springs field whose source of supply and transportation centers about Black Buttes station.

The district was opened in 1868, when the Union Pacific Railroad was built along Bitter Creek valley. Several mining camps have been established, but none of them are very extensive. The mines in one camp are operated on a coal bed near the base of the Black Rock coal group, and those in all the other camps on coal beds in the Black Buttes coal group.

BLACK BUTTES CAMP.

The first mine in the Black Buttes district was opened in 1868 in the hill east of Black Buttes station. It is commonly known as Morgan's mine and produced considerable coal. The coal, however, was inferior to the Rock Springs coal and the mine was soon abandoned. About 1890 it was reopened and continued in operation until 1893, producing about 50,000 tons. It was then again abandoned, presumably on account of poor markets for coal of that kind. The company worked an upper bed 4 feet thick and the main bed, 15 feet lower, 8 feet thick. The latter supplied most of the coal while the mine was in operation. In the summer of 1907 the mine was filled with water, so that no further investigation could be made.

During the days of the overland stage a small mine was opened just back of the stage station where coal was mined for local use. Another small mine, known as Maxwell's mine, was opened in the SE. ¼ NE. ¼ sec. 9, T. 18 N., R. 100 W., but was abandoned shortly afterward. Nothing further was learned regarding it.

In 1907 the Rock Springs-Gibraltar Coal Company opened a mine about 1 mile southwest of the old Black Buttes mine, on the same coal beds. The upper or principal bed is 6 feet 6 inches thick, and the other, 78 feet below, is 4 feet 6 inches thick. Another bed of good coal 2 feet 2 inches thick, which at present is not prospected, lies 13 feet 8 inches below the second bed. In working the coal the miners go in a short distance and then drift along parallel to the outcrop. A slope on the upper bed is opened down the dip to a depth of 300 feet. The output of this mine in the fall of 1908 was about 200 tons a day.

HALLVILLE CAMP.

The old Hall mine, about 4 miles northwest of Black Buttes station, on the west side of the railroad, was opened in 1868 on the same group of coal beds as those at Black Buttes. Regarding this mine Clarence King [a] makes the following statement:

> There are four seams of coal known to exist upon the claim. The upper one, 4 feet 8 inches in thickness, is near the surface and has never been developed, as the coal would be likely to prove of inferior quality. The second seam is 5½ feet in thickness, and has been worked to considerable extent, furnishing all the coal that has been sent to market from this mine. The third seam, 12 feet below the second and separated from it by a stratum of shale, is 9 feet 8 inches in thickness and promises to furnish a coal fully equal in quality to that taken from the one above. No work has been done upon it further than to prove its existence. The lower seam is not developed but is supposed to be about 3 feet in thickness.

This mine was situated just south of a large fault which carries the beds on the south side several miles toward the west. The mine was opened on a large fault block between Hallville and Black Buttes,

[a] U. S. Geol. Expl. 40th Par., vol. 3, 1870, p. 470.

and the beds are considerably distorted and irregular.[a] The mine was worked for a short time and then abandoned. At present only the ruins of the old camp remain.

In 1906 a mine was opened in a Black Rock coal bed east of the railroad, in sec. 28, T. 19 N., R. 100 W., by the Sioux City-Rock Springs Mining Company. This mine is south of a large fault which here, as well as at the old Hall mine, carries the beds on the south side several miles to the west. The company soon became involved in litigation, and all development work was abandoned. The mine was opened in a bed of coal 21 feet 10 inches thick by a slope driven down the dip to a depth of 300 feet. The first 100 feet was open-cut work, the remainder under cover. Along the slope about 8 feet of coal was removed, the rest of the bed being left in place.

OTHER DISTRICTS.

Many prospects and small local mines have been opened in various parts of the field (see Pls. XIV and XV) from which coal is taken in small quantities for local ranch use. These mines have not passed the prospect stage and will therefore not be considered at this time. There is no doubt that as future demands increase many new districts will be opened in the Rock Springs field, and that each district will contain several flourishing mining camps.

ECONOMIC CONSIDERATIONS.

MINING OPERATIONS.

Coal-mining operations in Sweetwater County have so far been conducted chiefly by two companies, the Union Pacific Coal Company and the Central Coal and Coke Company. At present the former operates almost wholly for the purpose of supplying coal to the Union Pacific Railroad. At Rock Springs the Central Coal and Coke Company has been mining coal for commercial markets since 1889. This company operates all the mines at Sweetwater and one mine at Rock Springs. The shipments of coal from other localities in this field have been meager and never exceeded a few hundred tons a day. Mines at present are being worked in the vicinity of Gunn, where the Gunn Mining Company is producing from 600 to 1,300 tons a day; at Point of Rocks, where the Rock Springs and Wyoming Coal Company is mining from 150 to 200 tons a day; and at Black Buttes, where the Rock Springs-Gibraltar Coal Company is mining about 200 tons a day. Outside of the Rock Springs and Black Buttes districts development has been confined to a slight amount of prospecting and to the opening of a few small mines from which to supply the local ranches.

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[a] See Bull. U. S. Geol. Survey No. 341, 1909, Pl. XIV, p. 258.

No doubt as future development work progresses most if not all of the mining in this field will be done by carrying slopes from the outcrop, much in the same way as at present. In places it may be found advantageous to sink shafts along the valleys some distance back from the outcrop where the overlying Tertiary beds have been removed. The room-and-pillar system prevails throughout the field. As a rule the pillars are not pulled at present. Mining is generally done by shooting off the solid face of the bed, but undercutting by hand and machine is employed in some of the mines. There is comparatively little gas, and accidents from this cause are relatively rare.

FUTURE DEVELOPMENT.

When new mines are to be opened in this field, whether in those districts where mines are already in active operation or in new districts far removed from any active mines or railroad stations, it will be necessary to consider carefully such factors as transportation, timber, and water supply, as well as the number, thickness, and persistence of coal beds, as all these items play important parts in the economic development of a new mine or district.

The most accessible routes for railroad transportation, and those of easiest grade, lie along the larger valleys or main drainage tributaries of Bitter Creek, namely, Little Bitter, Salt Wells, Black Buttes, and Killpecker creeks and their tributaries. Spur tracks built along any of these valleys will become feeders to the main line along Bitter Creek and afford an easy means of transportation, as gravity can be utilized in part in running the loaded coal cars from the mining camp or district to the nearest point on the main line.

In most of the mines thus far developed the roof and floor of the coal beds are firm and give little trouble in mining. It is necessary, however, to use timbers in parts of the mines. All props used in the mines must be shipped in, as there is very little timber in the region. Besides the few pines on Steamboat Mountain, in Pine Canyon, on Pine Buttes, and on Little Mountain, the only available timber is the juniper or scrub cedar used for posts, corrals, and fuel. The nearest sources of timber supply for mine use are (1) the Uinta National Forest, south of the field; (2) the Teton National Forest, in northern Uinta County, whence the timber could be floated down Hams Fork to Kemmerer or Granger and then shipped eastward by rail; (3) the mountain ranges on the east, including the Sierra Madre and the Ferris and Green Mountains; (4) the Wind River Mountains on the north, whence the timber could be hauled direct to the mines in the northern part of the field or could be floated down Green River and its tributaries to the town of Green River, and thence shipped eastward over the Union Pacific Railroad.

This entire region lies in the Red Desert of Wyoming. The only water available is that of Bitter Creek and a few small streams in the southwestern part of the field. The water of Bitter Creek is scanty in amount and not fit for domestic use. The few isolated springs that are scattered over the region are located for the most part along fault lines or along the contact of the lower shale of the Green River formation with the underlying formation. They furnish, as a rule, only a small quantity of water and can not be depended on to supply a mining camp. At Rock Springs water from Bitter Creek and water pumped from the mines is used to some extent for stock, but all water for domestic or household purposes is pumped from Green River. For the other mining camps in this district water for domestic purposes is shipped in large tanks by rail from Green River or Point of Rocks. In addition to the water shipped in, the water from small springs that rise along the faults in these localities is used by the miners at Superior and Point of Rocks, but this supply is not sufficient for a mining camp.

It appears, from well records and flowing wells at Rock Springs, Superior, Bitter Creek, and other points along the Union Pacific Railroad, that water can be obtained in almost any part of the Rock Springs field, outside of the Baxter Basin, which lies in the central part of the dome, by drilling to considerable depths. Whether the supply in all places will be large enough to meet the full demand of a mining camp or sufficient for irrigation or other agricultural needs can be determined only by careful and systematic drilling. In many parts of the field, particularly in the Great Divide Basin and other points along the east side of the dome, water may be obtained by drilling to relatively shallow depths, say several hundred feet. This water is likely to be highly alkaline and not good for domestic use.

MARKETS.

This field is situated about midway between the coal fields of Uinta County in southwestern Wyoming and those of Carbon County in south-central Wyoming. The coal from the Rock Springs field has about the same markets as that at present shipped from the Kemmerer and Hanna fields. Coal from these two fields has been carried eastward as far as Omaha, where it comes into competition with the coals of Iowa and Missouri; southward as far as Denver, where it is marketed with the Colorado coals; northward to the Black Hills, where it competes with the Sheridan and Cambria coals; and westward as far as the Pacific coast. During 1907 the demand of the western markets became so great that eastward shipments from Rock Springs were entirely abandoned and all the commercial coal produced was sent westward. So far as can be predicted the local market for the coal will be slight. Outside of Rock Springs and the villages and towns lying to the east and west along the Union Pacific Railroad and Oregon Short Line, with their various connecting lines and centers of industry, the use of the coal in this field will be confined to that needed by a few scattering ranches and in the development of the mineral resources of the surrounding mountains. No doubt a large part of the coal will be used by the railroad companies for fuel. Up to the present time only a small amount of the Rock Springs coal has found its way into commercial channels. Besides the present market furnished by the Union Pacific, Southern Pacific, and other western railroads using this coal for locomotive fuel, there is a ready market in many cities in the Rocky Mountain and Pacific States. The good quality of the coal and its nearness to the great smelting and sugar-refining industries in Salt Lake valley, Snake River valley, Anaconda, and Butte should command a good market. At present nearly all of the commercial Rock Springs coal goes west, the greater part of it to Salt Lake City, Utah.

AVAILABLE COAL.

In computing the amount of available coal in the southern part of the Rock Springs field, mapped in the summer of 1908 and discussed in this report, only those coal beds which are 2 feet 6 inches or more thick have been taken into consideration, although it is well known that bituminous coal beds 2 feet and less in thickness are being mined at present in Missouri, Arkansas, and many other States. The average thickness of the beds may be obtained from the representative sections given in the discussion of the four coal groups. It is assumed that the average thickness of the coal bed as computed from the measurements made along the outcrop will hold equally well for the bed down the dip. All the coal in the Rock Springs coal group belongs to the bituminous class and that of the Almond, Black Buttes, Knobs-Cherokee, and Black Rock coal groups to the low-grade bituminous and high-grade subbituminous classes. The specific gravity of these coals is about 1.3. A bed with a specific gravity of 1.3 and 1 foot thick contains about 1,132,500 short tons per square mile, or 1,770 short tons per acre. Using this factor in the calculation and taking all coal beds 2 feet 6 inches or more in thickness to a depth of 1,500 feet below the surface, or about 200 feet less than the deepest mine worked at present at Rock Springs, we obtain for the Rock Springs field the following gross tonnage:

MAP OF ROCK SPRINGS COAL ZONE IN THE SOUTHERN PART OF ROCK SPRINGS COAL FIELD
SWEETWATER COUNTY, WYOMING

Estimated gross tonnage of coal to a depth of 1,500 feet in the Rock Springs coal field, Wyoming.

[Short tons.]

Coal group.	Southern part of field.	Northern part of field.[a]	Total.
Rock Springs	3,032,100,000	4,843,000,000	7,875,100,000
Almond	3,818,200,000	3,110,783,000	6,928,983,000
Black Buttes	3,000,000,000	2,790,450,000	5,790,450,000
Knobs-Cherokee	2,000,000,000	6,000,000,000	8,000,000,000
Black Rock	8,590,950,000	35,576,640,000	44,167,590,000
	20,441,250,000	52,320,873,000	72,762,123,000

[a] Schultz, A. R., Bull. U. S. Geol. Survey No. 341, 1909, p. 282.

If the same factors are used but the computation is extended from the surface to a depth of 3,000 feet, or to the lowest limit of coal at present considered by the Geological Survey as workable, the estimated gross tonnage for these coal groups would be approximately twice that given in the above table.

It should be borne in mind that the amounts given above are merely estimates and that the total may vary from these figures by 25 to 50 per cent. The factors for computing the amount of coal present in the Knobs-Cherokee coal group are much more uncertain than those for the other groups, as it is not known where the base and top of these beds lie and how thick or numerous the coal beds are where they are under cover in the Rock Springs field. The tonnage given for this group is therefore merely a guess, based on what is known regarding the group west of the Rawlins dome and the general structural relations of the coal groups in the Rock Springs field.

WEATHERING OF COAL IN THE ARID REGION OF THE GREEN RIVER BASIN, SWEETWATER COUNTY, WYOMING.

By Alfred R. Schultz.

INTRODUCTION.

Coal beds in arid as well as in moist climates show considerable deterioration along the outcrop, and this deterioration in many places extends to the base of the belt of weathering or well down into it. The belt of weathering, from a geologist's point of view, is the surficial belt extending from the surface of the earth to the level of ground water. In this belt all the important reactions characteristic of the zone of katamorphism, namely, oxidation, carbonation, hydration, and solution, exert their maximum activity. The zone of katamorphism is the zone in which alterations of rocks result in the production of simple compounds from more complex ones. This zone extends from the surface of the earth to a depth of 10,000 meters,[a] and is divisible into two belts—an upper belt of weathering and a lower belt of cementation—the two being delimited by the level of ground water. As the ground-water level in arid regions lies at considerably greater depths below the surface than in well-watered regions, it is but natural to suppose that the belt of weathering extends to proportionately greater depths in dry than in moist climates. It would then follow that the deterioration of coal should extend farther below the surface in arid regions than in regions where the top of the water table lies only a few feet below the surface of the ground. That the deterioration of the coal does not always extend to the bottom of the belt of weathering, as above defined, or even to a considerable depth into this belt, is a fact not well known. In order to ascertain to what extent and depth the coal beds in the arid regions have been altered, some time was given to a study of the phenomena of weathering in the course of the geologic and stratigraphic investigation of the coal beds in the Rock Springs field, which range in age from lower Montana (Cretaceous) to Wasatch (Tertiary). A large number of coal samples were collected from beds both above and below the ground-water table, and show to what extent the coal has been altered. All samples except those taken from active oper-

[a] Van Hise, C. R., A treatise on metamorphism: Mon. U. S. Geol. Survey, vol. 47, 1904, p. 160.

ating mines came from a point in the bed above the top of the ground-water level. In the summer of 1907, when the northern half of the Rock Springs coal field was studied, 59 samples of coal were collected from various places in operating mines, abandoned prospects, and surface diggings. In 1908, when the southern half of the field was studied, 26 samples of coal were collected from various points, making a total of 85 samples collected and analyzed. Of these 45 were collected from coal beds in the Rock Springs group, 20 from coal beds in the Almond group, 10 from coal beds in the Black Buttes group, and 10 from coal beds in the Black Rock group.[a]

Considered with regard to physical as well as chemical properties, the coals occurring in these four groups fall into two classes—bituminous and subbituminous. The bituminous class includes all the high-grade coal of the Rock Springs group; the subbituminous class all the coal of the Almond, Black Buttes, and Black Rock groups. The difference between these two classes is physical as well as chemical. The Rock Springs coal usually has a lower percentage of water, remains firm and compact on exposure to air, and stands shipping well without breaking down. The coals from the three overlying groups, although from different horizons and of different ages, have essentially the same physical properties and bear a regional resemblance to one another. On exposure to the sun and open air they alter very rapidly, lose their bright luster, air slake, and break down into irregular blocks or powder. Cracks usually form along the bedding planes and somewhat irregularly in other directions. The coal does not stand shipping without breaking down or slaking, unless it is kept from the sun and circulating air while in transit. It may be stocked without slaking if kept from the sun and air. Chemical analyses of the samples taken from the coal beds of the four groups under approximately the same conditions seem to indicate that there is very little difference between the coals of the upper three groups, but that there is a marked difference between the coals of the two classes above mentioned when reduced to a pure-coal (moisture and ash free) basis. The unaltered Rock Springs coal averages approximately 600 British thermal units higher than the coals in the three overlying groups. It is probable that the former has undergone a more complete devolatilization, deoxygenation, and concentration, and does not assimilate oxygen so rapidly on exposure to the air as the other coals. The hydrocarbon compounds represented by the Rock Springs coal appear to be much more stable under atmospheric conditions than those represented by the higher coals.

Oxygenation, or weathering, along the outcrop of a coal bed manifested itself very strikingly as the examination progressed. Unlike

[a] The stratigraphic relationship of these coal groups is explained on pp. 222–224.

the difference in physical characteristics, this alteration seems to be much the same in the two classes. It is clearly evident that along the outcrop of a coal bed and down the dip at least three zones may be recognized—those of surface weathering, underground weathering, and unaltered coal.

ZONE OF SURFACE WEATHERING.

From work along the outcrop and samples collected from surface diggings and shallow prospects it is apparent that there is a belt of weathering near the surface in which all the coals are affected in much the same way. The good unaltered coal can not be reached until this weathered zone is removed. The chemical composition and the physical properties of the coal from this zone clearly show the altered and weathered condition. Samples taken from surface prospects and placed in air-tight cans soon lose their bright luster, the surface in some cases becoming covered with a velvety brown coating which no doubt is due to the alteration of the weathered coal. Evidence of the effects of exposure is seen in the H:O and VC:C ratios, as well as in the calorific deficiencies. Oxidation and decomposition in the belt of weathering soon alter the unstable chemical compounds of the coal so that it loses all traces of its original physical characteristics and the calorific values in an air-dried sample fall off one-fourth to one-half from those of the unweathered coal. Analysis of a sample taken from this belt of weathering affords an uncertain criterion for determining the value of the coal except in so far as it indicates the approximate amounts of sulphur and ash. The belt of surface weathering ranges in depth from 10 to 50 feet.

ZONE OF UNDERGROUND WEATHERING.

Besides the alteration observed in the belt of surface weathering similar phenomena were observed at much greater depths along the walls of more extensive prospects, slopes, entries, and rooms of mines, where the coal has been exposed to the air for a long period of time.

Oxygenation of the coal due to similar conditions was observed in many of the larger prospects, shallow mines, and drifts in the Rock Springs coal group. Many of these prospects were opened for 40, 100, or 150 feet and driven at the time of opening some distance back into unaltered coal, so that all of the deterioration now observed has occurred since their abandonment. Similar conditions were found in a shallow mine opened by Mr. Kappes in the SE. ¼ SW. ¼ sec. 14, T. 17 N., R. 105 W., and in the old Union Pacific mine No. 5 at Rock Springs. The same conditions were found in the three coal groups overlying the Rock Springs group. The chemical and physical results of weathering are not so apparent in these higher coals as in the Rock Springs coal, owing to the lack of large mines on the higher coal beds and to the smaller number of samples collected. Some of the best examples of these higher coals showing oxygenation as the result of exposure to air for a long time in mines of considerable depth come from the Rock Springs and Wyoming Coal Company's mine at Point of Rocks and from the old Union Pacific mine No. 6 at Rock Springs. Both of these mines were operated on beds in the Almond coal group and were worked for some time.[a] The same phenomena were observed in the old Black Buttes mine at Black Buttes,[b] opened on the Black Buttes beds and also on prospects driven into the unaltered coal to depths of 90 and 190 feet.

Oxygenation along the drift, prospect, and mine walls has not altered the coal so completely as in the belt of surface weathering. The coal along the faces of these underground openings where exposed to the air for a long period of time gradually assimilates oxygen, which it takes into combination, forming new hydrocarbon compounds from those present in the unstable equilibrium of normal coal as it lies in the coal bed. This assimilation of oxygen causes the coal to slake and its physical properties to change. On close examination it clearly shows deterioration; it has lost its bright luster and the smooth, firm surface of fresh coal and shows a decided calorific deficiency. Although the coal obtained from the faces of these old openings may seem firm and little altered, it seldom shows as good chemical results as samples obtained from working faces, and for this reason the analyses of many of the samples from deep prospects, old abandoned mines, and small country banks should not be taken as indicating the real merits of the coal. On the other hand, the analyses of such samples seldom show as poor results as those of coals taken from surface prospects or country banks in the belt of weathering. The following table shows the chemical composition of the Rock Springs coal in the three stages of weathering and the alteration of the coal from its nonweathered stage to its highly oxidized stage in the zone of surface weathering:

Summary of analyses of Rock Springs coal from zones of surface weathering, underground weathering, and unaltered coal. [c]

ZONE OF SURFACE WEATHERING.

Number of samples.		Moisture.		Volatile matter.			Fixed carbon.			Ash.		
		As received.	Air dried.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
7	Minimum	16.39	12.08	29.35	33.43	41.78	30.71	34.98	46.20	3.89	4.38	5.23
	Maximum	33.79	24.59	36.78	38.68	45.67	39.35	42.88	51.97	8.21	8.63	9.81
	Average	**26.40**	**19.68**	**32.31**	**35.90**	**43.91**	**36.18**	**40.20**	**49.18**	**5.10**	**5.65**	**6.91**

[a] See Bull. U. S. Geol. Survey No. 341, 1909, pp. 276, 277; also p. 272 of this bulletin.
[b] See Bull. No. 341, p. 276.
[c] For complete analyses see Bull. U. S. Geol. Survey No. 341, 1909, pp. 270–272.

Summary of analyses of Rock Springs coal from zones of surface weathering, underground weathering, and unaltered coal—Continued.

ZONE OF SURFACE WEATHERING—Continued.

Number of samples.		Sulphur.			Hydrogen.			Carbon.			Nitrogen.		
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
	Minimum	0.37	0.41	0.51	4.79	4.47	3.18	39.29	44.75	59.34	1.00	1.10	1.37
7	Maximum	.95	1.00	1.14	5.86	5.22	3.97	50.09	52.95	63.20	1.26	1.39	1.75
	Average	**.65**	**.72**	**.87**	**5.55**	**4.93**	**3.58**	**45.65**	**50.12**	**61.80**	**1.17**	**1.28**	**1.59**

Number of samples.		Oxygen.			Calories.				British thermal units.			
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	Pure coal.	As received.	Air dried.	Dry coal.	Pure coal.
	Minimum	34.72	31.97	24.11	3,356	3,822	5,068	5,588	6,042	6,884	9,122	10,057
7	Maximum	46.90	41.07	26.06	4,511	4,800	5,730	6,046	8,120	8,640	10,314	10,883
	Average	**41.68**	**36.35**	**25.00**	**4,018**	**4,465**	**5,452**	**5,856**	**7,231**	**8,029**	**9,813**	**10,540**

ZONE OF UNDERGROUND WEATHERING.

Number of samples.		Moisture.		Volatile matter.			Fixed carbon.			Ash.		
		As received.	Air dried.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
	Minimum	10.94	6.69	28.17	30.00	34.24	42.70	43.35	47.95	1.64	1.87	2.00
11	Maximum	21.22	12.76	38.28	39.34	44.35	51.80	55.38	62.94	15.56	15.80	17.47
	Average	**15.43**	**10.16**	**33.17**	**35.25**	**39.39**	**47.02**	**50.02**	**55.52**	**4.37**	**4.56**	**5.08**

Number of samples.		Sulphur.			Hydrogen.			Carbon.			Nitrogen.		
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
	Minimum	0.32	0.36	0.41	4.73	4.55	3.71	53.95	54.77	60.58	0.87	0.88	0.98
11	Maximum	1.01	1.03	1.13	6.11	5.66	5.16	64.54	67.44	74.19	1.33	1.41	1.54
	Average	**.70**	**.74**	**.83**	**5.40**	**5.01**	**4.40**	**58.87**	**62.82**	**69.37**	**1.15**	**1.22**	**1.35**

Number of samples.		Oxygen.			Calories.				British thermal units.			
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	Pure coal.	As received.	Air dried.	Dry coal.	Pure coal.
	Minimum	23.78	21.85	15.09	4,633	4,892	5,608	5,898	8,339	8,806	10,094	10,615
11	Maximum	36.91	33.39	26.32	6,292	6,575	7,233	7,456	11,326	11,835	13,019	13,420
	Average	**29.04**	**25.14**	**18.48**	**5,449**	**5,793**	**6,445**	**6,795**	**9,809**	**10,430**	**11,601**	**12,212**

Summary of analyses of Rock Springs coal from zones of surface weathering, underground weathering, and unaltered coal—Continued.

ZONE OF UNALTERED COAL.

Number of samples.		Moisture. As received.	Moisture. Air dried.	Volatile matter. As received.	Volatile matter. Air dried.	Volatile matter. Dry coal.	Fixed carbon. As received.	Fixed carbon. Air dried.	Fixed carbon. Dry coal.	Ash. As received.	Ash. Air dried.	Ash. Dry coal.
18	Minimum	8.53	6.04	31.52	33.35	36.15	47.10	49.16	53.83	1.44	1.51	1.67
	Maximum	14.63	10.85	36.41	37.94	40.66	52.61	54.43	59.07	9.04	9.30	10.02
	Average	**11.60**	**8.10**	**34.02**	**35.60**	**38.74**	**49.78**	**52.08**	**56.67**	**4.02**	**4.21**	**4.58**

Number of samples.		Sulphur. As received.	Sulphur. Air dried.	Sulphur. Dry coal.	Hydrogen. As received.	Hydrogen. Air dried.	Hydrogen. Dry coal.	Carbon. As received.	Carbon. Air dried.	Carbon. Dry coal.	Nitrogen. As received.	Nitrogen. Air dried.	Nitrogen. Dry coal.
18	Minimum	0.72	0.77	0.82	5.36	5.14	4.59	61.47	64.16	70.66	1.09	1.15	1.24
	Maximum	1.46	1.52	1.69	6.05	5.79	5.25	68.98	71.85	77.04	1.49	1.57	1.66
	Average	**.97**	**1.02**	**1.10**	**5.71**	**5.46**	**4.97**	**65.33**	**68.45**	**75.00**	**1.22**	**1.28**	**1.39**

Number of samples.		Oxygen. As received.	Oxygen. Air dried.	Oxygen. Dry coal.	Calories. As received.	Calories. Air dried.	Calories. Dry coal.	Calories. Pure coal.	British thermal units. As received.	British thermal units. Air dried.	British thermal units. Dry coal.	British thermal units. Pure coal.
18	Minimum	19.66	16.59	12.16	6,086	6,353	6,959	7,571	10,955	11,435	12,526	13,627
	Maximum	25.82	22.88	15.85	6,868	7,101	7,613	7,929	12,362	12,782	13,738	14,272
	Average	**22.71**	**19.64**	**13.65**	**6,479**	**6,784**	**7,308**	**7,726**	**11,662**	**12,206**	**13,272**	**13,908**

The above table shows the range and the average chemical composition of the samples of Rock Springs coal obtained in 1907. The following table gives the average of all analyses of samples of each group of coals obtained in the Rock Springs field in 1907–8 and is here given for the purpose of comparison:

Average of the analyses of air-dried samples of coal from the Rock Springs field, Sweet water County, Wyo.

ZONE OF SURFACE WEATHERING.

Coal group.	Number of samples.	Air-drying loss.	Proximate analysis. Moisture.	Proximate analysis. Volatile matter.	Proximate analysis. Fixed carbon.	Proximate analysis. Ash.	Ultimate analysis. Sulphur.	Ultimate analysis. Hydrogen.	Ultimate analysis. Carbon.	Ultimate analysis. Nitrogen.	Ultimate analysis. Oxygen.	Heat value. Calories.	Heat value. British thermal units.	British thermal units in pure coal.
Black Rock	2	10.55	20.41	34.05	30.93	14.65	1.17	4.50	43.16	0.92	38.23	3,602	6,484	9,997
Almond	6	6.80	14.66	32.98	44.89	7.46	.48	4.74	53.77	1.26	34.21	4,840	8,622	10,885
Rock Springs	8	10.92	16.88	36.24	41.45	5.43	.71	4.85	51.63	1.28	35.32	4,587	8,250	10,602

Average of the analyses of air-dried samples of coal from the Rock Springs field, Sweetwater County, Wyo.—Continued.

ZONE OF UNDERGROUND WEATHERING.

Coal group.	Number of samples.	Air-drying loss.	Froximate analysis.				Ultimate analysis.					Heat value.		British thermal units in pure coal.
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.	
Black Rock...	2	11.85	10.37	37.99	45.19	6.44	0.84	4.61	57.05	1.28	30.24	5,231	9,420	11,314
Black Buttes..	5	6.90	9.27	32.61	53.56	4.55	.53	4.94	63.83	1.60	24.39	6,047	10,919	12,682
Almond......	11	6.59	9.34	33.15	51.22	6.27	.64	4.70	62.15	1.29	25.28	5,743	10,337	12,255
Rock Springs .	12	6.89	9.90	35.59	49.93	4.56	.73	4.91	62.53	1.23	25.57	5,758	10,366	12,124
ZONE OF UNALTERED COAL.														
Black Rock...	6	7.80	8.47	37.14	46.22	8.16	1.72	5.22	62.40	1.29	21.20	6,116	11,009	13,200
Black Buttes..	5	11.02	9.30	32.87	53.23	4.59	.48	5.08	66.14	1.51	22.23	6,290	11,324	13,160
Almond......	3	12.66	5.97	33.33	56.80	3.88	.61	5.07	68.33	1.40	20.68	6,520	11,736	13,020
Rock Springs .	25	5.86	7.29	36.24	52.46	4.01	1.08	5.45	69.09	1.32	19.17	6,825	12,280	13,837

ZONE OF UNALTERED COAL.

The coal samples collected in 1907 clearly indicated that the phenomena of weathering are not confined to outcrops or shallow prospects, but extend back considerable distances, even several hundred feet, or to water level, in large mines as well as in shallow mines, country banks, and drifts. A large number of these samples show to what extent underground weathering or oxygenation has been effective along mine openings, but practically no samples were collected to show how far below the surface in the belt of weathering the coal was altered. For this reason coal samples were collected in the summer of 1908 from three of the four coal groups in the Rock Springs field to ascertain if possible to what depth the weathered belt extends below the surface where the coal has not previously been open and exposed to the air. In making these tests it was considered best to collect samples from some of the new mines recently opened, as they offered the best opportunities to sample fresh surfaces of coal from the outcrop down to the lowest depths of the workings. New mines were opened in 1907 and 1908 on the Rock Springs coal group by the Gunn-Quealy Coal Company at Gunn, on the Almond coal group by the Rock Springs and Wyoming Coal Company east of Point of Rocks, and on the Black Buttes coal group by the Rock Springs-Gibraltar Coal Company southwest of Black Buttes. At each of these localities a number of samples were taken, and the results of the analyses are given below. It was not considered necessary to take samples at the surface in the vicinity of the mines, as a sufficient number of analyses of samples collected the previous year showed the conditions in shallow or surface prospects at or near the surface.

COALS OF THE ROCK SPRINGS GROUP.

In the following table are the results of analyses of samples of the Rock Springs coal obtained at Gunn:

Analyses[a] of coal from the Rock Springs coal group, showing the effect of weathering at various depths below the surface.

[Samples taken in the Gunn-Quealy mines, Gunn, Wyo.; sec. 8, T. 19 N., R. 104 W. F. M. Stanton, chemist in charge.]

No.	Sample taken.			Air-drying loss.	Proximate analysis.				Ultimate analysis.					Heat value.	
	Mine.	Distance down manway (feet).	Thickness of cover (feet).		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
7090	B	10	24	17.30	23.30	31.94	41.49	3.27	0.53	5.53	50.17	1.04	39.46	4,500	8,100
					7.25	38.62	50.18	3.95	.64	4.36	60.66	1.26	29.13	5,441	9,794
						41.64	54.10	4.26	.69	3.83	65.41	1.36	24.45	5,867	10,561
						43.49	56.51	......	.72	4.00	68.32	1.42	25.54	6,128	11,030
7089	B	80	56	9.10	13.43	34.92	49.41	2.24	.95	5.76	64.33	1.21	25.51	6,365	11,455
					4.76	38.42	54.36	2.46	1.05	5.23	70.77	1.33	19.16	7,002	12,604
						40.33	57.08	2.59	1.10	4.93	74.31	1.40	15.67	7,352	13,234
						41.40	58.60	......	1.13	5.06	76.29	1.44	16.08	7,548	13,586
7092	B	150	70	11.50	15.91	33.23	47.13	3.73	1.10	5.99	61.76	1.29	26.13	6,044	11,879
					4.98	37.55	53.25	4.22	1.24	5.33	69.78	1.46	17.97	6,829	12,292
						39.52	56.04	4.44	1.31	5.02	73.44	1.53	14.26	7,187	12,937
						41.36	58.64	......	1.37	5.25	76.85	1.60	14.93	7,521	13,538
5805	A	200	96	5.30	13.59	34.99	48.12	3.30	1.02	5.89	64.12	1.27	24.40	6,396	11,513
					8.75	36.95	50.81	3.49	1.08	5.60	67.71	1.34	20.78	6,754	12,157
						40.49	55.70	3.81	1.18	5.07	74.20	1.47	14.27	7,402	13,324
						42.09	57.91	......	1.23	5.27	77.14	1.53	14.83	7,695	13,852
5806	B	300	225	4.90	13.65	34.83	50.08	1.44	.98	6.05	64.53	1.18	25.82	6,590	11,862
					9.21	36.62	52.66	1.51	1.03	5.79	67.85	1.24	22.58	6,929	12,473
						40.34	57.99	1.67	1.13	5.25	74.73	1.37	15.85	7,632	13,738
						41.02	58.98	......	1.15	5.34	75.99	1.40	16.12	7,762	13,971
7091	B	800	360	12.40	15.71	33.50	48.40	2.39	.93	6.11	63.11	1.30	26.16	6,191	11,144
					3.78	38.24	55.25	2.73	1.06	5.40	72.04	1.48	17.29	7,067	12,721
						39.74	57.42	2.84	1.10	5.17	74.87	1.54	14.48	7,345	13,221
						40.90	59.10	......	1.13	5.32	77.06	1.58	14.91	7,559	13,606
8534	B	1,100	374	9.40	17.61	31.09	47.50	3.80	1.13	6.24	60.36	1.30	27.17	5,982	10,768
					9.06	34.32	52.43	4.19	1.25	5.74	66.62	1.44	20.76	6,603	11,885
						37.73	57.66	4.61	1.37	5.19	73.26	1.58	13.99	7,260	13,068
						39.55	60.45	......	1.44	5.44	76.80	1.66	14.66	7,611	13,700

[a] Four analyses are given for each sample, arranged as follows: As received, air-dried, dry coal, pure coal (moisture and ash free).

The results of analyses of Rock Springs coal taken from surface prospects in the belt of weathering are given in Bulletin 341, page 271, Nos. 5812, 5372, 5371, 5376, 5814, 5809, 5813, and 7090. Analyses of coals in this group showing the various stages of underground weathering as a result of exposure to air appear in Bulletin 341, pages 270 and 271, Nos. 5694, 5696, 5698, 5697, 6043, 5370, 5369, 5368, 5357, 5373, 5699; and in the present report, page 243, No. 6791.

Analyses of good unaltered coal obtained near the surface in small country mines are Nos. 6796 and 6799 of this report (p. 242). No. 6796 was collected from the Millor mine, in the NW. ¼ NW. ¼ sec. 24,

T. 17 N., R. 105 W., and No. 6799 from the Kent mine, in the NE. ¼ NE. ¼ sec. 14, T. 17 N., R. 105 W. In both of these mines the coal has been exposed for some time, but every winter fresh coal is taken out for ranch use, so that it was possible to get unaltered coal from the working face back only 40 and 75 feet, respectively, from the mouth of the mine.

A comparative study of the analyses of the Rock Springs coal sampled at various places and depths in the Rock Springs, Sweetwater, Blairtown, Gunn, and Superior mines shows that there is a very small range in the percentages of the constituents. This indicates that the unaltered coal is remarkably uniform and bears a regional resemblance in the various mines.

Range in percentages of constituents and heat values of Rock Springs coal, as shown by analyses of air-dried samples from the mines at Rock Springs, Sweetwater, Blairtown, Gunn, and Superior.[a]

Moisture	5.51– 10.85
Volatile matter	33.35– 39.66
Fixed carbon	49.16– 55.25
Ash	1.51– 9.30
Sulphur	.77– 1.38
Hydrogen	5.22– 5.79
Carbon	64.17– 73.51
Nitrogen	1.15– 1.57
Oxygen	16.55– 22.91
Calories	6,352– 7,310
British thermal units	11,435–13,158

The twenty-five unweathered samples collected give no indication that the coal improves in depth or that the weathered zone extends very far below the surface of the ground, or, as often supposed, to the top of the ground-water level. Samples were collected near the top of the unaltered coal, approximately 50 feet below the surface, and at various other places throughout the mines to a depth of about 2,000 feet below the surface, that of No. 5358, sampled in entry No. 51 of the Union Pacific mine No. 1 at Rock Springs. Of all the mine samples collected the one showing the highest calorific value in the air-dried state is No. 6772, from the Wyoming Coal and Coke mine at Blairtown, taken 96 feet below the surface near the end of the second entry south, about 400 feet southwest of the slope opening on bed No. 3. This sample gives 13,158 British thermal units when air dried and heads the list of samples for dry coal with 13,811 British thermal units. On a pure-coal basis only six of the 25 samples show calorific values greater than 14,000 British thermal units. Of these six, four have higher values than sample No. 6772 and all come from shallow or very moderate depths in the mines. The order of these six samples is as follows:

[a] For complete analyses see Bull. U. S. Geol. Survey No. 341, 1909, p. 270; all analyses on the page cited, except Nos. 5694 and 5696, represent mine samples.

Calorific values of pure coal, samples from Rock Springs coal group.

	British thermal units.
5926	14,272
5928	14,162
5366	14,119
5785	14,114
6772	14,069
5365	14,053

From the table on page 289 it will be seen that the weathered coal zone does not reach a depth of 56 feet below the surface but extends to a depth greater than 24 feet, the division line at the Gunn-Quealy mine lying somewhere between these two limits. It is evident also that the coal below the belt of weathering does not improve in quality with increasing depth. On a pure-coal basis the unaltered Rock Springs coal has a calorific efficiency, in round numbers, of 13,600 to 14,300 British thermal units.

COALS OF THE ALMOND GROUP.

The results on the Almond coals are presented below.

Analyses[a] of coal from the Almond coal group, showing the effect of weathering at various depths below the surface.

[Samples taken in the Rock Springs and Wyoming mine, Point of Rocks, Wyo., sec. 26, T. 20 N., R. 101 W. F. M. Stanton, chemist in charge.]

No.	Sample taken.			Air-drying loss.	Proximate analysis.				Ultimate analysis.					Heat value.	
	Bed.	Distance along entry (feet).	Thickness of cover (feet).		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
7088	Upper	50	37	7.50	14.26	33.24	47.06	5.44	0.74	4.69	54.16	1.35	33.62	4,630	8,334
					7.31	35.93	50.88	5.88	.81	4.17	58.55	1.46	29.13	5,005	9,009
						38.77	54.89	6.34	.87	3.63	63.17	1.57	24.42	5,400	9,720
						41.38	58.62	......	.93	3.88	67.45	1.68	26.06	5,766	10,379
7095	...do.	150	81	8.60	13.96	31.14	50.81	4.09	.56	5.38	60.29	1.26	28.42	5,653	10,175
					5.87	34.07	55.58	4.48	.61	4.84	65.96	1.38	22.73	6,185	11,133
						36.19	59.06	4.75	.65	4.45	70.07	1.46	18.62	6,570	11,826
						37.99	62.01	......	.68	4.67	73.56	1.53	19.56	6,897	12,415
[b] 5351	...do.	227	103	2.40	16.01	33.17	46.43	4.39	.76	5.04	59.36	1.19	29.26	5,474	9,853
					13.95	33.98	47.57	4.50	.78	4.89	60.82	1.22	27.79	5,609	10,095
						39.49	55.28	5.23	.90	3.88	70.68	1.42	17.89	6,517	11,731
						41.67	58.33	......	.95	4.09	74.58	1.50	18.88	6,878	12,379
5352	Lower	575	200	2.80	16.61	30.24	43.96	9.19	.68	5.28	55.64	1.10	28.11	5,230	9,414
					14.21	31.11	45.22	9.46	.70	5.11	57.24	1.13	26.36	5,381	9,685
						36.26	52.72	11.02	.82	4.11	66.72	1.32	16.01	6,272	11,290
						40.75	59.25	......	.92	4.62	74.98	1.49	17.99	7,049	12,688
7087	Upper	300	136	12.00	16.92	28.36	51.32	3.40	.55	5.75	60.61	1.24	28.45	5,785	10,413
					5.58	32.23	58.33	3.86	.62	5.02	68.88	1.41	20.21	6,575	11,835
						34.14	61.77	4.09	.66	4.66	72.96	1.49	16.14	6,963	12,533
						35.59	64.41	......	.69	4.86	76.07	1.55	16.83	7,260	13,068
7094	...do.	500	128	12.40	17.92	29.51	49.30	3.27	.50	5.87	59.46	1.24	29.66	5,678	10,220
					6.30	33.69	56.28	3.73	.57	5.13	67.87	1.41	21.29	6,482	11,668
						35.96	60.06	3.98	.61	4.73	72.44	1.51	16.73	6,918	12,452
						37.44	62.56	......	.64	4.93	75.44	1.57	17.42	7,204	12,967
7102	...do.	1,000	132	13.60	18.83	29.45	48.20	3.52	.55	5.90	58.97	1.21	29.85	5,619	10,114
					6.05	34.08	55.80	4.07	.64	5.08	68.25	1.40	20.56	6,504	11,707
						36.28	59.38	4.34	.68	4.69	72.65	1.49	16.15	6,923	12,461
						37.93	62.07	......	.71	4.90	75.95	1.56	16.88	7,237	13,027

[a] Four analyses are given for each sample, arranged as follows: As received, air-dried, dry coal, pure coal (moisture and ash free).
[b] Analysis No. 5351 as published in Bulletin 341, p. 271, is incorrect.

The results of the analyses of the Almond coal taken from surface prospects in the belt of weathering are given in Bulletin 341, page 272, Nos. 5950, 5597, 5599, 5348, 5349, and 5350.

Exceptionally good illustrations of underground weathering or oxygenation are given in the Rock Springs and Wyoming mine at Point of Rocks and in the old No. 6 mine at Rock Springs. The mine east of Point of Rocks was opened in 1868 and operated to December, 1869, about 7,256 tons of coal being taken out. From that date to 1907 the mine was not worked. Samples Nos. 5351 and 5352 (Bulletin 341, pp. 271, 272) were collected from the mine in 1907, while the old mine was being cleaned out. On a comparison of the analyses of these two samples with those of the last three in the above table the altered condition of the coal represented by the former will be apparent. Sample No. 5351 was taken from the upper bed at the end of a fresh unfinished crosscut about 20 feet from the old drift opened in 1868–69, 103 feet below the surface and 227 feet from the mouth of the mine. Sample No. 5352 was taken from the lower bed about 70 feet below the upper bed, at the end of an old drift 575 feet from the mouth of the mine.

Old No. 6 mine at Rock Springs, opened on a coal bed of the Almond group in 1882, continued in operation until 1886 and was then abandoned. Analyses No. 6042 (Bulletin 341, p. 271) and No. 6773 (p. 243 of the present report) show the same amount of oxygenation due to exposure to the air. Both of these samples were collected from the main slope approximately 300 feet from the mouth of the mine. Similar results are indicated in samples Nos. 5804, 5353, and 5347 (Bulletin 341, pp. 271, 272) and in Nos. 6797, 7095, 6775, and 7088 (p. 243 of this volume). The above table shows that back from the old mine openings the weathered coal zone does not extend to a depth of more than 100 feet below the surface. How much less the depth is can not be told from the samples here collected, as they were taken along the old entries. The table also shows that on a pure-coal basis the heat value of the unaltered Almond coal approximates 13,000 British thermal units.

COALS OF THE BLACK BUTTES GROUP.

In the subjoined table are the results for the Black Buttes coal.

Analyses[a] of coal from the Black Buttes coal group, showing the effect of weathering at various depths below the surface.

[Samples taken in the Rock Springs-Gibraltar coal mine, Black Buttes, Wyo., sec. 20, T. 18 N., R. 100 W. F. M. Stanton, chemist in charge.]

	Sample taken.				Proximate analysis.				Ultimate analysis.					Heat value.	
No.	Bed.	Distance down slope (feet).	Thickness of cover (feet).	Air-drying loss.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
7103	Upper	50	10	13.10	**17.22**	**30.32**	**48.23**	**4.23**	**0.35**	**5.36**	**56.22**	**1.51**	**32.33**	**5,216**	**9,389**
					4.74	34.89	55.50	4.87	.40	4.49	64.69	1.74	23.81	6,002	10,804
						36.63	58.26	5.11	.42	4.17	67.91	1.82	20.57	6,301	11,342
						38.60	**61.40**	......	**.44**	**4.39**	**71.57**	**1.92**	**21.68**	**6,641**	**11,954**
7170	...do.	100	40	7.90	**18.87**	**28.93**	**48.07**	**4.13**	**.43**	**5.82**	**59.20**	**1.43**	**28.99**	**5,607**	**10,093**
					11.91	31.41	52.20	4.48	.47	5.36	64.28	1.55	23.86	6,088	10,958
						35.66	59.25	5.09	.53	4.59	72.97	1.76	15.06	6,911	12,440
						37.57	**62.43**	......	**.56**	**4.84**	**76.88**	**1.85**	**15.87**	**7,281**	**13,106**
5808	...do.	130	50	5.80	**18.86**	**29.17**	**47.85**	**4.12**	**.49**	**5.64**	**58.96**	**1.45**	**29.34**	**5,713**	**10,283**
					13.86	30.97	50.80	4.37	.52	5.31	62.59	1.54	25.67	6,065	10,916
						35.95	58.98	5.07	.60	4.38	72.65	1.79	15.51	7,040	12,672
						37.87	**62.13**	......	**.63**	**4.61**	**76.53**	**1.89**	**16.34**	**7,416**	**13,349**
5811	Lower	140	(a)	6.10	**10.42**	**31.02**	**45.02**	**4.54**	**.51**	......	......	......	......	**5,677**	**10,219**
					14.18	33.04	47.94	4.84	.54	......	......	......	......	6,046	10,882
						38.50	55.87	5.63	.63	......	......	......	......	7,045	12,680
						40.80	**59.20**	......	**.67**	......	......	......	......	**7,465**	**13,436**
7097	Upper	150	60	13.10	**18.69**	**29.23**	**48.35**	**3.73**	**.44**	**5.79**	**58.45**	**1.41**	**30.18**	**5,582**	**10,047**
					6.43	33.64	55.64	4.29	.51	4.98	67.26	1.62	21.34	6,423	11,561
						35.95	59.46	4.59	.54	4.56	71.89	1.73	16.69	6,865	12,357
						37.68	**62.32**	......	**.57**	**4.78**	**75.34**	**1.81**	**17.50**	**7,195**	**12,951**
7096	...do.	225	75	14.50	**19.54**	**28.21**	**47.85**	**4.40**	**.37**	**5.89**	**57.34**	**1.40**	**30.60**	**5,465**	**9,837**
					5.90	32.99	55.96	5.15	.43	5.01	67.07	1.64	20.70	6,392	11,506
						35.06	59.47	5.47	.46	4.62	71.27	1.74	16.44	6,792	12,226
						37.09	**62.91**	......	**.49**	**4.89**	**75.40**	**1.84**	**17.38**	**7,185**	**12,933**
7093	...do.	355	75	15.60	**20.77**	**28.38**	**47.12**	**3.73**	**.36**	**5.98**	**57.11**	**1.06**	**31.76**	**5,507**	**9,913**
					6.12	33.62	55.84	4.42	.43	5.03	67.66	1.26	21.20	6,526	11,747
						35.81	59.48	4.71	.45	4.63	72.08	1.34	16.79	6,950	12,510
						37.58	**62.42**	......	**.47**	**4.86**	**75.64**	**1.41**	**17.62**	**7,293**	**13,127**

[a] Four analyses are given for each sample, arranged as follows: As received, air-dried, dry coal, pure coal (moisture and ash free).
[b] 78 feet below upper bed.

No samples of coal for analysis were collected from surface prospects on the Black Buttes beds. The conditions here are much the same as those for the Almond coals. From the above table it may be seen that the zone of surface weathering at this mine extends approximately 100 feet down the slope and is about the same in the lower and the upper bed, although the lower bed lies 78 feet stratigraphically below the upper bed.

Slight weathering was observed in samples Nos. 5951 and 5810, collected from the ends of prospects open 90 and 190 feet, respectively; also in sample No. 5952, from the old abandoned Black Buttes mine southeast of Black Buttes station, collected 250 feet down the entry from the mouth of the mine and 10 feet above water level. Complete analyses of these three samples are given in the following table:

Analyses[a] of coal from the Black Buttes coal group, showing the effect of weathering along mine entries and prospect pits.

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

No.	Sample taken.		Air-drying loss.	Proximate analysis.				Ultimate analysis.					Heat value.	
	Mine.	Distance along entry (feet).		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
5810	Prospect.	190	3.70	**15.14**	**32.58**	**47.88**	**4.40**	**0.62**	......	......	......	......	**5,766**	**10,379**
				11.88	33.83	49.72	4.57	.64	......	......	......	......	5,988	10,778
					38.39	56.42	5.19	.73	......	......	......	......	6,795	12,235
					40.49	**59.51**	......	**.77**	......	......	......	......	**7,167**	**12,905**
5952	Mine.	250	3.60	**12.85**	**30.36**	**52.48**	**4.31**	**.56**	**5.21**	**60.27**	**1.47**	**28.18**	**5,877**	**10,579**
				9.60	31.49	54.44	4.47	.58	4.99	62.52	1.53	25.91	6,096	10,974
					34.83	60.23	4.94	.64	4.34	69.16	1.69	19.23	6,743	12,137
					36.64	**63.36**	......	**.67**	**4.56**	**72.76**	**1.78**	**20.23**	**7,093**	**12,768**
5951	Prospect.	90	6.20	**13.92**	**29.50**	**52.49**	**4.09**	**.52**	......	......	......	......	**5,776**	**10,397**
				8.23	31.45	55.96	4.36	.55	......	......	......	......	6,158	11,084
					34.27	60.98	4.75	.60	......	......	......	......	6,710	12,078
					35.98	**64.02**	......	**.63**	......	......	......	......	**7,045**	**12,680**

[a] Four analyses are given for each sample, arranged as follows: As received, air-dried, dry coal, pure coal (moisture and ash free).

From the analyses given above it appears that the weathered zone of the Black Buttes coal extends approximately 100 feet down the dip of the beds and 40 feet below the surface. The calorific values of unaltered air-dried coal are between 11,500 and 12,000 British thermal units; on a basis of pure coal the values approach 13,000 British thermal units.

COALS OF THE BLACK ROCK GROUP.

No large mines have been opened on the Black Rock beds, but there are several small country mines from which a small amount of coal is taken annually for local ranch use, so that it is possible to get good samples of unaltered coal. The results of analyses of Black Rock coal taken from surface prospects in the belt of weathering are given in Bulletin 341, page 272, Nos. 5375 and 5367. Both of these samples give in the calorimeter approximately one-half the efficiency of the unaltered coal sampled in the small country mines.

Two illustrations of partial weathering and oxygenation are afforded by samples No. 5374 (Bulletin 341, p. 272) and No. 6771 (p. 245 of the present report). All other samples of Black Rock coal were taken from freshly cut faces of small mines that had passed through the weathered zone and furnished good samples of unaltered coal As all these samples were taken at distances from 30 to 150 feet from the mouth of the mine it shows that the belt of weathering does not extend very far below the surface. The heat values as shown by samples Nos. 6794, 6774, and 6795, page 245 of this report, and Nos. 5930, 5803, and 5802, page 272 of Bulletin 341, may not be so high as those of the coal taken from greater depths. From the regularity here shown it appears that most if not all of these samples were obtained near or below the lower limit of the weathered zone. The calorific value of unaltered air-dried coal lies between 11,000 and 11,650 British thermal units; on the basis of pure coal it exceeds 13,000 British thermal units.

CONCLUSIONS.

It was not considered advisable in this preliminary paper to take up the results of weathering observed by other men in different localities under somewhat different conditions, or to refer to published articles on the weathering of coal. This was left for a fuller discussion of the subject of weathering to be taken up at some future time. In presenting the foregoing observations on the weathering of coal the factors involved are restricted entirely to those present in the Rock Springs field, and the following conclusions are therefore based on these local data.

The results obtained in the Rock Springs field indicate that so far as coal decomposition or deterioration is concerned the belt of weathering in arid regions may be divided into two members. Coal in the lower member of the belt apparently shows no greater effect of weathering or deterioration than the coal below the level of ground water, but coal in the upper member, or in the surficial belt of weathering, shows remarkable deterioration and decomposition. The protection of the coal above the level of ground water in the lower member of the belt of weathering may in part be accounted for by the accompanying beds of clay and shale, which tend to shut out the oxygen and free circulation almost as completely as the ground water.

On comparison of averages in the table of analyses of Rock Springs coal showing the three stages of alteration it will be seen that the moisture and oxygen are greatly in excess in the surficial belt of weathering and that the fixed carbon and carbon both show a corresponding deficiency, or a loss of approximately 20 per cent from the carbon content in the unaltered mine samples. Volatile matter, ash, sulphur, hydrogen, and nitrogen are fairly uniform in the three stages. There is, however, a slight increase in the ash content in the weathered belt and a decrease in the sulphur content, which indicates that some of the iron sulphide in the coal has been changed to iron oxide. This view is further supported by the iron stain or oxide seen on the face of the coal in the air-slaked or weathered stage. The sulphur, probably combined with hydrogen, is taken into solution in the underground water and carried off as hydrogen sulphide.

The values for calories and British thermal units show that the factors of weathering are negligible in the Rock Springs coal in the Gunn B mine at a point 80 feet down the slope, or 12 feet vertically below the opening of the mine, where the coal has a cover of 56 feet. On an ash and moisture free basis the unweathered coal shows over 13,700 British thermal units, the average for the 25 unweathered Rock Springs coal samples being 13,875 British thermal units. In the Almond coal weathering seems to have altered the coal to a distance of more than 227 feet along the entry and 103 feet below the surface. Part of this weathering no doubt is due to the circulation of air along the old mine entry; and in the lower bed the alteration extends back more than 575 feet. Unweathered coal from this mine gives over 13,000 British thermal units on the moisture and ash free basis. In the Black Buttes coal weathering seems to have progressed to a point 100 feet down the slope, or approximately 40 feet below the surface. Unweathered coal from this mine has a fuel value of more than 13,100 British thermal units on the moisture and ash free basis.

The analyses show that the proportions of the various constituents are about the same whether the sample of coal was taken near the surface or at a greater depth, the only exception being the oxygen, which in every case is perceptibly higher near the surface than at greater depths and by its excess shows the extent of the surficial belt of weathering. The ash, sulphur, and hydrogen content remain fairly constant. There appears to be a slight increase in the amount of hydrogen and ash in the samples obtained near the surface, with a corresponding decrease in the amount of sulphur. It appears from this that the belt of surficial weathering is one of marked oxidation and in this field for the most part lies near the surface, in few places, if anywhere, extending to the ground-water level. If the coal is not open or exposed to the air, the weathered zone does not as a rule extend more than 150 feet down the dip of the beds, or 50 feet below the surface. Along slopes and mine or prospect entries the coal weathers back several hundred feet from the mouth of the mine and several hundred feet below the surface. It is known that in one old mine the coal has changed at least 20 feet back from the face of an old entry approximately 227 feet down in the mine and that deterioration extends back into the mine 575 feet from its mouth. It is very probable that in an abandoned mine remaining open to the air oxygenation in time extends throughout the mine and that the coals of lower grade show the effect of oxygenation much more than the high-grade coals.