COAL FIELDS OF NORTHWESTERN COLORADO AND NORTHEASTERN UTAH.

By Hoyt S. Gale.

INTRODUCTION.

NATURE OF THE PRESENT INVESTIGATION.

This paper is a preliminary statement of the results of work in the coal fields of northwestern Colorado and northeastern Utah during the summer of 1907.[a] In 1905 a preliminary reconnaissance of the Yampa coal field, of Routt County, was made.[b] In the summer of 1906 similar work was extended southwestward from the Yampa field, and the Danforth Hills and Grand Hogback coal fields, of Routt, Rio Blanco, and Garfield counties, were mapped.[c] The work of the past season was a continuation of that of the two preceding years, extending the area studied westward through Routt and Rio Blanco counties, Colo., and including some less extensive coal fields in Uinta County, Utah, and southern Uinta County, Wyo.

ACCESSIBILITY.

At present these fields have no railroad connection, although surveys for several projected lines have recently been made into the region. Of these lines, the Denver, Northwestern and Pacific Railway ("Moffat road") is under active construction in the eastern part of Routt County and bids fair to push westward not far from the lower Yampa and White River fields in the near future. An extension of the Uintah Railway has been surveyed from Dragon to Vernal, Utah, crossing the projected route of the "Moffat road" near Green River. The Union Pacific Railroad has made a preliminary survey south from Rawlins, Wyo., intending to reach the Yampa Valley in the vicinity of Craig.

[a] A more complete report combining the results of the preceding season's work in the Danforth Hills and Grand Hogback fields with those of last season's work as outlined here, togethor with detailed contour maps of the whole area, will be published as a separate bulletin of the Survey.

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

[c] Gale, H. S., The coal fields of the Danforth Hills and Grand Hogback, Colorado: Bull. U. S. Geol. Survey No. 316, 1907, pp. 264-301.

FIELD WORK.

Personnel.—The members of the field party engaged in geologic work throughout the season were John A. Davis, Charles W. Stoops, and the author. T. W. Stanton spent about three weeks with the party at the beginning of the season, for the purpose of collecting fossil evidence bearing on the age of the coal-bearing beds. W. H. Beekly and J. Sidney Heil rendered valuable assistance in the management of the camp and in the field work.

Methods and conditions.—This work was planned for the purpose of making a preliminary examination and classification of the public lands upon which valuable coal was supposed to exist, but about which very little authoritative information was available. Much of the field work was based on the recently established lines of the township resurveys in this part of Colorado. In each township or part of a township that contained coal, a large proportion of the section lines were retraced for the purpose of locating the coal. This was done with a pocket compass, the distances being measured by pacing and checked by the corners that were found along the lines. An average of about five working days for one man was devoted to each township, and this may serve as a rough measure of the detail that could be obtained in such a review of the area. In addition to this work meanders were made along roads and trails or in gulches and canyons for the purpose of examining the most favorably exposed geologic sections and procuring such additional data as could not be obtained by other methods.

In territory where the new surveys had not been completed it was necessary to pursue a method of traverse, for which both plane table and compass and notebook were used. In the absence of the constant checks on well-established land corners it was not possible to obtain so satisfactory a result as by the other method.

By far the greater part of the valuable coal is concealed at the surface, and its presence over much of the region can only be inferred from a study of the sections where it is better exposed. Individual beds can not be traced from place to place for any considerable distance without doing a great amount of development work along the outcrops, and indeed it is extremely doubtful if such work could ever be satisfactorily done in much of the field until all or most of the beds are actually opened in mining or have been prospected by the drill. More and more detailed examinations will doubtless become necessary from time to time as the development of the field progresses and the coal lands themselves become more valuable.

GEOLOGY.

STRATIGRAPHY.

SIGNIFICANCE OF THE ROCK FORMATIONS.

The deposits in which the coal was originally formed are a part of a great series of sedimentary strata that were laid down at a time when this part of the continent was largely submerged. The submergence probably ranged from deep sea to shallow water and swampy conditions, as well as from salt-water or marine to brackish and fresh water stages. These strata were deposited in an approximately horizontal position. Subsequent movements of the earth's crust have folded or even broken the originally continuous deposits, so that it is now necessary to study their attitude and order of superposition in order to explain the relations of one set of beds to another. Their position in the stratigraphic section indicates in a general way their relative geologic age, although there are also evidences that great time intervals have elapsed in which no deposits were being formed, or in which was being laid down material that was subsequently removed, leaving little or no record of its existence.

SUMMARY AND DESCRIPTION OF FORMATIONS.

The following table is a brief description of evidence that has been collected from this general region, but includes only that part of the stratigraphic column most directly related to a discussion of the coal-bearing rocks.

Rock formations of the northwestern Colorado coal fields.

Geologic age.	Formation.	Description of strata.	Topographic features.	Thickness.	Economic value.
Probably late Tertiary or younger.	"Browns Park" formation.	Consists of loose or slightly consolidated sandy material with local harder sandstone beds and some beds of gravel. Contains much calcareous material in the form of cement or filling between the quartz sand grains. Its color is everywhere chalky or limy white.	Forms low sand hills or valley country, commonly covered sparsely with sagebrush, greasewood, cedar, or piñon. Typically exposed in Axial Basin about Juniper Mountain, and supposed to extend continuously northwestward into Browns Park.	Not determined.	

Marked unconformity.

Rock formations of the northwestern Colorado coal fields—Continued.

Geologic age.	Formation.	Description of strata.	Topographic features.	Thickness.	Economic value.
Tertiary.	Green River formation.	Composed of shale, sandstone, and beds of öolitic rock. The shaly beds predominate and are very compact and firmly bedded. They are generally exposed in escarpments and high bluffs in which the weathered beds have a very characteristic chalky-white aspect. The shales are, however, of various shades of gray, drab, and light brown and are in many places hard and thin bedded. In some districts the lower part contains much massive white sandstone.	Characterized by plateaus where it is flat lying; these regions being bordered by high and abrupt escarpments at the margins or near the uptilted areas. This formation is only slightly affected by weathering except where broken or exposed in a tilted position. It is cut by deep canyons along the stream channels, as it readily gives way to erosion by the attrition of mechanically transported harder material. It is well represented in the Roan or Book Cliffs Plateau, the Cathedral Bluffs, and the Gray Hills.	Measured sections exceed 2,400 feet; upper limit not reached.	Gilsonite and related hydrocarbons in the Uinta Basin.
	Wasatch formation.	Composed chiefly of clay or soft clay shale; commonly variegated, but various shades of red and drab predominate. It also contains beds of pebbles or conglomerate of very perfectly rounded silicious material, such as jasper, colored vein quartz, chert, or flint. Sandstones in places very massive and hard.	Commonly weathers to low valley or ridge country, at some places scarred by badland washes. It is usually distinguished by the banded or colored clays in the bluffs underlying or adjacent to the escarpments of the Green River formation. Cactus Valley, on Grand River, is eroded from these beds.	From 4,000 feet on the eastern side of the Uinta Basin to about 2,500 feet near the Utah line.	Oil and asphaltum deposits near Vernal, Utah.
	Name and correlation not determined; possibly of Fort Union or earlier age.	Beds not readily distinguished from the Wasatch in the Uinta Basin, but apparently more clearly differentiated in the Yampa field. As developed in the latter region they consist of massive white or light-colored sandstones and shales containing valuable coal beds sharply defined at the base by a conglomerate or conglomeratic sandstone, without doubt marking an unconformity of considerable magnitude.	Forms ridges and hilly country, especially where the sandstone members are prominent and numerous. Topography resembles that of the other coal-bearing formations, although not commonly so rugged as that of the Mesaverde.	Estimated as about 800 feet on Lay Creek north of Lay.	Workable coal.
		Unconformity.			

Rock formations of the northwestern Colorado coal fields—Continued.

Geologic age.	Formation.	Description of strata.	Topographic features.	Thickness.	Economic value.
Cretaceous.	Laramie formation.	Consists of massive sandstones and light-colored sandy or clay shales and many beds of lignite or subbituminous coal. As mapped, this formation includes the strata in which the massive sandstones are most prominent as distinguished from the softer strata of the underlying Lewis shale. As a whole the formation represents the transitional deposits of brackish or fresh-water origin, conformably overlying the uppermost marine formation. The lowermost sandstones mapped with the Laramie contain a marine fauna similar to that of the underlying Lewis shale.	In the eastern part of the Yampa River valley the Laramie is clearly distinguished from the underlying Lewis both lithologically and in its effect on the topography. It is similar to the overlying and supposedly lower Tertiary beds, from which it is distinguished only by the presence of the intervening conglomerate and evidence of unconformity. In the western part of the region the lower limit of the Laramie is less clearly defined, as the sandstones probably occur lower than they do farther east. The base of the formation is well represented at Hayden, in the escarpment bluff north of Yampa River.	Estimated as 1,200 feet between Craig and Lay.	Workable coal.
	Lewis shale.	Composed largely of soft dark-gray or black clay shale with calcareous seams and sandy beds, the latter developing in many places as massive and continuous ledges. The absence of the sandstones is the most prominent distinction between the Lewis and the overlying and underlying formations.	The outcrop of the Lewis shale is commonly marked by low valleys bounded on one side by the sandstone ridges of the Mesaverde and on the other by the escarpments of the Laramie. In the western part of the Yampa field the distinction is not so well marked, as sandstone occurs within the interval assumed to represent the Lewis.	Roughly estimated 1,000 feet in the valley of Horse Gulch.	Develops some valuable agricultural land on alluvial material along the valley bottoms.
	Mesaverde formation.	Includes an alternating succession of sandstone, sandy shale, and coal beds. The most prominent members are the massive white or light-colored sandstones. The weaker shaly members are more commonly covered by débris of the harder beds. The coal beds are even more generally concealed, although their positions are rendered conspicuous by the great amount of burning that has taken place along the outcrop.	Forms hogback ridges and rugged, hilly country. The topographic forms are usually strong, contrasting with the valleys of overlying and underlying formations. The character of the ridges is chiefly dependent on the attitude of the underlying strata. Where steeply tilted the harder beds form sharp-crested hogbacks, and where more nearly horizontal they form broader flat or round-topped ridges bordered by escarpments or long, gentle dip slopes.	From about 3,000 to over 5,000 feet.	Coal. This formation commonly includes many thick beds of good bituminous coal.

Rock formations of the northwestern Colorado coal fields—Continued.

Geologic age.	Formation.	Description of strata.	Topographic features.	Thickness.	Economic value.
Cretaceous.	Mancos shale (including Benton fossils in its lower part).	A thick mass of dark drab or gray shale, containing lenticular members of sandstone or sandy strata, and near its base very constantly one or more beds of fine-grained dark sandstone and some limestone. In Utah the lower sandstone is lighter colored, coarse, and more prominent. In that part of the field coal is also found associated with these lower sandstone members. At the base is a compact dark slaty shale.	Forms open valleys and broad parks, many of which are extensive. These are commonly traversed by some of the larger streams, and in places broad bottom lands are developed. The sides of the valleys generally show terraces or "mesas" at various elevations above the valley bottoms. All these features are well represented in Agency Park, Axial Basin, Raven Park, and elsewhere.	5,000 feet.	Oil in the Rangely district. Agricultural lands where favorably situated. Workable coal near the base in the Vernal district.
	Dakota sandstone.	Commonly consists of two or more members of massive sandstone or quartzite, in many places conglomeratic, with sandy or clay shale intervening. In places carbonaceous shale is found in this formation. It is limited at the base by varicolored clays, clay shales, and associated strata now supposed to belong to the Jurassic.	Is developed as an independent hogback where tilted, and differentiated by intermediate shale bodies from the underlying Jurassic sandstones. Very commonly combined with the latter in high, sharp hogbacks with elevated broad dip slopes usually covered with brush or timber.	From 100 to 300 feet or possibly more.	

Below the formations described in the foregoing table a great thickness of older rock strata occur which are not described here, as they are not directly connected with the discussion of the commercially important coal fields.

AGE OF THE COAL-BEARING ROCKS.

As indicated in the table, workable coal is found in a number of formations, including the Mancos, Mesaverde, Laramie, and an overlying formation supposed to represent the Fort Union or earlier rocks. Beds of coal and carbonaceous or lignitic material are even more widely distributed in the geologic section. Two localities were observed where coal occurs in beds older than the Cretaceous formations described in the table. Of these one of possible commercial value in the Henrys Fork field, in Utah, is described on page 311. A thin bed of coal of doubtful quality has also been noted in Jurassic strata on upper Red Wash, on the south side of Blue Mountain, Routt County, Colo.

Carbonaceous shale somewhat resembling coal has also been noted in the sandstone in the lower part of the Mancos in the same general locality as that of the Jurassic coal just noted. Coal has been opened in a mine 3 or 4 miles south of Lily Park, Colo., where it occurs in beds closely adjacent to the Dakota sandstone.

The strata overlying the Dakota include by far the greater part of the valuable coal. A brief summary of the occurrences of the coals of the various formations is given below; this will be followed by more detailed descriptions of the individual coal beds.

The coal near the base of the Mancos shale is important in the Vernal field of Utah, where it is mined to a considerable extent for domestic use.

The Mesaverde is the most important coal-bearing formation in the region, constituting by far the largest extent of coal territory and containing the greatest thickness of workable beds.

The Laramie coal is found in the Yampa field north of Yampa River and is developed to a very moderate extent near Hayden and Craig.

The post-Laramie coal of Fort Union or earlier age is also found in the Yampa field and is developed in a small way at several points north of Yampa River.

GENERAL FEATURES OF THE MESAVERDE FORMATION.

As stated above, the Mesaverde is the most important of the coal-bearing formations in these fields. On account of the magnitude of this formation, which is approximately a mile thick in many parts of the Danforth Hills and Grand Hogback fields, the arrangement and character of its beds and the grouping of the coals are important factors in influencing the areal distribution of the coal available for development.

The Mesaverde formation is composed predominantly of sandstone and sandy shale. Among these strata the coal beds are usually arranged so that they may be naturally divided into three groups. Recognition of these groups of coal beds has already become fairly established in the local usage, especially in some of the better-known districts, where the whole Mesaverde section is exposed.

In the Uinta Basin the term "lower coal group" is applied to coal beds near the base of the Mesaverde formation. In the fields here discussed this group usually consists of a few unimportant beds of coal, locally of fair or good quality, but usually too thin to work. Where thicker beds occur they are commonly broken into many thin benches by bony or shaly material, so that the coals are in general not workable. Some exceptions to this rule occur, but they are not known in the area here described. The strata associated with the lower coals are largely of marine origin, as shown by the fossils they contain. This lower marine portion of the Mesaverde formation is distinguished by a separate pattern on the geologic maps.

The middle group comprises most of the workable coal beds found in the Mesaverde formation. The strata associated with these coals are in many places rather sharply delimited from the lower marine part of the Mesaverde formation, both by the marked change in the character of the strata from barren below to coal bearing above, and in many parts of the fields by the occurrence of a large and conspicuous white sandstone bed just below the base of the coals. This may very properly be included with the lower or relatively barren part of the formation, as in numerous places it contains marine fossils. Where it can be identified it furnishes a very convenient key rock from which to measure the stratigraphic positions of the various beds that overlie it. As noted in previous reports on this general region, it is commonly referred to as the "white rock."

Above the "white rock," coal beds of the middle coal group show almost everywhere, either in weathered outcrops or more generally as bands of reddened and baked rock or slag, where the coal has been burned along its outcrop. Higher in the formation the coal beds are scattered irregularly and vary from place to place, so that individual sections do not correspond closely in the number and grouping of the coal beds. The massive sandstone ledges are by far the most conspicuous features, in many places masking by their débris the outcrop of the intervening strata of weaker rocks.

An upper coal group near the top of the Mesaverde section is commonly separated from the middle group by a considerable interval of relatively barren strata. There is some evidence that the coal of this part of the section is of lighter weight than the average of the older coals and that it usually slacks more rapidly, in this way resembling the subbituminous coals of the Laramie and later formations. Though this difference may not hold constantly throughout the fields, it seems nevertheless to be general.

The total thickness of workable coal in the whole formation of course varies largely. It is perhaps at or near a maximum at Newcastle, Colo., where 108 feet of coal is found distributed in seven workable beds. At Meeker the section is known to contain at least 75 feet of coal distributed in ten beds, with possibly others not shown by present development. Unfortunately the sections of this formation in the fields here described are too incompletely known to give any reliable estimates of the total amount of coal they contain.

The three coal groups defined in the report on the Yampa coal field do not correspond to the limits assigned to these groups in the western part of the same field or in the fields to the south. The lower and middle groups of the eastern Yampa field are not distinguished as separate in the fields to the south and west and together are included in the middle group. The upper coal group is probably at approximately the same stratigraphic position in the two fields, although no positive evidence can be offered to prove this point.

STRUCTURE.

General outline.—The sedimentary strata were without doubt originally deposited in an approximately horizontal position, but they have later been tilted, exposing them in various attitudes and resulting in much irregularity in the outline of their outcrops. This displacement of the strata and subsequent erosion have also brought about the separation of some fields that were probably once continuous. It also seems likely that some of the deposits were laid down in separated basins and so may never have been continuous, although apparently separated by relatively narrow barriers.

Major structural basins.—The coal fields of northwestern Colorado lie in two major structural basins, surrounded by areas of older rock formations that are relatively uplifted. The northern of these two is known as the Green River Basin, which extends into Colorado as far as the upper valley of Yampa River. The Yampa coal field occupies a part of this basin. The southern of the two major structural basins is known as the Uinta Basin, and the Colorado portion is also termed the Grand River Basin. This is separated from the Green River Basin in the Yampa coal field by the anticlinal axis of the Uinta Mountains, which extends eastward from that range in Utah through Axial Basin and joins with the uplifts of the White River Plateau and the western spurs of the Rocky Mountain system. The Grand Hogback, Danforth Hills, and lower White River coal fields are a part of the Uinta or Grand River Basin of Colorado.

That part of the Uinta Basin which was examined during the last year extends from the Danforth Hills westward to and beyond the Colorado-Utah State line. The Green River Basin includes the western part of the Yampa field and the Henrys Fork field of Utah and Wyoming, which are also described in this report.

Minor folds.—Details of the minor structural features of these two major basins are brought out by the structure symbols on the accompanying maps. It is evident from the sinuosity of outcrop of the tilted strata that their positions at the surface are the direct result of the depth to which erosion has progressed into the structurally irregular underlying beds.

Larger folds of the White River and Vernal fields.—The structural irregularity of the northeastern margin of the Grand River Basin is pronounced, forming a series of domes and anticlines and correlative synclinal folds. As several of these features are referred to in the following pages in relation to their influence on the trend of the coal-bearing rocks, they will be briefly reviewed here.

South of the Axial Basin anticline and west of the Danforth Hills lies the Coyote Basin, or Crooked Wash, essentially a broad syncline toward which the coal-bearing strata dip from the east, north, and west and around which the rocks outcrop in a continuous rim except on the south side. A subordinate anticline with a north-south axis arches the strata through the very center of this basin, crossing White River at the mouth of Blacks Gulch, near Piceance Creek, but does not bring the coal rocks to the surface. West of the Coyote Basin syncline the structures are more intimately related to the folds of the Uinta Mountains, as these features are more or less symmetrical from Blue Mountain southward in Colorado and also from that uplift northward in the Utah part of the region. The summit and southern flanks of Blue Mountain are due to a great anticlinal flexure whose axis extends east and west and pitches in either direction. At its eastern extremity it bends toward the southeast and merges with the western flank of the Coyote Basin syncline. To the west this fold pitches more abruptly and disappears very abruptly near the Colorado-Utah State line. It has been called the Midland uplift or anticline, a name given to it in the early work of the Hayden Survey. Northwest of the termination of the Midland anticline a similar fold with axis parallel to that uplift and also pitching to the west, is recognized in Section Ridge. This fold extends westward as far as Green River and is referred to as the Section Ridge anticline. North of Section Ridge a still more pronounced arch of the strata, very similar in character and direction to the others, forms the high ridge known as Split Mountain, through which Green River passes in a canyon. This fold, known as the Split Mountain anticline, pitches to the west and disappears along the lower course of Brush Creek west of Vernal. North of Split Mountain a broad structural depression to which the name Island Park syncline is given lies between the Split Mountain anticline on the south and the main Uinta Range on the north.

South of Blue Mountain in Colorado a low, oval dome on White River is known as the Raven Park anticline, and this has already been described in some detail as an oil field.[a] South of the Raven Park uplift a similar though broader and more gentle flexure occupies an extensive area on Douglas Creek. It has been convenient to give names to some of the intervening synclines, and such names are explained in the text.

Influence on distribution of coals.—All these folds influence the trend of the outcrops of coal-bearing rocks, and consequently a general knowledge of the distribution and arrangement of the folds is essential to an understanding of the relations of the various parts of the coal fields.

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[a] Gale, H. S., Geology of the Rangely oil district, Rio Blanco County, Colo.: Bull. U. S. Geol. Survey No. 350, 1908.

DETAILED DESCRIPTION OF THE COAL FIELDS.

SCOPE OF TEXT AND MAPS IN PRESENT REPORT.

The extent and areal distribution of the outcrops of the geologic formations, with special reference to those containing the valuable coals, are represented on the geologic maps (Pls. XVI–XX). These maps are arranged to suit convenience of publication and description, retaining the scale of 4 miles to the inch which was used in the reports on adjacent districts and which is also that of the Hayden and King maps of this part of Colorado.

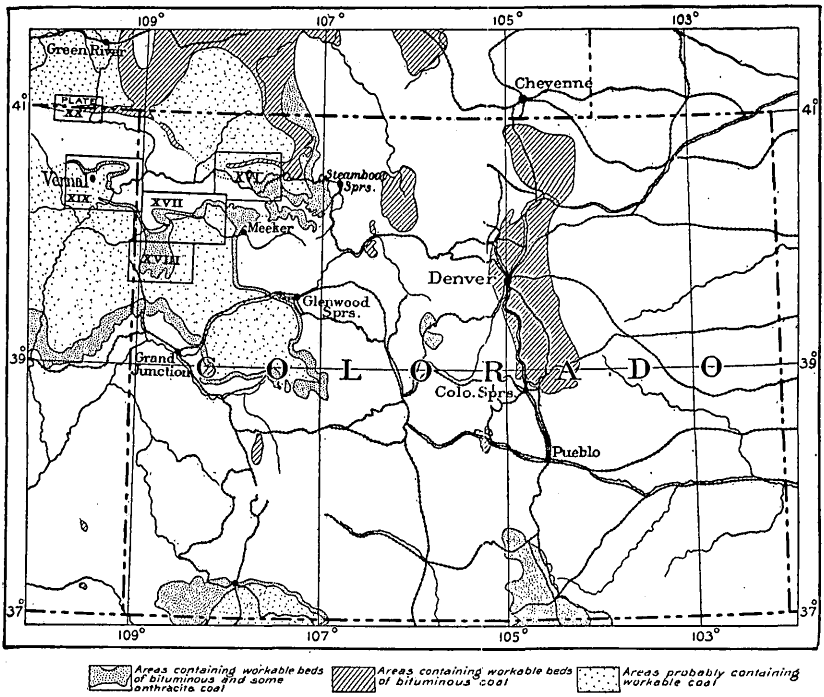


FIG. 5.—Map of Colorado and northeastern Utah coal fields, showing areas represented by Pls. XVI–XX: Western part of Yampa field (Pl. XVI); lower White River field north of the base line (Pl. XVII); Douglas Creek district, lower White River field south of the base line (Pl. XVIII); Vernal field (Pl. XIX); Henrys Fork field (Pl. XX).

In the brief space of this preliminary report only a very general description of the conditions in the several fields can be given in the text. The territory examined naturally belongs to several more or less distinct fields, as shown by fig. 5. These fields are described in the following pages.

WESTERN PART OF THE YAMPA FIELD.

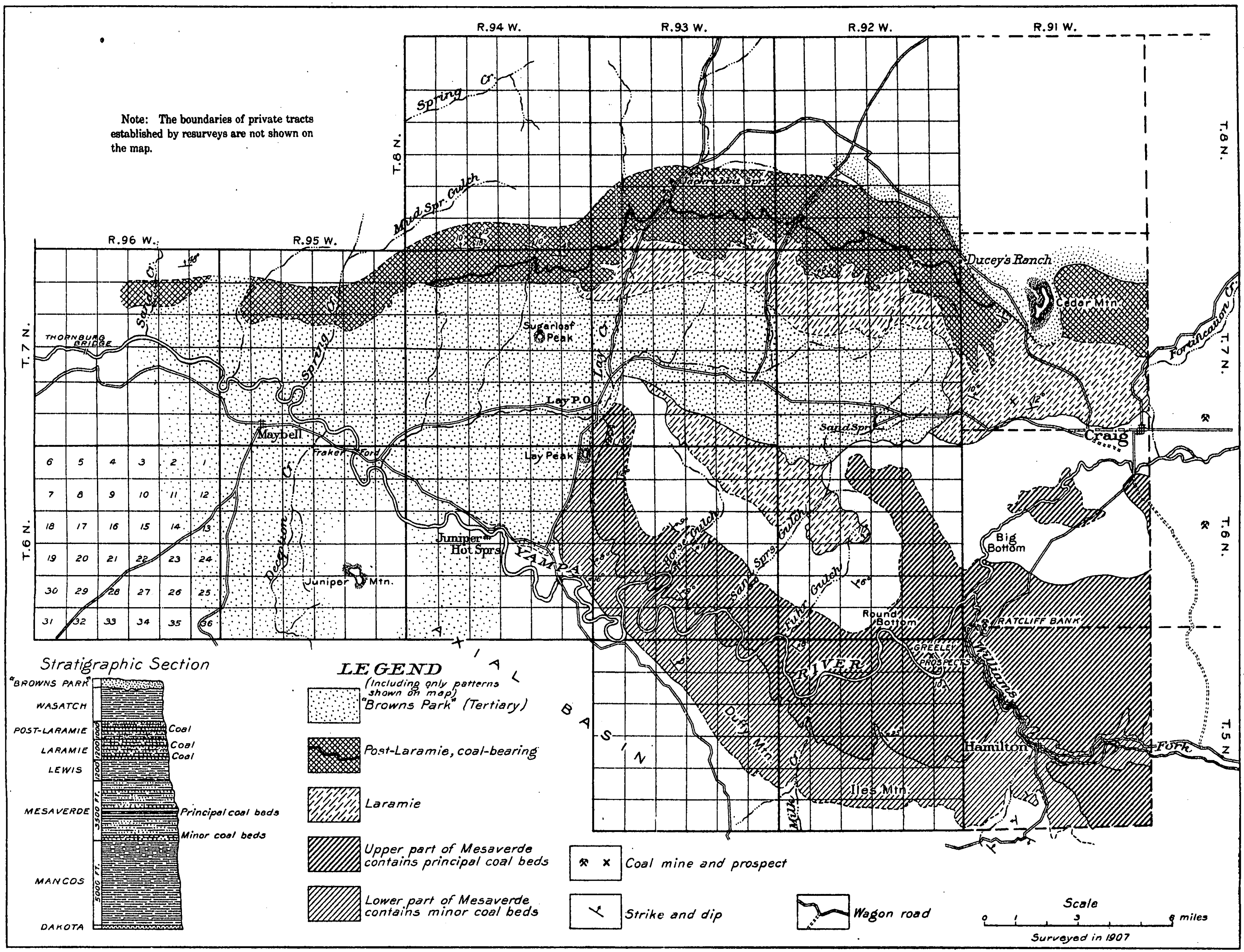
DISTRICT COVERED IN PRESENT REPORT.

The examination of the Yampa field in the former work in that region was not carried on in much detail west of the mouth of Williams Fork, although the coal-bearing rocks of the Mesaverde and overlying formations outcrop continuously westward from the main part of the Yampa field at least as far as Lay. In view of the recent completion of the township resurveys west of the line between Rs. 91 and 92 W., that part of the field was examined in more detail during the last season, and the map forming Pl. XVI embraces the results obtained during this examination.

MESAVERDE COAL.

Distribution and structure of Mesaverde rocks.—Along the valley of Yampa River west of the mouth of Williams Fork the Mesaverde rocks are tilted in several broad folds. The principal structure in this part of the field is the Axial Basin anticline, which forms the southern limit of the Green River Basin. The strata rise toward the axis of that uplift, from the summit of which the Mesaverde formation has been eroded so that the coal field terminates with the southward-facing escarpments of Iles and Duffy mountains. Northeast of the Axial Basin uplift a corresponding syncline passes through Round Bottom, on Yampa River, with an axis approximately parallel to the major anticlinal fold. Northeast of the Round Bottom syncline a secondary anticline, with axis parallel to the other two folds, extends northwestward from the mouth of Williams Fork. This is exposed as far as Sand Springs, near the Craig-Lay wagon road, and doubtless influences the underlying structure much beyond that point, although concealed by the overlying unconformable deposits. The prevailing dips in all these structures are light, for the most part not exceeding 10° to 15°.

Typical sections and coal groups.—The complete section of the Mesaverde formation exposed in the western part of the Yampa field is about 3,500 feet thick. This resembles the section of the same formation exposed in the Danforth Hills, although in the Yampa field it appears to be somewhat thinner. The evidence on which the lower members of the formation in the two fields are correlated consists of (1) the structural relations in Axial Basin, (2) the striking correspondence in arrangement in the basal group of sandstones and shales on either side of the erosional break, and (3) the correspondence of fauna and flora obtained from the two sections, of which some representative collections have been made and studied by T. W. Stanton. The arrangement and grouping of the coal beds in the Yampa field correspond well with the sections exposed in the Danforth Hills. Above the lower and relatively barren zone no distinction can be made between the lower and middle coal groups as these were described in the report on the Yampa field, and they thus merge into a single large coal group. The lower coal group of this part of the field, as in the Danforth Hills, is recognized as a group of relatively inconspicuous beds occurring lower than any distinguished in the groups that were described in the report on the main Yampa field.



MAP OF THE WESTERN PART OF THE YAMPA COAL FIELD, ROUTT COUNTY, COLORADO

By Hoyt S. Gale, J. A. Davis, and C. W. Stoops

Total thickness of workable coal.—Little additional evidence beyond that contained in the previous report has been obtained as to the probable total amount of available coal in the Mesaverde formation in the Yampa field. Owing to the lack of more complete exposures, these figures must still remain largely as estimates. The section exposed at the Greely prospects on Yampa River, below the mouth of Williams Fork, reveals 30 to 50 feet of coal as a minimum. According to former measurements, the section so well exposed at Lay shows 55 feet of coal, within a stratigraphic range of only 320 feet, and the total amount of coal at that place is doubtless still greater.

Local development of the coal.—The most extensive development is at Lay, where the beds have been well prospected by A. G. Wallihan. Other prospects visited are those of the Greely group, just mentioned, a single entry in Horse Gulch, and several small prospects near Round Bottom. From none of these has any great amount of coal been mined.

LARAMIE COAL.

Distribution of Laramie strata.—As shown by the map (Pl. XVI), the outcrop of the Laramie formation extends westward from the main part of the Yampa field in a belt several miles wide, passing just north of Craig. These beds are doubtless continuous farther west, beyond the limits of the territory here described, but are so largely concealed by overlapping "Browns Park" beds that their outcrop covers a relatively small area. The total thickness of the formation is roughly estimated at 1,200 feet in the vicinity of Craig. There is a prevailing light dip to the north and a very uniform westerly trend of the outcrop, except where it is deflected from this course by the Round Bottom syncline and adjacent folds.

Coal beds.—Coal is found at various horizons, apparently irregularly distributed throughout the formation. Near Craig and also at Hayden some large beds occur near the base of the formation. Coal beds of considerable thickness are found higher in this formation, and are exposed in secs. 6 and 7, T. 7 N., R. 92 W. Other probably smaller beds at approximately the same horizon as the upper beds just mentioned were observed near Lay Creek, in sec. 7, T. 7 N., R. 93 W. No estimate is available of the total amount of coal in the Laramie section, as exposures are far too scattering and incomplete to afford the necessary data. About the best observed exposure is at the Kimberly bank, just east of Craig. Here an 8-foot bed of solid coal, with a dip of 14° N., has been opened in a prospect entry. It does not, however, seem to have found favor with the local residents of Craig, who prefer to make a considerably longer haul to get the Mesaverde coal rather than mine and use this coal. It is of lighter weight than the older coal and is said to slack more rapidly.

POST-LARAMIE COAL.

Nomenclature and stratigraphic position.—A considerable group of workable coals is found in the formation unconformably overlying the Laramie. On account of the uncertainty as to whether these beds should be called Fort Union and classed as a part of the Tertiary system or form an upper and unconformable part of the Cretaceous system, the coals are for the present referred to as post-Laramie, as they constitute the only recognized coal group overlying the Laramie formation in this field. The zone containing the workable coals is in the lower part of these later beds. The principal coal group appears to be in a zone 400 to 500 feet above the basal conglomerate member already described as marking the unconformity at the top of the Laramie.

Distribution of post-Laramie coal-bearing strata.—The coal-bearing beds immediately succeeding and overlying the Laramie in the Yampa field outcrop in a belt of hills and ridges north of the Laramie district. They extend continuously westward from the vicinity of Cedar Mountain as far as and probably beyond Maybell, but beyond Sand Creek they are concealed by the unconformable "Browns Park" beds.

Local development of the coal.—West of Cedar Mountain these coals are found near Ducey's ranch, in the northeast corner of T. 7 N., R. 92 W., where a local bank has been opened on one of the beds in the NW. ¼ sec. 2. The coal exposed at the entry is 7 feet 2 inches thick and is overlain by soft clay or shale; about 2½ feet of the top of the coal has been left as roof. West of this point the coal may be readily traced by numerous outcrops through T. 8 N., Rs. 92 and 93 W., and T. 7 N., Rs. 94 and 95 W.

In the valley of Lay Creek one of the beds of this group has been worked for local use at the Blevins mine, in the NW. ¼ sec. 28, T. 8 N., R. 93 W. The coal at the Blevins mine appears to be fairly representative of most of the coals of this group. The bed is 11 feet 4 inches thick, and all of it is taken out in the entry, together with about 5 inches of laminated blue clay at the top. Above the clay is a massive, coarse-grained white sandstone forming a solid roof at least 40 feet thick. The beds dip 4° N. 5° E. The coal bed is without seam or parting. The floor is covered by 4 or 5 inches of bony coal, below which is a solid white sandstone. There are no signs of burning of the outcrops in this immediate vicinity; in fact, the coals of this group seem less subject to combustion at the outcrops than the older coals.

Some of the post-Laramie coals are also opened in Spring Creek Gulch, in T. 7 N., R. 95 W., where several local banks have been worked at various times.

Character of the post-Laramie coal.—The coal breaks down at the face of the Blevins mine very easily when loosened, but is very tough and has to be shot, as it can not be picked out before it is broken. It is reported that exposure to the open air for three weeks will slack the coal completely. When first lighted it emits a pale blue smoke resembling that given off by dry soft wood, but this color soon disappears, leaving a clear, smokeless flame.

The analysis of the post-Laramie coal (No. 5514, p. 314) shows it to be of somewhat lower efficiency than the average Mesaverde coals of the Yampa field. The coal would probably fall in the class of subbituminous coals formerly described as black lignite. The amount of moisture (12½ per cent on air-dried coal) is rather too high to place the coal in the bituminous class, although the fixed carbon (50 per cent) compares very favorably with that in many of the high-grade coals. The ash (7½ per cent) is a fair average for commercial coal. The appearance of this coal when first mined is very like that of the high-grade bituminous coals. Its principal disadvantageous feature is the fact that it slacks readily when exposed to the air.

Total thickness of workable beds.—All the coal beds of this group are not exposed in any one section, and hence complete measurements were not obtained in the present investigation. A. G. Wallihan, of Lay, states that some good exposures are to be found in the ridges west of Emerson's ranch, on Lay Creek, where he claims to have opened by digging twelve different coal beds, ranging from 4 to 20 feet in thickness and aggregating a total of more than 100 feet of workable coal as measured at the croppings.

LOWER WHITE RIVER FIELD.

POSITION AND OUTLINE.

West of the Danforth Hills the Mesaverde strata and the valuable coal beds which they contain are continuous to and beyond the Utah line, as shown by Pl. XVII. This field occupies in part the divide between White and Yampa rivers, but by far the greater part of it lies in the drainage basin of White River in Colorado. As White River joins Green River about 40 miles west of the Colorado-Utah line, and as the coals are mostly confined to the Colorado portion of that drainage basin, it has seemed most appropriate to apply the name "lower White River" to the Colorado field.

This field includes a continuous outcrop of the Mesaverde rocks, extending from the northwestern part of the Danforth Hills, describing roughly a semicircle around the north end of Crooked Wash, or Coyote Basin, and thence passing southward along Piñon Ridge to White River at the mouths of Wolf and Yellow creeks. From this point the outcrops of the coal-bearing rocks bend abruptly westward, forming a narrow hogback on the north side of White River. In the vicinity of Raven Park the rocks spread out in broader folds and cover an extensive territory, reaching from the vicinity of Blue Mountain on the north to a line within a few miles of the Book Cliffs divide at the head of Douglas Creek on the south. Northwest of Raven Park the coal-bearing strata have been traced continuously into Utah as a narrowing belt, which is described in a subsequent section of this paper as the Vernal field.

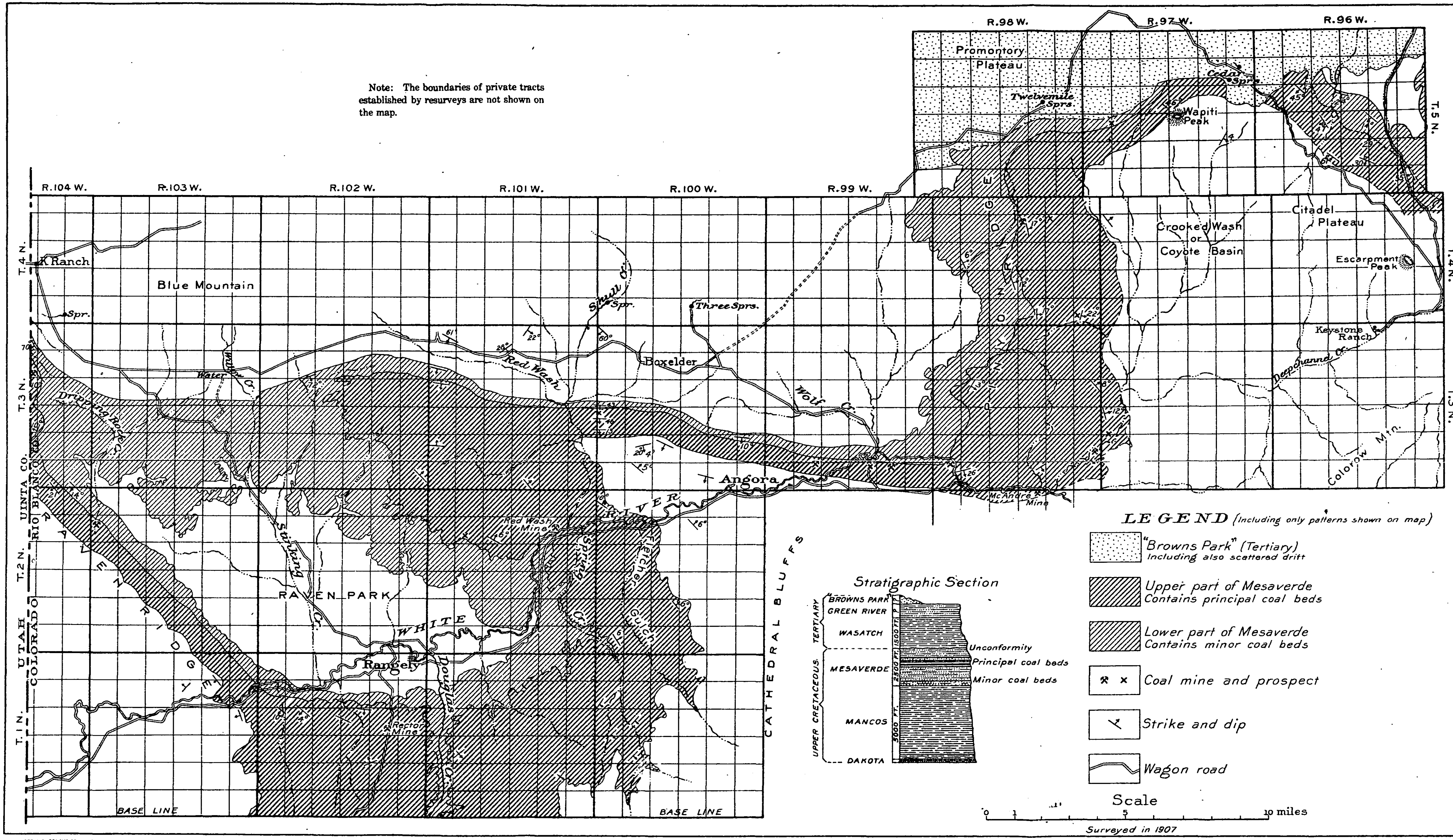
The examination of the lower White River field was commenced in Tps. 4 and 5 N., R. 96 W., and continued westward along the outcrops of the coal-bearing rocks, as indicated on the map (Pl. XVII).

AGE OF COAL-BEARING ROCKS.

As explained briefly under the heading "Stratigraphy," the Mesaverde constitutes the only important coal-bearing formation of the lower White River field, the Laramie being absent from the geologic section south of Axial Basin. Furthermore, the post-Laramie formations appear to be barren of valuable coals, and it is still uncertain if any of the strata of the Grand River Basin, of which the White River field is a part, are strictly to be correlated with the coal-bearing strata that overlie the Laramie beds of the Yampa field. The correlation of the basal Tertiary beds of the two fields will therefore be left an open question for the present, as it is necessary to discuss here only the Mesaverde beds in the fields of the southern basin.

SUBDIVISION OF THE WHITE RIVER FIELD.

The lower White River field is considered in two parts as divided at the base line, and is represented in this way on Pls. XVII and XVIII. This is done partly as a matter of convenience for publication of the maps and partly to separate the results of the more detailed examination made north of the base line from those of the hasty reconnaissance of the area south of the line. Most of the territory north of the base line has been either recently resurveyed by the General Land Office, or the contracts have been let and it is expected that the work will be completed in the near future. On the other hand, in the territory south of the base line and west of the twelfth auxiliary guide meridian, the old land surveys are believed to be in large part practically without value, and very few corners were discovered in the present investigation. In the Douglas Creek drainage basin only three land corners were found, and these do not appear to check with each other nor to agree with their stated distances and directions from the base line. These corners are situated in the immediate valley of Douglas Creek, and it is extremely doubtful if many corners were ever set or if the lines were run at all in the adjoining hills. An attempt to classify the lands in this southern area, therefore, seems unwarranted at present.



ANDREW B. GRAHAM CO. PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

MAP OF THE LOWER WHITE RIVER COAL FIELD, NORTH OF THE BASE LINE, COLORADO

By Hoyt S. Gale, J. A. Davis, and C. W. Stoops

AREA NORTH OF THE BASE LINE.

General section of Mesaverde formation.—As the rocks of the lower White River field form a direct westward continuation of the outcrops of the same formations that are exposed in and adjacent to the Danforth Hills, no sharp distinction nor marked variation in the beds of the two fields is to be noted. As explained more in detail in the discussion of the Vernal field, the Mesaverde appears to become thinner as traced toward the west, being in the vicinity of Red Wash only 2,500 feet thick, or half the thickness exposed on White River near Meeker. This thinning is thought to be due to the fact that erosion of a former land surface had progressed to a considerable depth into those beds before the succeeding Tertiary strata were laid down upon them.

Total amount of coal in the Mesaverde section.—As explained in the published report on the Danforth Hills coal field, the only available section where satisfactory measurements of the total amount of coal in the Mesaverde formation can now be had is that exposed on White River a few miles below Meeker. Here at least 73 feet in ten beds, each of workable thickness, was well enough opened by development so that the coal could be measured. It is thought likely that a complete measurement at that place would show even more coal than this. Unfortunately the scattered prospects and small amount of development in the lower White River field do not permit even a fair estimate of the total amount of coal. To judge from the few exposures available, and from such general indications as natural exposures of coal smut and the relative intensity of baking where coal beds have been burned in outcrops, the distribution of the groups of coal beds is thought to be very similar to that of the Danforth Hills. Owing to the thinning of the coal-bearing formation toward the west, thought to be caused by the absence of its upper members, it seems likely that the upper coal group of the Danforth Hills may be partly lacking west of Coyote Basin, and it is almost certainly absent a short distance west of the mouth of Wolf Creek.

An additional and probably still more important factor influencing the total amount of available coal in the lower White River field is an apparently local decrease in the thickness and number of workable beds in the part of the formation exposed between the district at the mouths of Wolf and Yellow creeks and a district just west and south of the mouth of Red Wash. Here, in spite of relatively more active local demand for fuel supply in the adjacent valley of White River, but few important coal beds seem to have been discovered, and several that are of workable thickness are badly broken by layers of shale or bone. With the possibility that valuable beds will still be discovered in this vicinity, it seems very likely, nevertheless, that the total thickness of available coal here will prove to be but a fraction of that contained in the Mesaverde section near Meeker.

In the strata surrounding the Raven Park anticline the total amount of coal evidently increases again, as is shown by the prospects and a few local mines and by the abundance of large beds of slag and burned rock. An estimate based on the observed indications would, however, place the total thickness in the maximum sections as not more than one-half to two-thirds that of the Danforth Hills field, and probably much less in many parts of that area.

Local descriptions.—The general character of this coal field may be judged from a brief review of some of the observed outcrops and a general description of the field.

South of Juniper Mountain, in Axial Basin, near Cedar Springs, Twelvemile Springs, and Wapiti Peak, the Mesaverde rocks occupy the main divide between Yampa and White rivers. A small amount of prospecting recently done in this general region has served to show some thick beds of excellent bituminous coal. Some exposures near Wapiti Peak indicate beds 10 feet or more in thickness. Most of the dips in this district are steep, 20° to 60°, and are toward the south, or inward toward the center or axis of the Coyote Basin syncline.

Along Piñon Ridge, on the west side of Coyote Basin, the rocks are tilted at lighter angles. The coal beds constitute two groups, separated by a relatively barren zone, so that the area of coal land is also split into two strips or zones corresponding to these outcrops. A coal bank or prospect drift has been dug in or near the NW. ¼ sec. 15, T. 4 N., R. 98 W., where coal 5 feet 3 inches thick is developed under a good sandstone roof with an easterly dip of 17°. The upper zone is prospected in the eastern side of sec. 25, T. 3 N., R. 98 W., by a drift 30 feet in depth exposing 6 feet of coal with a dip of 3° SE. To judge from the number and size of the surface indications, many other and doubtless some thicker beds occur in this region.

Along the valley of White River below this place the local settlement has created a greater demand for coal, but, as stated above, observed exposures seem to indicate a notable decrease in the amount of available coal in the Mesaverde formation. A few mines have been opened near the river banks. The Bassett mine, in or near sec. 31, T. 3 N., R. 98 W., shows a bed 3 feet 7 inches thick, which appears to contain very good coal, probably similar to the average Mesaverde coal in the Meeker district. An old entry south of the river, near the mouth of Wolf Creek, exposes at least 8 feet of good coal, which appears to be only part of a thicker bed, although there is much bony material in the section. West of the mouth of Wolf Creek an old mine known as the Stadtman bank shows at about the same horizon a thinner bed consisting of two benches which together contain 4 feet 2 inches of good coal. At Angora post-office, on the north side of the river, two beds at about the same horizon have been opened. In one of these 6 feet 4 inches of coal has been mined, leaving about 1 foot 3 inches of good coal in the roof. A bed stratigraphically about 80 feet lower shows 3 feet 7 inches of good coal that has also been worked.

All the Mesaverde rocks of the Angora district are steeply tilted, forming a long, narrow hogback, approximately parallel to the course of White River. West of Angora this ridge continues for several miles to the region where the influence of the Raven Park anticline broadens the outcrop of the coal-bearing rocks and considerably enlarges the available coal field.

The coal-bearing rocks encircle the Raven Park anticline, although the more important coal beds are completely eroded on the north side of it between the Raven Park and Blue Mountain folds. The coal rocks dip away in all directions from Raven Park as a center or axis, for a greater or less distance, according to the proximity of other folds that modify this simple structure.

DOUGLAS CREEK DISTRICT, SOUTH OF THE BASE LINE.

Location and extent.—The coal-bearing rocks of the White River field are continuous south of the base line in the vicinity of Raven Park, forming a considerable area of actual croppings of the principal coal-bearing group of the Mesaverde formation which lie mainly in the drainage basin of Douglas Creek and its tributaries. This district, as shown by Pls. XVII and XVIII, is a part of the lower White River field, and the division along the base line is arbitrary, as already explained.

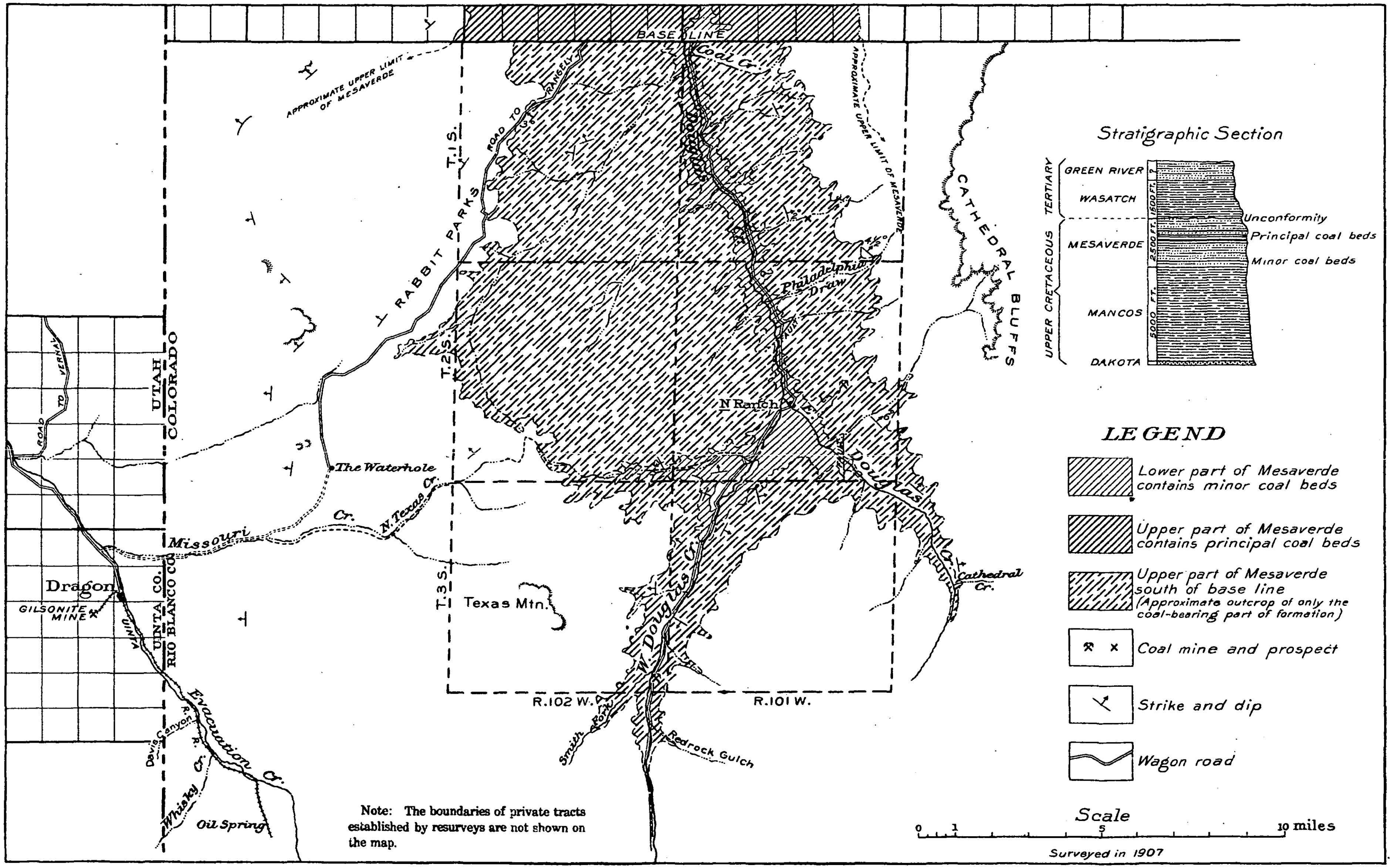
General structure.—Structurally the Douglas Creek district is probably continuous with the Book Cliffs coal field, on the Grand River side of the Book Cliffs divide. Between these two fields the coal-bearing rocks are buried under several thousands of feet of overlying strata in the high hills of the Roan or Book Cliffs plateau.

The structure of the district is perhaps most clearly revealed by a general view from the high escarpments surrounding the valleys and somewhat broken and hilly "parks." The bordering escarpments expose the bare ledges of the Tertiary strata dipping away in nearly all directions from the eroded center. In passing up the valley of Douglas Creek southward from White River the beds at first dip south, conforming to the structure of the Raven Park anticline. Before the base line is reached, however, they assume a practically horizontal position and then may be seen to rise toward the south, approximately at the grade of the streams. This structure is very regular, and with the exception of a few small faults, mentioned in a following paragraph, the strata continue to rise gradually southward to a point about 3 miles south of the N Bar ranch, which is situated in the main forks of the creek about 18 miles south of White River. (See Pl. XVIII.) South of the N Bar ranch, on the west fork of Douglas Creek, a small topographic basin opens out, evidently eroded from the shale at the base of the Mesaverde formation, and this is therefore the center of a structural dome or uplift, from which the beds may be observed to dip outward in all directions. At a point just above or south of this valley the strata bend abruptly down (southward) and there may also be a fault at this place. For some distance south of this point the beds are horizontal, but farther on they again rise approximately at water grade until they approach the headwaters of this branch of Douglas Creek. Here the coal-bearing rocks, although still rising toward the south, pass below the surface-water level. Thus this group of beds apparently extends under the Roan or Book Cliffs plateau only 10 to 15 miles north of the outcrops of the same formation on the south side of that divide, in the Grand River drainage basin.

In the western part of the Douglas Creek district the strata lie very nearly horizontal, with more or less irregularity of structure along the margin of the basin country, this being evident in the sinuosity of the limiting rim of the escarpments of the Green River formation. The general light dip toward the west or into the main Uinta Basin of Utah is, however, evident in the overlap and succession of higher and higher beds in that direction; so that the coals are probably buried at greater and greater depth by the accumulation of younger beds.

Faults.—A number of faults were observed in the Douglas Creek district, as well as numerous local slides or slumps. Two miles north of the N Bar ranch a fault trending N. 30° E. crosses Douglas Creek with a downthrow of 200 feet, more or less, on the south side. This fault brings the coal-bearing strata down to stream grade for a short distance, but beyond they rise again southward to the ridge tops—their customary situation. Another fault was observed on the east fork of Douglas Creek about 2 miles above the N Bar ranch. The direction of this fault is about N. 4° W., and the downthrow is 200 or 300 feet on the east side. The fault plane seems to be inclined toward the west at a steep angle on the north side of the gulch and toward the east on the south side of the gulch. The strata are sharply bent, showing the drag near the fault, and the burned coal-bearing strata are dropped to water level on the east side. The abrupt fold above the small anticlinal basin on the west fork of Douglas Creek is probably accompanied by one or more faults, and in this displacement the downthrow is on the south side.

Stratigraphy and occurrence of coal.—The stratigraphic section exposed at the main forks of the creek, near the N Bar ranch, is more or less typical of the Mesaverde rocks so extensively exposed along the canyon walls that line Douglas Creek. The lower 400 feet above



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RECONNAISSANCE MAP OF THE DOUGLAS CREEK DISTRICT, LOWER WHITE RIVER COAL FIELD, SOUTH OF THE BASE LINE, COLORADO

By Hoyt S. Gale, J. A. Davis, and C. W. Stoops

water level is composed of huge white cliff-forming sandstone beds and some intervening shale, the whole somewhat conspicuous by contrast through the absence of any signs of burning. These beds are thought to represent in part at least the lower, relatively barren sandstone portion of the Mesaverde formation. At the base, near the creek level, is a coal bed about 8 inches thick, noticeably of lenticular character, and this is thought to be one of the lower coal group described on page 289. This bed shows much variation, thickening and thinning and dividing in a manner similar to that sketched in the published plate of Endlich's report.[a] It is doubtless 300 to 400 feet or more above the base of the Mesaverde formation as exposed around the margin of Raven Park. The strata above the huge white sandstone bed show a section of about 300 feet reaching to the summits of the adjacent peaks and ridges, composed of shale and sandy beds, all fire reddened or colored by heat and baked as hard as pottery ware. This burned rock is exceedingly magnetic, probably owing to the reduction of the iron from the ferruginous seams contained in the strata before they were burned.

In a rather extensive territory adjacent to the lower valley of Douglas Creek, or including nearly all except the farthest headwaters of that stream, the middle or principal coal group of the Mesaverde can be readily traced by the eye from any prominent point overlooking the district or by traveling along the canyon bottoms. The brilliantly colored rocks may be seen to occupy in large part the summits of the ridges, whereas the canyons are commonly cut into the more massive white beds that everywhere underlie these coals.

On the west fork of the creek, above the small anticlinal basin previously mentioned, the principal coal group may be traced approximately at water level to a point within 5 miles of White's ranch in the upper valley of the main stream. The lower bluffs bordering the canyon form an almost continuous rim of brilliant vermilion rocks. The most brilliant of these is a zone 100 to 300 feet or more in thickness. At the forks of the west fork of Douglas Creek, about 8 miles above the N Bar ranch, an old entry exposes a bed of coal that has been worked for domestic use at an old settlement said to have been known as Smith's ranch. Now, however, both ranch and coal entry are abandoned and fallen into ruins.

The east fork of Douglas Creek runs approximately parallel to the high escarpment of the Green River formation known as the Horseshoe of Cathedral Bluffs. It also follows approximately the upper limit of the outcrop of the coal-bearing rocks, a geologic boundary which trends in the same direction as the high rim of the Green River bluffs. All these beds have light dips, and the formation above the principal coal-bearing group carries a great series of mass-

[a] Tenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1878, Pl. V, p. 81.

ive sandstone beds of cliff and ledge forming character, all of which appear to be almost identical with the unbaked sandstones of the coal-bearing rocks. Just between the sandstone ledges of the upper Mesaverde or lower Wasatch and the foot of the main escarpment of the Green River shale there is on Cathedral Creek and elsewhere a deep, open valley, showing that there exists a zone of weaker or less resistant beds in the upper Wasatch or lower Green River formation. Some clays of red and white color occur, but are not so universally distinctive of the Wasatch as they are in many other parts of this general region.

The principal coal district immediately accessible is, as before stated, restricted to the Douglas Creek drainage basin. Baked rocks indicative of the burning of coal beds are a conspicuous feature in nearly all the bluffs that border the main stream as far south as a point beyond the principal forks. These burned rocks were described in a report of the Hayden Survey by F. M. Endlich,[a] who thought they represented the reddish strata of the Wasatch formation, evidently failing to recognize the significance or cause of their color. The red cliffs, slag, ashes, baked and hardened rock, and clinker are so conspicuous that it seems as if they could scarcely be overlooked by any-one who travels through the region. There are also natural exposures of the coal itself, but these are comparatively rare. For some distance along the gulch or canyon walls the sandstone on the west side of Douglas Creek south of the base line outcrops in brown and weathered ledges with numerous reddened bands, having a slight resemblance to the beds found in the red and white banded Wasatch strata which normally overlie these Mesaverde rocks in the fields of the Uinta Basin.

Owing to the sparsity of settlement in this district, but little demand has been created for the development or use of any of the coals that might be available. A single local coal bank in a gulch about 1¼ miles northeast of the N Bar ranch has been worked within the last few years for domestic use at the ranch. It consists of a short slope running down N. 25° E. on a pitch of 5°. The dip of the beds is about 7° N. 10° W. The coal itself is 5 feet thick and possibly thicker, the floor being concealed in the present entry, so that a complete measurement could not readily be obtained. The roof consists of a thin-bedded sandy carbonaceous shale 2 feet 3 inches thick, overlain by a massive sandstone at least 15 feet thick. The coal is apparently of good quality, similar to the coals of the Meeker district, but it seems to have been somewhat affected by the heat from the huge burned zone that overlies it. This bed is one of the lowest of the middle coal group of the Mesaverde formation. The strata do not appear to be burned at all on the east side of the gulch

[a] Tenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1878, p. 80.

at this place, and the coal should be available there from the higher beds as well as from the one opened at the mine. Owing to its peculiar situation it is very doubtful if all of the coal of the Douglas Creek district can be assumed to be of commercial value at the present time. The almost universal burning in this part of the field has destroyed practically all of the coal at its outcrops, and by reason of the location of these beds in the summits of the ridges the burning may also have extended to considerable depth. The fact that much of the coal is situated wholly above ground water would make the complete burning of practically all the valuable beds very probable in many and perhaps most of the narrow ridges. Such a condition is all the more likely on account of the intricate network of steep canyons that intersect the region. The coal is thus subdivided into patches of an almost infinite detail of outline, the actual tracing of which would be rather difficult.

Toward the flanks of the broad, gently arched uplift these coal-bearing beds descend to and below water level or are more deeply covered, and in that portion of the district they are thus in more favorable positions and attitudes for mining purposes.

Throughout the western part of the district, or west of the actual drainage basin of Douglas Creek itself, no coal was noted, but it is evident that erosion has progressed rather deeply into the Wasatch beds at many points, and it is very likely that some of the more valuable coals may some time prove to be accessible at no great depths within these valleys, should demand ever be made for their development.

East of the settlement at Dragon, which is the terminus of the Uintah Railway, the upper valleys of Evacuation, Missouri, and Texas creeks are evidently eroded in the Wasatch beds underlying the Green River formation. These strata are shown by the bluffs of red and white banded clays and soft sandstones which line the lower canyon walls or form the bare washes in their lower valleys. These valleys are covered with slabs and blocks of oolitic rock and sandstone.

Character of the coal.—It seems fair to assume that the coal of this district is similar in character and thickness to that of the White River districts to the north and also to that of the better known and exploited fields on the south side of the Book Cliffs divide. Analyses of coals from the south side of Raven Park (Nos. 5519 and 5520, p. 314) are doubtless as truly representative of the Douglas Creek district as they are of the White River field in general.

A comparison of the relative efficiency or heating value of this coal, as shown by the calorimetric determinations, indicates that it is very similar to most of that in the Danforth Hills field and also to the Mesaverde coal of the Yampa field of Routt County, and that it may be properly classed as bituminous.

VERNAL FIELD.

LOCATION AND SETTLEMENT.

The valley of Ashley Creek, in which the town of Vernal, Utah, is situated, contains perhaps the most extensive settlement in this part of the State, or at least in the northern part of Uinta County. This district supports a prosperous agricultural community of considerable importance.

CHARACTER OF THE UTAH LAND SURVEYS.

West of the State line and east of the Green River valley no land-survey corners were found that could be identified with any certainty, and although some satisfactory surveys may at one time have been made in this territory it seems very likely that the corners if ever established were not permanently marked, and that only slight and rather uncertain evidence of them remains to-day. It also seems clear that the original surveys of Utah overlapped the Colorado State line. This was probably due to the uncertainty regarding the correct location of that boundary at the time of the work.

The map of the Vernal field presented here depends for its adjustment primarily on the control obtained from a railroad survey extending from Colorado down Cliff Creek to Green River, and also on plane-table traverse and triangulation done during the present investigation. The land lines east of Green River shown on the map are projected through from corners found in the valley lands. West of Green River the more extensive settlement and farming lands laid out by subdivisions and largely fenced afforded more complete evidence of the land-survey system.

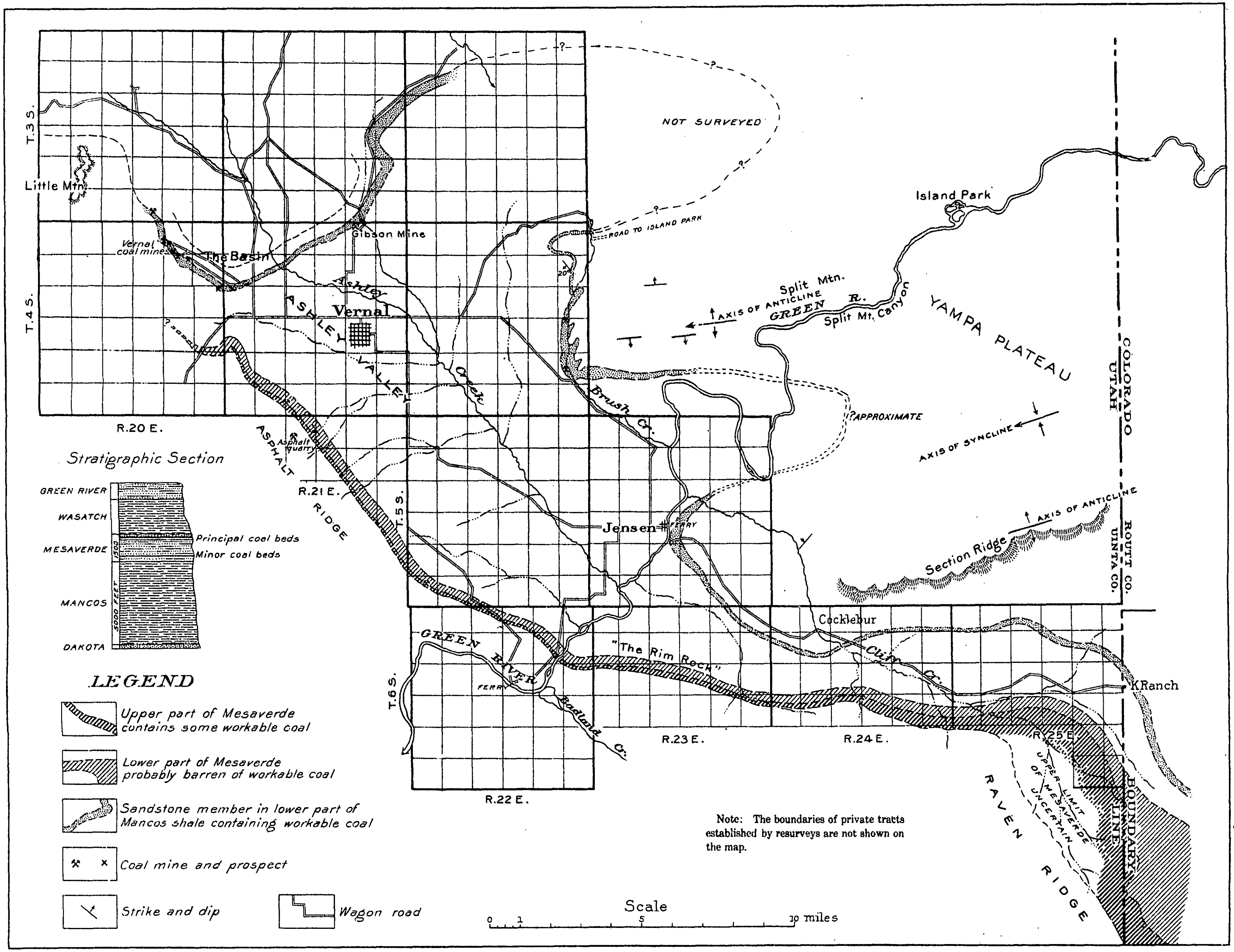
RELATIONS TO THE COLORADO FIELDS.

As shown by Pl. XIX, the Mesaverde coals in this part of the Uinta Basin are directly connected with the same group in the White River fields of Colorado, but the State line offers a convenient division line for the separation of the Utah portion, in which these coals have not as yet been shown to be of much importance, at least in comparison with the richer and more extensive deposits of Colorado.

An additionally distinctive feature is shown by the Utah fields in the fact that as the Mesaverde coals become relatively unimportant, older strata at the base of the Mancos shale develop workable beds, which at the present time carry the only coal considered worth exploitation in or near this part of the Green River valley.

MESAVERDE COAL.

Tracing of the Mesaverde formation.—West of the State line the basal sandstones of the Mesaverde are the most conspicuous members of that formation, constituting a rim-rock ridge somewhat analogous



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MAP OF THE VERNAL COAL FIELD, UTAH

By Hoyt S. Gale, J. A. Davis, and C. W. Stoops

to the "rim rock" of Raven Park. This ridge is very distinct and easily traced to and beyond Green River and the position of the Mesaverde coal beds may be inferred from it, even where they are not actually exposed. As a whole, however, the Mesaverde formation is relatively much thinner in Utah than in Colorado, and the thinning is apparently due to the absence of upper members of the formation which are represented elsewhere. Thus the Wasatch strata unconformably overlying the Mesaverde appear to sink deeper and deeper as they are traced to the west. The coal beds that are commonly found in the upper part of the Mesaverde formation in other fields are probably wanting here. The whole formation, which measures approximately 5,000 feet in the Grand Hogback field and 2,500 feet on Red Wash in Colorado, is probably not more than 1,500 feet thick and possibly less near Green River. In each place the section toward the base of the formation appears to remain practically constant, but the upper beds are beveled off, disappearing one by one toward the west.

Local development of the Mesaverde coal.—Coal is exposed from place to place along these outcrops, and has been mined to a small extent. A bed of coal at least 7 feet thick and possibly thicker has been opened in a gulch about 2 miles south of "Cocklebur," in T. 6 S., R. 24 E., of the Salt Lake base and meridian, and a slope has been run in on the dip of the strata, which is 35° at this place. The mine is 9 or 10 miles from the ferry at Jensen, on Green River, which is the nearest present market for the coal. The product appears to be a very good grade of bituminous coal, well suited for domestic use, but a poor road for hauling has probably hindered the development of the mine.

West of Green River several attempts have been made to mine the Mesaverde coal, but at present all these operations are abandoned. An old mine in T. 5 S., R. 22 E., is situated on the northeast side of a small isolated knob on the western side of the valley lands. This is said to have been opened in 1893 and worked at intervals until about 1904. The coal bed is reported to have broken off at the face, probably along a local fault or slump. The coal at present exposed is 3 feet 5 inches thick, but the whole bed is reported to have been about 5 feet as worked. This coal has the smell of asphaltum or oil, and as it occurs just below the outcrop of an asphaltum deposit, that material has very probably saturated the coal as it has much of the neighboring rock. The coal is said to have caked somewhat when burned, spreading over the grates and forming a heavy clinker, a property possibly due to the asphaltum it contains. It is also reported to have slacked rapidly—within a month after taken from the mine—if left in the open air.

Another prospect about 3 miles southwest of Vernal exposed a small bed of coal which did not appear to be of much importance.

Beyond that point no coal was observed in the Mesaverde rocks, and farther west the formation may be either cut out entirely by the unconformity between the Cretaceous and Tertiary rocks or concealed by some of the Tertiary and later deposits.

MANCOS COAL.

Age.—The older coal of the Vernal field is associated with fossiliferous strata both above and below the workable bed, and collections from these horizons are reported to be distinctive of the Benton shale of other fields. Where a group of sandstones and the contained coal beds form a conspicuous lithologic unit, as they do in most of this Utah field, their outcrop is indicated on the map as far as it has been traced, and it is referred to in the legend of the map and elsewhere in the report as the Mancos coal group.

Position of the outcrop.—The coal group in the lower part of the Mancos shale presents a sinuous outcrop in the vicinity of the Green River valley near Vernal. These beds follow the sharp folds of the older strata of the Uinta Mountain axes as continuous curved ridges, tracing around the ends of the pitching anticlines and into the deep reentrant valleys of the synclines. Only a small portion, considerably less than one-half of the length of outcrop exposed, is known to contain valuable coal. Thus the sandstone beds of this horizon are exposed in the banks of Green River at Jensen, but are not known to contain coal. They are also exposed west of Green River around the foot of Split Mountain. On Brush Creek the coal is of workable thickness at a few places. Very little is known concerning the coal around the northeast end of the Island Park syncline, but it is said to be of small practical value. Along the cropping of this bed north and northeast of Vernal it is or has been mined at a few places along the valley of Brush Creek, but the principal developments are grouped in a locality 7 to 8 miles northwest of Vernal, on the southeast side of Little Mountain.

Character of the bed mined.—The coal bed presents the same or a similar character in the number and thickness of its partings and is doubtless at the same horizon throughout the field. One or two other small beds of coal are reported at various places, but only the large bed has ever been shown to be of value. Most of the accessible mines and prospects were visited and measurements taken of the coal, as well as a set of representative samples for chemical analysis. The results of the analyses are included in the table on pages 314–315. The thickness of the bed and the nature of its partings are well shown in the following table of measurements, which are arranged in the order of their position along the outcrop from northwest to southeast.

Measurement of Mancos coal as mined near Vernal.

Section.	George Gray mine.	Joe Rich mine.	A. N. Timothy mine.	C. C. Rich mine.
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Coal	1 10½	2 3	1 11½	1 6½
Bone	11	9	8½	10
Coal	7	9½	10	9
Bone	7½	5½	3½	4½
Coal	10½	11	11½	9
Bone	2	3½	5½	4
Coal	6½	6½	6	4
Total coal	3 10½	4 6	4 3	3 4½
Total bed	5 7	6	5 8½	4 11

The roof is white sandstone at each mine; the floor at the Gray and Timothy mines is bone.

The coal bed at the Gibson mine, north of Vernal, that in the prospects near the Pollard mine, on Brush Creek, northeast of Vernal, and that at the Bowen mine, farther south on Brush Creek, east of Vernal, all show much resemblance to the sections given above, especially in the character of bony beds and partings contained, although the actual thicknesses vary considerably from place to place.

Quality of the coal.—As may be seen by reference to the analyses the coal from this field is of very much the same quality and degree of efficiency. It is similar to the average Mesaverde coal of the Meeker district, and is distinctly inferior to the coals of the Newcastle and Glenwood Springs districts. The abundance of bony material in the bed is the chief disadvantage and interferes rather seriously with economical mining.

The variation along the outcrop of the bed is very slight, probably not greater than that which is likely to occur in almost any coal bed. The only apparent exception is found in the mine due north of Vernal, which had not been worked for some time when the sample was taken and the coal of which had evidently deteriorated somewhat by exposure to the air.

The lower limit of efficiency of high-grade bituminous coals, as shown by calorimetric determinations, is approximately 12,000 British thermal units, so that the best of the coals in this region fall just within that class.

Demand and market.—The coal directly available in this field is moderate in amount, especially when compared with the extensive coal fields in the adjacent parts of Colorado. The local demand is already a considerable factor, probably as much so now as it will be later, when the coming of a railroad may open up competition with the larger fields to the east.

HENRYS FORK FIELD.

GENERAL STATEMENT.

Coal has been reported from the vicinity of Henrys Fork in northeastern Utah and southern Wyoming, although very little precise information concerning this field has heretofore been available. About ten days at the close of the season were spent in the field, reviewing the geology and looking up some of the known occurrences of coal.

LOCATION.

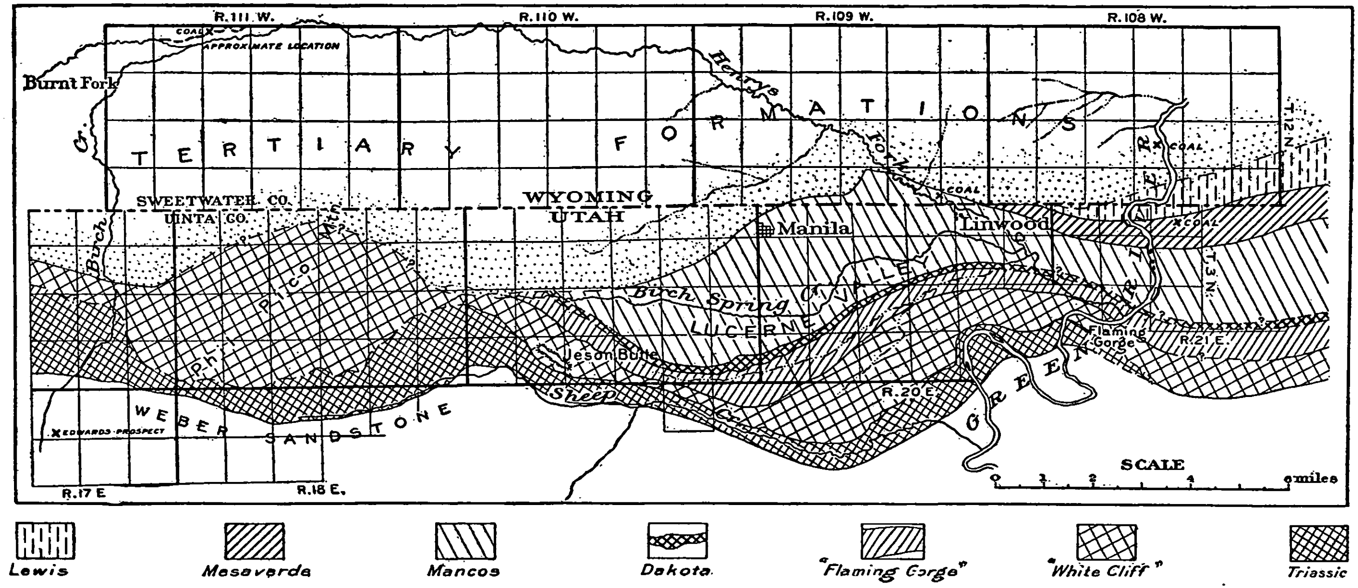
The name, Henrys Fork coal field, has been applied in a rather indefinite way to reported coal croppings in the vicinity of the valley of Henrys Fork, near the junction of that stream with Green River. This district lies along the State line in northeastern Uinta County, Utah, and southern Uinta County, Wyo. It is 40 to 60 miles from the Union Pacific Railroad either at Green River or at Carter, Wyo., the customary mail route going to the latter point.

STRUCTURE.

The field lies north of the Uinta Mountains and is structurally a part of the Green River Basin, or of the Bridger Basin if the larger structural feature be considered as divided by the Rock Springs dome. In general the strata in this field are tilted to the north away from the axes of the Uinta Range. These mountains separate the Henrys Fork field from the Vernal field, just described. Structurally the Henrys Fork field is directly related to the Yampa field, with which its rocks are doubtless connected or continuous, except where they are eroded and covered by the overlap of the Tertiary rocks or are cut out by faulting. The northern flank of the Uinta Range is much broken by faults and as some of these are largely obscured by the Tertiary strata that unconformably overlie the older rocks, the geology of a part of the field is not very clearly revealed.

STRATIGRAPHY.

The Cretaceous formations correspond to those of the Yampa field. Where not faulted out the Mesaverde formation is coal-bearing. The relations of the Lewis shale to the overlying Wasatch strata are obscure, but it seems certain that either displacement by faulting or erosional unconformity has obscured the Laramie, at least near Green River, where those beds might be expected, on the east side of the valley above Flaming Gorge.



MAP OF PART OF THE HENRYS FORK COAL FIELD, UTAH AND WYOMING.

PENNSYLVANIAN (UPPER CARBONIFEROUS) COAL.

An older coal than any heretofore noted in northwestern Colorado was found on upper Birch Creek, tributary to Burnt Fork, which is in turn a branch of Henrys Fork of Green River. This is in sec. 3, T. 2 N., R. 17 E., of the Salt Lake base and meridian, Utah, south of Zeb. Edward's ranch, and occurs in rocks of the same age as the Pennsylvania coal measures.[a] The same horizon has been prospected at intervals for several miles along the foothills in this locality, but the coal appears to be of rather uncertain value.

The coal at the Edward prospect is said to have been tested by the Union Pacific Railroad Company, and the report has spread that it proved to be of coking quality. The specimens seen had certainly withstood exposure to the weather in an exceptional manner. Other reports state that the coal has been used in a local forge, where it burned very well and gave a good heat. The exposure seen was in a very unsatisfactory condition for examination. Some pits had been dug in a heavily wooded slope, in a block of strata very evidently slipped from a point higher on the ridge and tilted out of its normal position. The beds are very soft and broken, but nevertheless some of the coal is still hard. The coal bed is very irregular and at no place was more than a few inches of coal visible, although it was confidently stated that the bed was 3 feet thick at the bottom of the pit, which had then caved. No trustworthy estimate of the true character of the bed can be obtained until the coal is found in place and in a normal position.

It is reported that several prospects on Burnt Fork, farther west, show the same bed in place; in these it is much thicker but is not of commercial value, being carbonaceous shale rather than coal.

These beds are of interest as affording an unusual occurrence for the western fields.

MESAVERDE COAL.

As shown on Pl. XX, the Mesaverde formation outcrops at Green River near the center of the broad valley area north of Flaming Gorge, and just north of the mouth of Henrys Fork. Toward the west the formation is evidently cut off by a fault near Linwood postoffice, on Henrys Fork. East of Green River the formation may be followed as a long, curved, double ridge extending up the broad strike valley north of the mountains, apparently bending southward and abutting against the mountain mass, and possibly terminated there by another fault. These beds were not examined far east of Green River.

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[a] Fossils collected in the prospect pit were examined by G. H. Girty, who has made the age determination and identified the following forms: *Fenestella*, 2 sp.; *Lingula?* sp.; *Spirifer rockymontanus*; *Pleurophorella costata?*; *Edmondia* aff. *gibbosa*; *Aviculipecten hertzeri?*; *Aviculipecten* sp.; *Naticopsis* sp.

A well-exposed section was found near the east bank of the river at the mouth of Spring Creek, about one-half mile southwest of the 289 milepost on the Utah-Wyoming State line. Here the Mesaverde formation contains many massive sandstones and intervening shale bodies, which are very similar in character to the same formation in the Yampa field. The whole formation was not examined in detail, but coal was found in it at several horizons. A small amount of prospecting uncovered some beds at least 5 feet thick, and local reports state that the coal has been taken out at some point west of the river for use at the ranches in the valley.

Opposite Linwood post-office, about one-fourth mile north of Henrys Fork, two thick beds of coal are exposed in nearly vertical position. These beds have been prospected somewhat but have never been worked to any considerable extent. The following section was measured at this place:

Section of coal-bearing strata north of Linwood, Utah.

	Ft.	in.
Sandstone, coarse, yellowish, flaggy, and thin bedded	15	
Coal, apparently good, without partings	8	9
Shale, blue and gray, fine	20	
Coal, apparently good, without partings	10	
Bone, irregular bed	1	
Sandstone, fine grained, clayey, white	20+	
	74	9

The strike of the beds is N. 67° W. and the dip 80° to 85° S. The outcrop of this bed splits up within less than 200 yards to the west, and the bed changes in character, becoming chiefly a brown and gray shale with coal streaks. Toward the east the bed follows the course described for a few hundred feet, then bends abruptly south and disappears under an upper terrace level capped by consolidated river deposits. In the next gulch to the east, one-fourth mile or so away, beds of soft black shale, evidently representing the same horizon, have been prospected. Although resembling coal somewhat in appearance, the material is merely a dark clay shale. These beds have been filed on as coal land from time to time, but the filings have always been allowed to lapse without making final proof.

As these beds occur along a line of evident structural displacement, probably a fault of considerable magnitude, it is not certain to what formation they may properly be assigned. The inclosing beds resemble the Mesaverde strata, and their position overlying the Mancos shale suggests that they belong to that formation. Coal is also found in the overlying Tertiary strata, some of which might not be easily distinguished from the Mesaverde.

TERTIARY COAL.

Coal beds in the Tertiary strata have been noted at a number of localities along the north side of Henrys Fork. Outcrops are reported along the bluff bordering that stream for a distance of several miles east of Burnt Fork, Wyo., and the coal is probably continuous for a still greater distance, although no further information on this point has been obtained.

Some exposures of these beds were examined 3 or 4 miles east of Burnt Fork post-office, along a road in a little gulch leading up to the mesa, less than one-fourth mile from the creek and opposite the Mass ranch. The coal is exposed at several horizons. A coal bed near the lower end of the gulch measured 2 feet 10 inches, as shown in natural outcrop, and although considerably weathered, much of it was a clear, glossy black. The roof is a sandy and calcareous shale, alternately thick and thin bedded. The floor is a brown, woody clay, which is evidently softened by exposure. The beds are nearly horizontal, the dip being very low toward the north. The bed is evidently continuous for some distance, as its croppings can be plainly traced around the hillside. The coal is doubtless subbituminous, although this statement is no more than a rough estimate based on the appearance of the weathered exposure.

On another bed exposed 100 yards or so farther up the gulch a small amount of digging uncovered 2 feet of coal, but the bed is doubtless somewhat thicker. A prospect drift had been dug at this place but is now wholly caved. Some very perfect impressions of a symmetrically coiled spiral gasteropod were collected from the roof of this coal bed, but unfortunately they do not fix the geologic age of the strata, except to indicate that they belong to the fresh-water Tertiary. The coal-bearing beds are very probably of Wasatch age, as they are succeeded by strata which resemble the Green River shales and sandstones, and these in turn are overlain by undoubted Bridger beds with their vivid green banding.

Other coal beds in Tertiary strata were observed at the bank of Green River, north of the mouth of Henrys Fork. This locality is about 1.3 miles N. 5° E. of the 290 milepost on the Utah-Wyoming line. The coal was very poorly exposed and could not be shown to be of workable thickness without further development. A collection of fossils from neighboring rocks contain some fresh-water shells resembling clams and gasteropods elsewhere found in the Wasatch, but the same species also occur in later Eocene formations of this region.

SUMMARY OF THE HENRYS FORK FIELD.

Coal is rather widely distributed both stratigraphically and geographically in the Henrys Fork valley. Little effort has yet been made to develop or even to prospect the beds, probably owing to the fact that timber is plentiful and not hard to get. With the possible exception of the beds at Linwood, no coal beds of unusual thickness or importance are known to exist there. Many of the reported beds are probably thin, and the Tertiary coal is of a rather light weight (subbituminous) variety. The most promising part of the field is thought to be in Spring Creek valley east of Green River, just north of Flaming Gorge, in the Mesaverde rocks that are exposed in that locality. It must be admitted, however, that the examination of this section of strata was too incomplete to warrant any estimate of the quality or total quantity of the coal.

ANALYSES.

The character of the coal from the several fields discussed in this paper is indicated by the subjoined analyses, which were made at the Survey fuel-testing plant, Pittsburg, Pa.

Analyses of coal samples from the Uinta Basin, Colorado and Utah.

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

Name of coal field	Yampa.				Lower White River.			Vernal.	
Geologic age or formation	Post-Laramie.	Mesaverde.			Mesaverde.			Mancos.	
Laboratory No.	5514	3463	3461	3462	5516	5519	5520	5511	5753
Sample as received:									
Prox. Moisture	17.46	14.65	13.31	12.31	10.96	11.39	14.10	8.46	8.64
Prox. Volatile matter	28.21	34.73	35.18	36.17	33.13	32.36	31.83	34.32	36.42
Prox. Fixed carbon	47.17	44.48	46.53	45.40	47.05	48.44	48.81	47.17	47.62
Prox. and Ult. Ash	7.16	6.14	4.98	6.12	8.86	7.81	5.26	10.05	7.32
Ult. Sulphur	1.14	.99	.90	1.10	.73	.45	.38	1.58	1.25
Ult. Hydrogen	5.66	5.80	....	5.75	....	5.48	5.65	5.33	5.57
Ult. Carbon	56.33	60.07	....	62.72	....	62.64	62.15	62.79	65.55
Ult. Nitrogen	.79	1.10	....	1.16	....	1.14	1.06	1.00	1.09
Ult. Oxygen	28.92	25.90	....	23.15	....	22.48	25.50	19.25	19.22
Calories	5,391	5,869	....	6,163	5,939	5,965	6,075	6,250	6,600
British thermal units	9,704	10,564	....	11,093	10,690	10,737	10,935	11,250	11,880
Loss of moisture on air drying	5.70	5.30	4.50	4.00	3.20	3.10	4.80	2.90	2.60
Air-dried sample:									
Prox. Moisture	12.47	9.87	9.23	8.66	8.02	8.55	9.77	5.73	6.20
Prox. Volatile matter	29.92	36.68	36.84	37.68	34.22	33.40	33.43	35.34	37.39
Prox. Fixed carbon	50.02	46.97	48.72	47.29	48.61	49.99	51.27	48.58	48.89
Prox. and Ult. Ash	7.59	6.48	5.21	6.37	9.15	8.06	5.53	10.35	7.52
Ult. Sulphur	1.21	1.05	.94	1.15	.75	.46	.40	1.63	1.28
Ult. Hydrogen	5.33	5.50	....	5.53	....	5.30	5.38	5.16	5.42
Ult. Carbon	59.74	63.43	....	65.33	....	64.65	65.28	64.66	67.30
Ult. Nitrogen	.84	1.16	....	1.21	....	1.18	1.11	1.03	1.12
Ult. Oxygen	25.29	22.38	....	20.41	....	20.35	22.30	17.17	17.36
Calories	5,717	6,197	....	6,420	6,135	6,156	6,381	6,437	6,776
British thermal units	10,291	11,155	....	11,555	11,043	11,080	11,486	11,586	12,197
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	11 4	20 3	9	7 10	4 2	11 11	11 11	6 7	6 7
Thickness of part sampled	11 4	5 7	7	5 5	3 8	11 11	7 4	3 10	3 9

Analyses of coal samples from the Uinta Basin, Colorado and Utah—Continued.

Name of coal field	Vernal.								
Geologic age or formation	Lower part of Mancos.								
Laboratory No	5512	5509	5754	5755	5513	5510	5515	5517	5518
Sample as received:									
Prox. Moisture	8.64	8.65	8.23	8.64	8.21	8.82	9.43	11.66	10.22
Prox. Volatile matter	36.09	36.16	35.69	36.74	34.30	36.60	32.77	34.40	32.68
Prox. Fixed carbon	47.21	48.19	45.77	46.67	45.70	48.33	44.94	44.50	44.85
Prox. Ash	8.06	7.00	10.31	7.95	11.79	6.25	12.86	9.44	12.25
Ult. Sulphur	1.39	1.63	1.26	2.09	1.76	1.66	1.93	1.92	.77
Ult. Hydrogen	5.57	5.51	5.50	5.75	5.39	5.72	5.12	5.64	5.31
Ult. Carbon	64.10	65.10	63.52	65.68	61.03	65.11	57.81	59.16	60.04
Ult. Nitrogen	1.04	1.09	1.00	1.01	.98	1.09	.90	.92	.96
Ult. Oxygen	19.84	19.67	18.41	17.52	19.05	20.17	21.38	22.92	20.67
Calories	6,434	6,466	6,346	6,538	6,152	6,571	5,759	5,875	5,936
British thermal units	11,581	11,639	11,423	11,768	11,074	11,828	10,366	10,575	10,685
Loss of moisture on air drying	2.80	2.60	2.30	2.50	2.50	2.90	3.00	4.40	3.30
Air-dried sample:									
Prox. Moisture	6.01	6.21	6.07	6.30	5.86	6.10	6.63	7.59	7.16
Prox. Volatile matter	37.13	37.12	36.53	37.68	35.18	37.69	33.78	35.98	33.79
Prox. Fixed carbon	48.57	49.48	46.85	47.87	46.87	49.77	46.33	46.55	46.38
Prox. Ash	8.29	7.19	10.55	8.15	12.09	6.44	13.26	9.88	12.67
Ult. Sulphur	1.43	1.67	1.29	2.14	1.81	1.71	1.99	2.01	.80
Ult. Hydrogen	5.41	5.36	5.36	5.61	5.24	5.56	4.94	5.39	5.11
Ult. Carbon	65.95	66.84	65.02	67.37	62.60	67.05	59.59	61.88	62.09
Ult. Nitrogen	1.07	1.12	1.02	1.04	1.00	1.12	.93	.96	.99
Ult. Oxygen	17.85	17.82	16.76	15.69	17.26	18.12	19.29	19.88	18.34
Calories	6,619	6,639	6,495	6,706	6,310	6,767	5,937	6,145	6,138
British thermal units	11,915	11,950	11,692	12,070	11,358	12,181	10,687	11,061	11,050
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	5 11	5 11	5 8½	5 8½	4 11	4 11	7 2½	7 2½	7 2½
Thickness of part sampled	1 2½	3 ½	1 3	2 7	1 1	2 3½	1 2	3 6½	1 9

5514. Sec. 28, T. 8 N., R. 93 W.
3463. Sec. 31, T. 7 N., R. 93 W.
3461. Sec. 31, T. 7 N., R. 93 W.
3462. Sec. 31, T. 7 N., R. 93 W.
5516. White River, at the mouth of Red Wash, sec. 11, T. 2 N., R. 101 W.
5519, 5520. Raven Park, sec. 14, T. 1 N., R. 102 W. Sample 5519 represents coal not quite so fresh as sample 5520.
5511, 5753. NE. ¼ SE. ¼ sec. 3, T. 4 S., R. 20 E. Sample included all of the marketable coal of the section exposed. Some of the coal is divided into two grades, the top and bottom benches being sold as first grade and the intermediate coal as second grade.
5512, 5509. W. ½ SW. ¼ sec. 2, T. 4 S., R. 20 E. Sample 5512 represents lower two benches, marketed as second-grade coal. Sample 5509 represents upper two benches, marketed as first-grade coal.
5754, 5755. Lot 10, SW. ¼ sec. 2, T. 4 S., R. 20 E. Sample 5754 represents lower two benches, marketed as second-grade coal. Sample 5755 represents upper benches, marketed as first-grade coal.
5513, 5510. Lots 1 and 2, NW. ¼ sec. 11, T. 4 S., R. 20 E. Sample 5513 represents lower two benches, marketed as second-grade coal. Sample 5510 represents upper two benches, marketed as first-grade coal.
5515, 5517, 5518. NE. ¼ NW. ¼ sec. 2, T. 4 S., R. 21 E. Sample 5515 represents lower 14 inches of the top bench of good, hard coal 22 inches thick, the rest being bony. Sample 5517 represents a middle bench composed of a very soft, flaky coal; reported to be of coking quality. Sample 5518 represents lower bench, which is bright black and hard, and seemed to be the best coal in the bed.

THE GRAND MESA COAL FIELD, COLORADO.

By Willis T. Lee.

INTRODUCTION.

LOCATION OF THE FIELD.

The Grand Mesa coal field is located on the southern rim of the Uinta coal basin, which lies partly in northwestern Colorado and partly in Utah. It derives its name from Grand Mesa, a high table-land between Grand and Gunnison rivers. The coal beds underlie the mesa and outcrop along the south and west sides. They extend westward into the Book Cliffs field, north of Grand Junction,[a] and eastward into the Anthracite-Crested Butte region,[b] long known for its anthracite coal, and thence northward along the Grand Hogback, recently described by Gale.[c]

PURPOSE OF THE INVESTIGATION.

The investigation of this field was undertaken for the purpose, first, of ascertaining the relations of the coal-bearing rocks to other formations; second, of segregating the coal land from the noncoal land and classifying it according to the legal subdivisions of the General Land Office; and, third, of determining the thickness of the coal beds, the character and quality of the coal, its accessibility with reference to topography and its location with reference to lines of transportation. The economic results of the investigation are summarized in this paper. Details and the results of scientific importance will be found in a more comprehensive paper to be published later as a separate bulletin.

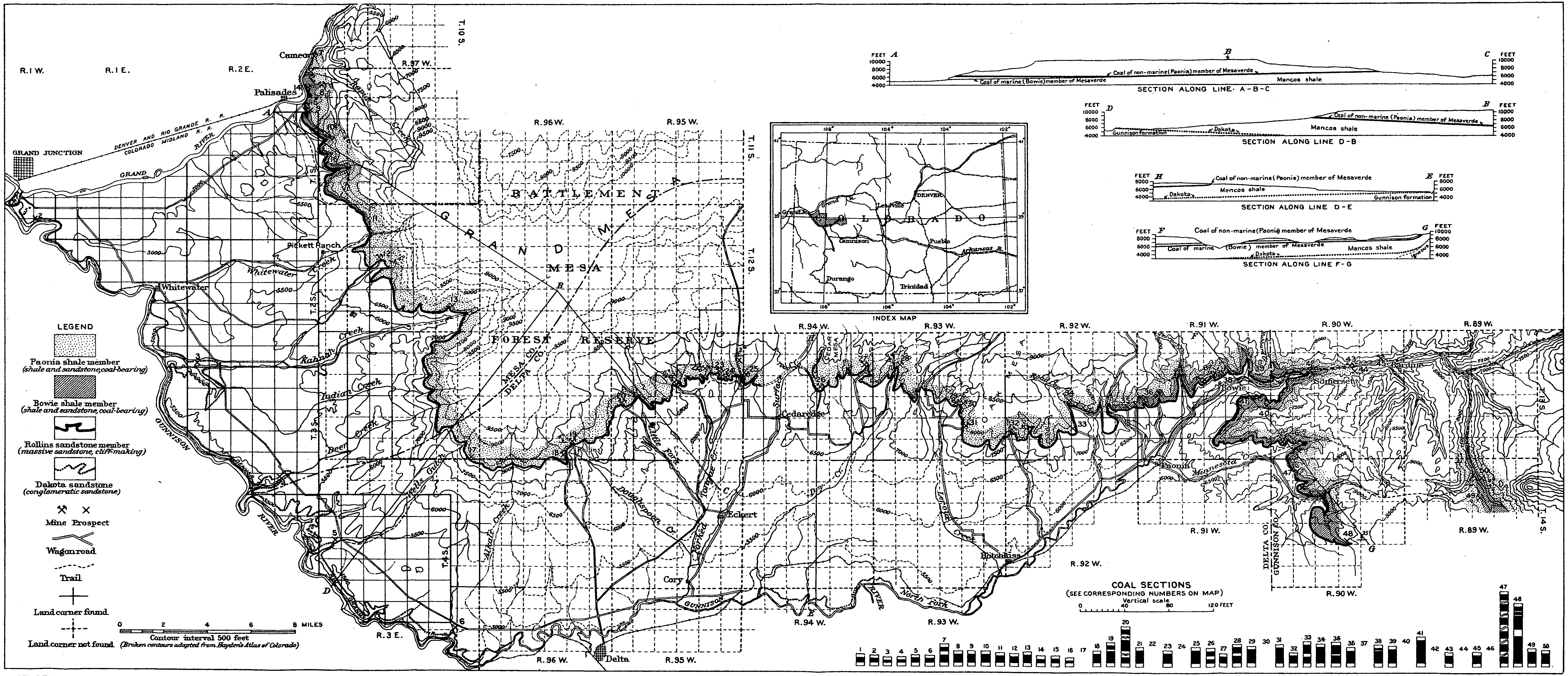
METHODS OF WORK.

The Grand Mesa field is comparatively free from complicated structures, and the geologic work consisted principally in determining the ages and areal distribution of the sedimentary rocks. Samples

[a] Richardson, G. B., The Book Cliffs coal field, between Grand River, Colorado, and Sunnyside, Utah; Bull. U. S. Geol. Survey No. 316, 1907, pp. 302-320.

[b] Eldridge, G. H., Anthracite-Crested Butte folio (No. 9), Geologic Atlas U. S., U. S. Geol. Survey, 1894.

[c] Gale, H. S., Coal fields of the Danforth Hills and Grand Hogback in northwestern Colorado: Bull. U. S. Geol. Survey No. 316, 1907, pp. 264-301.



MAP OF THE GRAND MESA COAL FIELD, COLORADO

By Willis T. Lee, Charles S. Blair, and A. J. Hazlewood were collected from the various coal openings for analysis and for comparison with coal from other fields, and data were collected concerning the characteristics of the coal that might affect its market value—such, for example, as its tendency to slack and its ability to coke. The accessibility of the coal is indicated on the accompanying map (Pl. XXI), which shows the general surface configuration of the field by means of contour lines.

In accordance with the object of this work, an attempt was made to map and classify the land by townships, ranges, and sections. As the work progressed, however, it was found that the land surveys were not adequate for this purpose. In the lowlands at the west end of the field almost all the corners were found, but in the central and eastern parts few could be located in the lowlands and practically none in the highlands, where the coal occurs. The presence of corners is indicated on the accompanying map by solid lines; the dotted lines indicate that none was found.

In the absence of Government corners near the coal, some other method of determining location had to be devised. In many places, because of the precipitous character of the country, it was impracticable to traverse the outcrop of the coal, and its location was determined principally by triangulation from such corners as could be found; many of these were several miles away. This method might have given satisfactory results if the corners used in triangulation had been accurately located, but that many of them were not became evident when locations of certain points made from one set of corners failed to coincide with locations of the same points made from other corners. Some of the inaccuracies are traceable to the original surveys and others to the attempts of local surveyors to reestablish lost corners or to establish new ones where they supposed the original corners should be. For these reasons, although the map is approximately correct, no final classification of the land can be made.

ACKNOWLEDGMENTS.

The writer was assisted in the field by Charles S. Blair, who spent part of the time in examining the coal and part of it in constructing the map, and by Russell R. Bryan, whose time was devoted wholly to mapping. The office work of preparing the map for publication was done mainly by A. J. Hazlewood. The writer also wishes to acknowledge his indebtedness to Alex Bowie, S. G. Porter, and other mine owners for aid and many courtesies during the fieldwork, and to J. W. Curtis, of Delta, who furnished much information regarding the land surveys.

The invertebrate fossils collected during the investigation have been identified by T. W. Stanton and the fossil plants by F. H. Knowlton. On their identifications depend the correlations made in this paper.

SURFACE FEATURES.

The Grand Mesa coal field is characterized by a very uneven surface. In the western and southern parts a broad belt of comparatively low relief borders a flat-topped table-land that rises to an altitude of more than 10,000 feet above the sea, or a mile vertically above the lowlands. In the middle-ground, where the coal crops out there is a belt of rugged country that differs in character from place to place according to the underlying rocks. Below the coal the rock consists of soft shale which is covered in many places with fragments of basalt derived from the sheet that caps the mesa. The shale is carved by erosion into broad, tongue-shaped mesas and badlands consisting of sharp irregular ridges and V-shaped ravines. Above the coal there are hard sandstones that form precipitous cliffs in some places and steep wooded or débris-covered slopes in others.

Near the east end of the field the surface configuration differs from that to the west in the absence of lowlands and the presence of high mountains that rise above the surface of the mesa. Narrow canyons have been cut by the streams to depths of 2,000 feet or more in the hard sandstone that overlies the coal. The highlands are covered more or less completely with timber, consisting principally of cedar in the western part of the field, and spruce, pine, and other forest trees farther east. In many places the cedars form dense thickets and the trees grow to considerable size, but few of the trunks are sound and they do not make good mine props. However, the pine and spruce trees that grow in considerable abundance in the canyons and on the mountain sides in the eastern part of the field are suitable for mining purposes.

The highlands have further potential importance in connection with the coal, inasmuch as they furnish the only supply of water available in many places. Near Palisades and Somerset the rivers furnish all water necessary for domestic purposes and for such coal washeries as may be needed, but in the greater part of the field the coal is far above the river level and the only available water is that supplied by numerous small streams from Grand Mesa. These highland waters are of good quality and with proper manipulation they can be delivered in any part of the field in quantities sufficient for mining purposes. The waters that issue from the shale below the coal or that flow over it are highly charged with salts that render them unfit for domestic use.

The means of approach to the coal are shown on the accompanying map (Pl. XXI) and require little comment. The main line of the Denver and Rio Grande Railroad crosses the coal outcrop at the northern border of the field and a branch of this road runs to the coal at Somerset, on the North Fork of the Gunnison. At no point within the field does the coal crop out more than 15 miles from a railroad in operation. However, much of the coal can not now be reached by wagon. No roads and but few trails cross the outcrop between Palisades and the Kuhnley mine (No. 18, Pl. XXI), a distance of more than 25 miles. East of the Kuhnley mine wagon roads have been built to the coal in many places, but on the North Fork there is no wagon road east of Bowie.

GEOLOGY.

STRATIGRAPHY.

The accompanying generalized section shows the character and succession of the rocks in this field.

Generalized section of rocks in the Grand Mesa coal field, Colorado.

System.	Group.	Formation.	Member.	Thickness (feet).	Characteristics.	Economic value.
Tertiary.		Green River.		200–1,800	White friable sandstone and clay shale, capped by basalt.	
		Ruby (probably Wasatch).		500–2,000	Conglomeratic sandstone and shale, varicolored. In the eastern part of the field the rocks are mainly red and conglomeratic beds are numerous. The basal conglomerate consists principally of quartz and chert pebbles and the higher ones of various crystalline, metamorphic, and extrusive rocks. In the western part of the field lighter colors prevail and the rocks are finer in texture.	
		Unconformity.				
		Ohio Creek.		100	White friable conglomeratic sandstone, containing pebbles of quartz, jasper, and igneous rock.	
		Unconformity.				
Cretaceous.	Montana.	Mesaverde.		2,000±	Gray quartzose sandstone, varying from soft and friable to hard and cliff making, and shale with plant remains and shells of fresh-water invertebrates.	Coal of doubtful value near the center of the section in the eastern part of the field.
			Paonia shale.	400+	Shale, carbonaceous in places, and sandstone, with plant remains and shells of fresh-water invertebrates.	Coal bearing throughout the field; one bed of workable thickness at west end and four or more at east end.
			Bowie shale.	425±	Dark-colored shale and gray sandstone, containing marine and brackish-water invertebrates. (Absent from central part of field.)	Coal bearing; one workable bed at west end of field and nine or more at east end. Coal much better than the fresh-water coal above, ranging in quality from bituminous to anthracite.
			Rollins sandstone.	100±	White cliff-making sandstone containing marine invertebrates.	

Creta-ceous.	Mon-tana. / Colo-rado.	Mancos.		3,000+	Dark-colored shale, with limestone concretions and marine invertebrates. Sandy limestone occurs locally near the top, and the base consists of black carbonaceous coal-bearing shale and flinty sandstone. The upper portion is correlated on fossil evidence with part of the Pierre shale and the lower portion with the Benton.	Coal of poor quality, in thin, irregular beds.
		Dakota.		10-100+	Conglomeratic sandstone.	
Juras-sic (?).		Gunnison.		600	Variegated shale and sandstone ranging from fine-grained and flinty to coarse-grained, conglomeratic, and friable. Colored in various shades of red, yellow, green, blue, etc.	

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The determination of the geologic age of the formations in the Grand Mesa coal field is based on paleontologic and stratigraphic evidence. The generalized section embodies the conclusions of the paleontologists regarding the geologic age and also the results of the field studies with respect to the character and relations of the various formations.

The Gunnison formation consists of variegated shale and sandstone, and is exposed in the Grand Mesa field only in the canyon of Gunnison River. It underlies the Dakota sandstone, a more resistant formation, which by its superior hardness maintains the steep cliffs and inclined mesas that border the river. The oldest coal of the Grand Mesa field occurs between the conglomeratic sandstone that is here referred to the Dakota and the overlying Mancos shale. It is locally known as the "Dakota coal," on the supposition that it occurs in the Dakota sandstone, but there are reasons which will be discussed in the more detailed description to be published later for referring it to the Mancos rather than to the Dakota. The coal outcrops between Grand Junction and Delta, as indicated on Pl. XXI, and again near the mouth of Gunnison Canyon east of Delta, but so far as is now known it is not of commercial value and is not here included among the coals of economic importance.

The Mancos is a marine formation and contains only the so-called "Dakota coal." The lower part corresponds to the Benton formation of other fields and the top to the lower part of the Pierre, as shown by fossil evidence.

The Mesaverde formation lies conformably upon the Mancos shale and is the only important coal-bearing formation in this field. The lower part of it was called "Fox Hills" and the upper part "Laramie" by the geologists of the Hayden Survey,[a] and other geologists have followed them in referring the coal to the Laramie. However, a study of the fossils, in connection with the stratigraphy of western Colorado, proves that it is much older than the Laramie, and the entire series of coal-bearing rocks in this field is now referred to the Mesaverde formation, originally named by Holmes,[b] in southwestern Colorado. Where the full section is exposed the Mesaverde is separated from the Laramie by a marine formation known as the Lewis shale, but in the Grand Mesa field there is no representative of the Lewis or of the Laramie beds. The sedimentary rocks of Tertiary age rest unconformably upon the Mesaverde.

In this field the upper part of the Mesaverde does not contain coal in beds thick enough to be of commercial value and need not be described. The lower part contains all the workable coal so far as

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[a] Hayden, F. V., Atlas of Colorado, 1877.

[b] Holmes, W. H., Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1875, pl. 35.

known and is separable into three members of economic importance. These will be fully described in the detailed report on this region, which is practically completed and will soon appear as a bulletin of the United States Geological Survey.

The lower member is a white, massive, cliff-making sandstone that is persistent throughout the field and marks the base of the coal-bearing rocks. The name Rollins sandstone, derived from the Rollins mine, north of Delta, where the sandstone forms a conspicuous cliff, has been adopted for this member.

Above this basal sandstone at either end of the field is a coal-bearing member that consists mainly of shale and beds of relatively hard and high-grade coal and contains shells of marine and brackish-water invertebrates. The name Bowie shale, from Bowie, a mining town on the North Fork of the Gunnison, where the shale is typically exposed, has been adopted for this member.

The third member of economic importance is the Paonia shale, so named from Paonia, a town on the North Fork of the Gunnison. It consists principally of shale with beds of relatively soft and low-grade coal and is characterized by plant remains and shells of fresh-water mollusks. The Paonia shale member rests upon the Bowie shale member with apparent conformity at the east end of the field, but unconformably upon the Rollins sandstone member in the central part. At the west end the Bowie shale member again appears, but there is an erosional unconformity between it and the overlying Paonia member.

These two coal-bearing members of the Mesaverde formation differ notably in physical character at the west end of the field. The Bowie member there consists principally of massive sandstone and thick beds of shale, with one bed of coal at the base. The Paonia member consists mainly of carbonaceous shale and thin beds of sandstone, with one thick bed of coal at the base and several thin beds above. At the east end of the field the lithologic distinction between these two members is not so pronounced, as both contain carbonaceous shale and sandstone in alternating layers, with beds of coal at many horizons. However, the two are usually separated by a sandstone that contains marine shells. The line of separation between the Bowie member and the Paonia member, although in places difficult to determine in the field, is economically important because of the difference in the quality of the coal, the upper coals being soft and lignitic and the lower coals bituminous and, locally, of coking quality.

No coal of commercial importance is known above the Paonia shale, and the overlying rocks are only of negative importance in the present consideration, as they cover the coal to depths of several thousand feet.

STRUCTURE.

The Grand Mesa coal field is a part of the southern rim of the Uinta coal basin of northwestern Colorado and eastern Utah. The rocks, inclining toward the lowest part of the basin, dip in a general northeasterly direction except near the east end of the field, where the dip is more to the north or northwest. The degree of dip varies locally, but the average is about 2½°. However, it is usually greater than this near the outcrop, owing to local upturning of the exposed edges of the strata. Near the east end of the field the structure has been complicated by the intrusion of great masses of igneous rock and the formation of laccolithic mountains, but within the area mapped the coal has not been greatly disturbed. A few small faults have been encountered in the mines, but so far as reported nowhere has the mining been seriously hindered by any disturbed condition of the beds. The only displacements of consequence that have been noted are at the mouth of Black Canyon of the Gunnison east of Delta and in the vicinity of Surface Creek. At the mouth of Black Canyon a local fold has been formed and for a short distance the sedimentary rocks are vertical. The coal-bearing beds east of Surface Creek are apparently about 400 feet higher than the same beds 2 miles farther west. The intervening space is covered with stream deposits and it could not be ascertained whether the displacement is due to faulting or to warping. However, the disturbance is in a locality where the least amount of coal occurs and apparently has no important bearing on the development of the field.

THE COAL.

GEOGRAPHIC DISTRIBUTION.

Aside from the coal at the base of the Mancos formation, which is not of commercial value, the outcrop of the coal in the Grand Mesa field forms a long, sinuous band in the western and southern slopes of the mesa, and can be best described by districts, as follows: (1) The Gunnison district lies between Grand Junction and Delta and includes only the Mancos coal; (2) the Palisades district extends from Grand River to the southern point of Grand Mesa; (3) the Rollins district extends from the southern point of the mesa eastward to Paonia, and (4) the Somerset district includes the coal east of Paonia.

GUNNISON DISTRICT.

The coal of the Gunnison district occurs in the zone of carbonaceous shale at the base of the Mancos formation and outcrops in the bluffs north of Gunnison River. It was formerly mined to some extent near Grand Junction (No. 1[a]), but the openings are now abandoned. It is still mined for local use in Wells Gulch (No. 5), and has been

[a] Numbers refer to coal sections and locations on Pl. XXI.

opened at several other places. The coal beds are irregular in thickness, ranging within short distances from a few inches to a maximum of slightly less than 4 feet. Near Grand Junction there are four beds, as shown in the following section:

Section of coal-bearing rocks at the junction of Grand and Gunnison rivers, Colorado.

	Ft.	in.
Shale, Mancos, containing at the base thin layers of quartzitic sandstone with fossils of Benton age.		
Coal	1	6
Shale		4
Coal	2	8
Shale, carbonaceous, with thin beds of coal	2	4
Shale, sandy	6	
Coal		10
Shale, sandy	8	
Coal	3	
Sandstone, coarse, quartzitic, thin bedded	8	
Shale, carbonaceous, with thin beds of coal	3	
Sandstone, conglomeratic (Dakota)	20	
	55	8

Farther east, at locality No. 2, the largest bed is 3 feet thick, but at Kahnah Creek (No. 3) and at Deer Creek (No. 4) less than 1 foot of coal was found. Still farther to the east, at Wells Gulch (No. 5), the coal is 3 feet 4 inches thick at the outcrop, but only 1 foot 6 inches 175 feet from the opening. At locality No. 6 the coal is 3 feet thick.

The coal is black, bituminous, of dull luster, and bony in many places, and it does not burn readily, probably because of long exposure. A sample for analysis (No. 5530 in table, p. 333) was taken near Grand Junction, and represents the upper two beds of the section, the 4 inches of shale separating them being discarded. The face of the bed was cleared in order to procure fresh coal, but the results of the analysis indicate that the coal is very poor. A sample was taken also near the east end of the district, from a face which was apparently not affected by weathering, and the analysis (No. 5534) indicates a coal of good quality. However, the beds are not thick enough to be included among those of economic importance.

PALISADES DISTRICT.

Upper coals.—The upper coal beds of the Palisades district occur at the base of the Paonia or nonmarine member of the Mesaverde formation, and extend with uniform thickness across the district. The coal-bearing part of the Paonia is 225 feet thick and contains eight or more beds of coal. The lowest bed, 7 feet thick, is the most valuable, none of the others, so far as known, being more than 3 feet thick. The coal is easily accessible for a distance of 3 miles along the river, east of Palisades, but for the next 4 miles to the south it outcrops high in the steep cliffs. Still farther south, although the coal occurs higher in the cliffs, it is more readily accessible because of the graded slopes leading up to it; but even here at only one place, the Patterson mine (No. 12), can the coal be reached by wagon. The lowest coal bed of this group is the same as the one worked at Cameo and described by Richardson.[a] Several openings have been made in this coal bed, but in only one, the Bailey mine (No. 7), was work being done at the time of the investigation. A considerable amount of work has been done at several of the openings, but none of them are equipped with machinery or trackage.

The coal is black and fine grained, with vitreous to dull luster, banded texture, and conchoidal fracture. It is comparatively soft and slacks on exposure. It shows a slight tendency to coke, the fragments adhering in the forge; but tests on coal from the Patterson mine are reported as failing to produce coke. The coal bed is regular in thickness, uniform in character, and contains only a small amount of foreign material.

Lower coal.—The lower coal of the Palisades district occurs at the base of the Bowie or marine coal-bearing member of the Mesaverde formation, about 450 feet below the upper coal. There is only one bed of coal in this member. It is 3 feet 4 inches thick at the north end of the district, where it is mined for the local market at the Stokes mine (No. 14), but it thins out a few miles south of Palisades. The coal is harder and cleaner than the upper coal and does not slack readily on exposure. Its quality is regarded as somewhat superior to that of the upper coal, but mining operations are difficult on account of the thinness of the bed.

Sections.—The sections given in the subjoined table show the character of the coal beds in the Palisades district:

Sections of coal beds in the Palisades district, Grand Mesa coal field, Colorado.

UPPER COAL (PAONIA SHALE MEMBER, OR FRESH-WATER MESAVERDE).

No. on Pl. XXI.	Name and location of mine.	Section.	Ft.	in.
7	Bailey; NW. ¼ SE. ¼ sec. 34, T. 10 S., R. 98 W.	Sandstone, massive.		
		Shale, sandy	5	
		Coal, impure	3	
		Shale, sandy	4	
		Coal	6	2
		Shale.		
			18	2
8	Hall; SE. ¼ NE. ¼ sec. 2, T. 11 S., R. 98 W.	Shale.		
		Coal (bottom not exposed)	7	
9	Prospect near De Rush mine; sec. 11, T. 11 S., R. 98 W.	Shale.		
		Coal	7	
		Shale, sandy	5	
			12	
10	Prospect 2 miles south of Palisades; sec. 14, T. 11 S., R. 98 W.	Shale, carbonaceous.		
		Coal	7	
		Sandstone.		

[a] Richardson, G. B., The Book Cliffs coal field between Grand River, Colorado, and Sunnys de, Utah: Bull. U. S. Geol. Survey No. 316, 1907, p. 308.

Sections of coal beds in the Palisades district, Grand Mesa coal field, Colorado—Cont'd.

UPPER COAL (PAONIA SHALE MEMBER, OR FRESH-WATER MESAVERDE)—Cont'd.

No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.	No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.
11	Prospect near Pickett ranch; sec. 6, T. 12 S., R. 97 W.	Shale, sandy.		13	Prospect on Kahnah Creek; sec. 26, T. 12 S., R. 97 W.	Shale.	
		Coal	6			Coal	7
		Sandstone.				Sandstone.	
12	Patterson; sec. 17, T. 12 S., R. 97 W.	Shale, carbonaceous.					
		Coal, bony	1				
		Coal	4				
		Shale	2				
			7				

LOWER COAL (BOWIE SHALE MEMBER, OR MARINE MESAVERDE).

No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.	No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.
14	Stokes; NE. ¼ SW. ¼ sec. 2, T. 11 S., R. 98 W.	Shale.		16	Prospect 2 miles south of Palisades; sec. 26, T. 11 S., R. 98 W.	Sandstone.	
		Coal	3 4			Coal	1
		Shale.				Sandstone.	
15	De Rush; SW. ¼ NW. ¼ sec. 11, T. 11 S., R. 98 W.	Shale.					
		Coal (base not exposed)	3 4				

ROLLINS DISTRICT.

The Bowie shale member is not represented in the Rollins district or central part of the field. All of the coal is in the Paonia member, which here rests upon the Rollins sandstone. Only one bed of commercial value is known in the western part of the district, but in the eastern part several beds of workable thickness have been opened. The thin beds above the workable coal near Palisades may thicken toward the east, but too little is yet known of them to state whether the beds of coal are continuous for long distances or are more or less lenticular, as they appear to be in the eastern part of the field where they are better exposed.

In the western part of the Rollins district the coal crops out high in the sides of the mesa, the maximum altitude being 8,100 feet. It is exposed in only a few places on account of a surface covering consisting of blocks of basalt derived from the cap rock of the mesa and on account of thickets of cedar, scrub oak, and underbrush that restrain erosion. In the eastern part of the district it crops out lower in the mesa, is better exposed, and has been prospected more extensively. The location of the principal openings is shown on the accompanying map, and the thickness of coal is given in the following table. The mines have all been worked more or less, and a considerable amount of coal is supplied each winter to the local market.

Sections of coal beds in the Rollins district, Grand Mesa coal field, Colorado.

No. on Pl. XXI.	Name and location of mine.	Section.	Ft.	in.
18	Kuhnley; SE. ¼ SE. ¼ sec. 34, T. 13 S., R. 96 W.	Shale.		
		Coal, bony in places	5	6
		Coal	2	
		Shale.		
			7	6
19	Rollins; NW. ¼ NW. ¼ sec. 35, T. 13 S., R. 96 W.	Shale.		
		Coal	3	
		Shale	2	
		Coal	11	
		Shale.		
			16	
20	Fairview; sec. 19, T. 13 S., R. 95 W.	Coal	4	
		Sandstone and shale	60	
		Shale	5	
		Coal	6	6
		Coal, bony	4	
		Sandstone	12	
		Shale, carbonaceous	5	
		Coal	5	
		Shale.		
			101	6
21	Winton; sec. 16, T. 13 S., R. 95 W.	Shale.		
		Coal	11	
		Sandstone.		
22	Watson; SW. ¼ SE. ¼ sec. 11, T. 13 S., R. 95 W.	Shale	2	
		Coal	3	6
		Shale		8
		Coal	1	6
		Shale.		
			7	8
23	Davis; SE. ¼ SE. ¼ sec. 11, T. 13 S., R. 95 W.	Sandstone.		
		Coal	3	
		Bone		1
		Coal	3	
		Shale	1	
		Coal	1	6
		Sandstone	8	
		Shale	1	6
		Coal	7	
		Shale.		
			25	1
24	Blossom; NW. ¼ NW. ¼ sec. 13, T. 13 S., R. 95 W.	Shale.		
		Coal		6
		Shale, carbonaceous	1	
		Coal	4	
		Sandstone.		
			5	6
25	States; NE. ¼ NE. ¼ sec. 13, T.13 S., R. 95 W.	Shale.		
		Coal	3	
		Shale	1	
		Coal	7	
		Shale.		
			11	
26	McGruder; sec. 15, T. 13 S., R. 94 W.	Shale.		
		Coal	3	6
		Shale, sandy	3	
		Coal	3	
		Sandstone.		
			9	6
27	Ward (Loomis); sec. 12, T. 13 S., R. 94 W.	Shale, carbonaceous		6
		Coal	5	4
		Shale, carbonaceous	3	
			8	10
28	Landerth; SW. ¼ NW. ¼ sec. 8, T. 13 S., R. 93 W.	Sandstone(?).		
		Coal	5	4
		Shale	2	6
		Coal	6	
		Shale.		
			13	10
29	Degrafenreid; sec. 22, T. 13 S., R. 93 W.	Shale (?).		
		Coal	12	
		Sandstone.		
30	Bennett; SW. ¼ NW. ¼ sec. 23, T. 13 S., R. 23 W.	Shale.		
		Coal	5	6
		Shale.		
31	Newman; SE. ¼ NW. ¼ sec. 26, T. 13 S., R. 93 W.	Shale.		
		Coal	14	
		Shale.		
32	Burdick; sec. 30, T. 13 S., R. 92 W.	Roof not exposed.		
		Coal	6	2
		Coal, bony.		
33	Stucker; sec. 27, T. 13 S., R. 92 W.	Shale.		
		Coal, bony in places	7	
		Shale, carbonaceous	3	
		Coal	5	
		Sandstone.		
			15	
34	Stucker prospect; sec. 21, T. 13 S., R. 92 W.	Shale.		
		Coal	2	6
		Shale		6
		Coal	10	
		Sandstone.		
			13	

The coal is black, subbituminous, with fine texture, dull luster, and conchoidal fracture, and slacks when exposed to the weather. It burns readily, making a good domestic fuel, but shows little tendency to coke. It is usually free from foreign matter, although in some places there is a considerable amount of bone. The coal varies from place to place in purity and in the thickness and number of the beds. At the Kuhnley mine (No. 18) the bed is about one-third bone; at the Rollins mine (No. 19) the same bed contains practically no bone. For several miles east of Surface Creek the beds are thin and few in number and the coal is bony; but still farther east they are more numerous and the coal improves in quality. At the Bennett mine (No. 30) four beds of workable thickness have been prospected, and the Newman mine (No. 31) opened on one of the upper beds has 14 feet of clean coal. Several other mines in the district have equally good coal in beds 7 to 10 feet thick.

The Rollins mine (No. 19) is the only one in the district equipped with steam power, but arrangements have been made for installing machinery at the Fairview mine (No. 20). At the other openings mining is done by hand. The inside haulage is by mules, and the coal is all taken to market in wagons, more or less well graded roads having been constructed to the mines for this purpose.

SOMERSET DISTRICT.

The eastern or Somerset district includes the coal east of Paonia. At its west end the coal crops out in the cliffs about 1,000 feet above North Fork, but at Somerset it is at river level. East of Minnesota Creek it underlies the mesa and crops out again on Coal Creek, which has cut its canyon down to the coal-bearing zone. The beds are extensively exposed farther south, or upstream in the Coal Creek canyon, but were not examined south of the Mosley mine (No. 49).

Coal occurs in both the Paonia and Bowie shale members of the Mesaverde formation in the Somerset district, as shown in the Johnson section (No. 47) of the following table. The upper four beds of this section are in the Paonia member. There are probably other coal beds in this member, but none have been opened and there are few natural exposures, the coal being either burned on the outcrop or covered with brush and surface débris. The Bowie shale contains seven beds of coal that have been prospected, and others of which little is known. The amount of clinker and ash in some places indicates the existence of unknown coal beds of considerable thickness. All the mines and nearly all the prospects of the Somerset district are in the coals of the Bowie shale, or marine Mesaverde.

The coal of the Somerset district is more abundant, better exposed, more easily accessible, and more extensively worked than that of the other districts. The average thickness of workable coal is probably not less than 65 feet. The productive beds occur at various horizons throughout the Bowie shale, and range in thickness from 4 to 25 feet. The lowest coal is worked at the Conine mine (No. 35), where the bed, 15 feet 8 inches thick, consists of two benches separated by 1 foot 6 inches of shale. The coal of the middle and upper parts of the Bowie shale is worked at the Cooperative mine (No. 36), where the bed is 10 feet 8 inches thick; at the new King mine (No. 38), where it is 12 feet 8 inches thick; and at the Somerset mine, where it is said to be still thicker on account of the coalescence of several beds.

The coal is better in many ways than the fresh-water coal of the Rollins district. It is harder, less liable to slack on exposure to the weather, stands shipment well, and some of it is coking coal. It is black, bituminous, fine grained, with bright vitreous luster and texture ranging from even to seamy, and some of it is conspicuously banded by alternating layers of coal that differ in luster. The coal throughout the district is free from bone or other foreign matter that seriously interferes with mining or marketing.

Sections of coal beds in the Somerset district, Grand Mesa coal field, Colorado.

No. on Pl. XXI.	Name and location of mine.	Section.	Ft.	in.
35	Conine; NW. ¼ SE. ¼ sec. 24, T. 13 S., R. 92 W.	Shale. Coal Shale Coal Shale 	 7 1 6 2 17	 8 6 6 8
36	Cooperative; SW. ¼ SW. ¼ sec. 17, T. 13 S. R. 91 W.	Sandstone. Coal, bony Coal Shale, carbonaceous. 	 2 8 11	 8 6 2
37	King (old); NE. ¼ NW. ¼ sec. 15, T. 13 S., R. 91 W.	Shale. Coal Coal, bony Sandstone. 	 4 4	 4 4
38	King (new); NE. ¼ NE. ¼ sec. 15, T. 13 S., R. 91 W.	Shale, carbonaceous. Coal Shale Coal Coal ("sulphur streak") Coal Shale, carbonaceous. 	 1 3 6 12	 2 3 7 4 8 8 8
39	Prospect on Hubbard Creek; sec. 12, T. 13 S., R. 91 W.	Shale. Coal Sandstone.	 12 	
40	Mallott; sec. 24, T. 13 S., R. 91 W.	Shale, sandy. Coal Shale Coal Shale, sandy. 	 4 12 16	 2 2 4
41	Whitlaw; sec. 23, T. 13 S., R. 91 W.	Shale. Coal	 21	
43	Sylvester; sec. 10, T. 13 S., R. 90 W.	Shale. Coal Shale.	 5 	 10
45	Hawks Nest; sec. 11, T. 13 S., R. 90 W.	Shale. Coal Base not exposed.	 7 	
46	Shoecroft (Porter claims); sec. 32, T. 13 S., R. 90 W.	Shale. Coal Shale.	 7 	

Sections of coal beds in the Somerset district, Grand Mesa coal field, Colorado—Cont'd.

No. on Pl. XI.	Name and location of mine.	Member	Section.	Ft.	in.
47	Johnson (Porter claims); sec. 5, T. 14 S., R. 90 W.	Paonia member.	Sandstone.		
			Coal	12	2
			Shale and sandstone	57	
			Coal	3	9
			Sandstone and shale	40	
			Coal	1	
			Sandstone and shale	40	
			Coal	10	
		Bowie member.	Sandstone	85	
			Coal	8	
			Sandstone	50	
			Ash and clinker	20	
			Coal, metamorphosed	2	
			Shale and sandstone	48	
			Coal, metamorphosed	2	
			Shale and sandstone	40	
			Coal	5	7
			Shale	25	
			Coal	6	
			Limestone, shelly	3	
			Shale	15	
			Coal	5	5
			Shale	14	
			Coal	6	
			Shale, sandy	21	
			Coal	4	6
			Shale, sandy	16	
			Coal	3	
			Shale.		
				543	5
48	Simonton (Porter claims); sec. 22, T. 14 S., R. 90 W.		Shale.		
			Coal	2	10
			Shale		10
			Coal	1	2
			Shale		5
			Coal	13	1
			Shale	6	
			Coal	16	
			Coal, bony	2	
			Coal	7	2
			Shale	2	
			Shale and sandstone	12	
			Coal	1	
			Shale.		
				64	6
49	Mosley; sec. 10(?), T. 13 S., R. 89 W.		Shale.		
			Coal	2	
			Shale	12	
			Coal	10	
			Bottom not exposed.		
				24	
50	Prospect near Mosley mine; sec. 3, T. 14 S., R. 89 W.		Shale	5	
			Coal	8	
			Sandstone	20	
			Coal	1	
			Shale, sandy.		
				34	

Along the North Fork to the east of Somerset, and on Coal Creek the coal is hard, massive, bituminous to anthracite, and of coking quality, although recent tests in the Denver laboratory of the fuel-testing plant show that the coke is not of the best quality. At the Mosley mine (No. 49) the coal, 10 feet thick, is metamorphosed, probably by the heat from an intrusive igneous rock, although no such rock was found in contact with it. However, it is located in the side of Mount Gunnison, at no great distance from extensive masses of igneous rock. The coal is hard, black, dull vitreous in luster, fine grained, even to seamy in texture, with conchoidal fracture, free from bone, does not slack on exposure to the weather, and cokes readily. A large quantity of equally good coal is reported from Coal Creek, south of the area investigated.

Anthracite coal of good quality occurs in the south slope of Mount Gunnison at an altitude of 9,700 feet. Several exposures were observed, and the beds have been carefully prospected by S. G. Porter. The rocks are faulted, crushed, and cut by dikes of igneous rock to such an extent that individual beds can not be traced for any considerable distance, nor is the coal constant in thickness or character. An opening, known as the Phillip prospect, was started on an 8-foot bed, but the coal is crushed in places, variable in thickness, and at a point 290 feet from the opening pinched out entirely.

The coal is hard and dull in luster, and is virtually a natural coke changed by the heat of igneous rocks, though without vesicular structure, probably because of the pressure of the overlying strata. This coal occurs in comparatively small blocks of the coal-bearing formation, surrounded by and included in the igneous rock of the mountains, and the coal is so disturbed and so uncertain in occurrence that it has not been included within the area here regarded as productive coal land. Although of excellent quality, it is scanty in quantity and difficult of access, and its value from a commercial standpoint is doubtful.

Four mines of the Somerset district were producing at the time of the investigation. Two of these, the Conine and Cooperative, were not equipped with machinery and the mining was done by hand. The King mine (No. 38) was well equipped for mining operations. It is located in the side of the canyon and the coal is lowered 600 feet by means of a gravity incline to the foot of the cliff, where it is screened and loaded directly into cars for shipment. The Utah Fuel Company's mine at Somerset is the largest producer in the district, and is the objective point of the North Fork branch of the Denver and Rio Grande Railroad. No information in regard to this mine could be obtained from the company.

QUANTITY AND VALUE OF COAL.

No close estimate can be made of the amount of coal in this field until more is known of the number of the coal beds and their variations in thickness. The average thickness of workable coal, based on available information, is 11 feet for the Palisades district, 15 feet for the Rollins district, and 65 feet for the Somerset district. It is probable that these figures will be increased when the beds are all prospected. If the practical limit of available coal is assumed to be 6 miles back from the outcrop, there are about 120 square miles of coal land in the Palisades district, about 235 square miles in the Rollins district, and about 195 square miles in the Somerset district. Coal of 1.3 specific gravity weighs 81.25 pounds per cubic foot, and a square mile of coal 1 foot thick contains 1,132,544 short tons. If the estimated thicknesses are correct, the Grand Mesa coal field contains 19,842,270,880 short tons of coal in workable beds. After deducting 25 per cent for waste in mining, there remain 14,881,703,160 short tons of available coal, mainly on Government land.

COMPOSITION OF COAL.

The following analyses show that good coal occurs throughout the field, but that the coal of the Bowie, or marine Mesaverde, is superior to that of the Paonia, or nonmarine beds. In general, Paonia coals have large percentages of moisture and low heating values, are comparatively soft, and slack more or less readily on exposure. The Bowie coals have low percentages of moisture and comparatively high heating values, are relatively hard, and do not slack easily. There is a gradual improvement in quality from west to east, or toward the mountains, and the coal nearest the intrusive rock at the east end of the field is semianthracite.

The samples for analysis were all taken in the manner described on pages 12–13, and great care was exercised to obtain representative coal.

Analyses of coal samples from the Grand Mesa coal field, Colorado.

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

District	Gunnison.		Palisades.		Rollins.					
Character of coal	Bituminous.			Subbituminous to bituminous.						
Laboratory No	5530.	5534.	5724.	5535.	5541.	5542.	5540.	5522.	5539.	5521.
Sample as received:										
Prox. Moisture	5.96	6.53	7.18	11.51	17.18	19.14	16.37	14.16	15.26	13.36
Prox. Volatile matter	26.41	33.85	32.97	32.60	30.67	31.20	29.79	31.29	30.24	33.72
Prox. Fixed carbon	41.21	50.95	50.98	45.53	41.41	41.73	45.39	48.48	45.83	48.69
Prox. Ash	26.42	8.67	8.87	10.36	10.74	7.93	8.45	6.07	8.67	4.23
Ult. Sulphur	.80	1.11	.58	.93	.70	.75	.45	.68	.60	.56
Ult. Hydrogen	......	......	5.53	......	......	6.06	5.87	5.90	5.87	5.88
Ult. Carbon	......	......	67.54	......	......	55.11	56.74	61.15	59.24	62.11
Ult. Nitrogen	......	......	1.24	......	......	1.10	1.13	1.22	1.11	1.30
Ult. Oxygen	......	......	16.24	......	......	29.05	27.36	24.98	24.51	25.92
Calories	4,697	6,078	6,649	5,782	5,202	5,322	5,616	6,016	5,780	6,226
British thermal units	8,455	10,940	11,968	10,408	9,364	9,580	10,109	10,829	10,404	11,207
Loss of moisture on air drying	2.10	2.10	2.40	2.70	5.00	5.90	4.30	4.90	5.50	4.60
Air-dried sample:										
Prox. Moisture	3.94	4.52	4.89	9.05	12.82	14.07	12.61	9.73	10.34	9.18
Prox. Volatile matter	26.98	34.58	33.78	33.51	32.28	33.16	31.13	32.90	32.00	35.35
Prox. Fixed carbon	42.09	52.04	52.24	46.79	43.59	44.34	47.43	50.99	48.49	51.04
Prox. Ash	26.99	8.86	9.09	10.65	11.31	8.43	8.83	6.38	9.17	4.43
Ult. Sulphur	.82	1.13	.59	.96	.74	.80	.47	.72	.64	.59
Ult. Hydrogen	......	......	5.39	......	......	5.74	5.63	5.64	5.57	5.63
Ult. Carbon	......	......	69.20	......	......	58.56	59.29	64.30	62.69	65.11
Ult. Nitrogen	......	......	1.27	......	......	1.17	1.18	1.28	1.17	1.36
Ult. Oxygen	......	......	14.46	......	......	25.30	24.60	21.68	20.76	22.88
Calories	4,798	6,208	6,813	5,942	5,476	5,656	5,868	6,326	6,116	6,526
British thermal units	8,636	11,175	12,262	10,696	9,856	10,181	10,563	11,387	11,010	11,747
Thickness of part of bed sampled	*Ft. in.* 3 4	*Ft. in.* 1 6	*Ft. in.* 6 2	*Ft. in.* 4	*Ft. in.* 7 6	*Ft. in.* 11	*Ft. in.* 6 5	*Ft. in.* 4	*Ft. in.* 5	*Ft. in.* 3 8
District	Rollins.							Somerset.		
Character of coal	Subbituminous to bituminous.							Bituminous to anthracite.		
Laboratory No	5523.	5524.	5538.	5525.	5537.	5536.	5552.	5551.	5526.	5527.
Sample as received:										
Prox. Moisture	13.57	9.85	10.24	13.97	15.54	16.67	22.40	8.90	13.64	9.37
Prox. Volatile matter	32.58	32.76	31.57	31.90	33.03	33.10	31.19	32.61	30.89	34.75
Prox. Fixed carbon	46.17	43.46	42.10	43.23	46.06	46.27	42.16	47.05	47.33	53.04
Prox. Ash	7.68	13.93	16.09	10.90	5.37	3.96	4.25	11.44	8.14	2.84
Ult. Sulphur	.83	1.83	.60	.54	.58	.47	.30	.81	.68	.50
Ult. Hydrogen	......	......	......	......	5.89	......	......	5.34	5.41	5.81
Ult. Carbon	......	......	......	......	60.08	......	......	62.03	58.06	69.94
Ult. Nitrogen	......	......	......	......	1.05	......	......	1.26	1.24	1.31
Ult. Oxygen	......	......	......	......	27.03	......	......	19.12	26.47	19.60
Calories	5,921	5,683	5,589	5,667	5,865	5,945	4,533	6,174	5,576	6,883
British thermal units	10,658	10,229	10,060	10,201	10,557	10,701	8,159	11,113	10,037	12,389
Loss of moisture on air drying	5.40	3.10	3.00	4.70	4.70	5.20	8.80	3.30	5.20	3.60
Air-dried sample:										
Prox. Moisture	8.64	6.97	7.46	9.73	11.37	12.10	14.91	5.79	8.90	5.98
Prox. Volatile matter	34.44	33.81	32.55	33.47	34.66	34.92	34.20	33.72	32.58	36.05
Prox. Fixed carbon	48.80	44.85	43.40	45.36	48.33	48.80	46.23	48.66	49.93	55.02
Prox. Ash	8.12	14.37	16.59	11.44	5.64	4.18	4.66	11.83	8.59	2.95
Ult. Sulphur	.88	1.89	.62	.57	.61	.50	.33	.84	.72	.52
Ult. Hydrogen	......	......	......	......	5.63	......	......	5.14	5.09	5.61
Ult. Carbon	......	......	......	......	63.04	......	......	64.15	61.24	72.55
Ult. Nitrogen	......	......	......	......	1.10	......	......	1.30	1.31	1.36
Ult. Oxygen	......	......	......	......	23.98	......	......	16.74	23.05	17.01
Calories	6,259	5,865	5,762	5,946	6,154	6,271	4,970	6,385	5,882	7,140
British thermal units	11,266	10,556	10,371	10,704	11,078	11,288	8,946	11,492	10,588	12,850
Thickness of part of bed sampled	*Ft. in.* 6 5	*Ft. in.* 3 6	*Ft. in.* 5 4	*Ft. in.* 5 6	*Ft. in.* 14	*Ft. in.* 6 2	*Ft. in.* 6 6	*Ft. in.* 7 8	*Ft. in.* 6 6	*Ft. in.* 8 8

Analyses of coal samples from the Grand Mesa coal field, Colorado—Continued.

District	Somerset.									
Character of coal	Bituminous to anthracite.									
Laboratory No	5760.	5533.	5531.	5532.	5406.	5405.	5807.	5529.	5344.	5528.
Sample as received:										
Prox. Moisture	3.37	2.41	2.34	2.64	5.49	5.96	21.44	19.23	8.94	4.22
Prox. Volatile matter	35.09	29.14	34.97	28.84	35.65	23.92	29.13	31.04	34.23	3.98
Prox. Fixed carbon	53.02	58.38	58.42	63.31	55.79	66.95	44.75	44.35	52.04	76.02
Prox. Ash	8.52	10.07	4.27	5.21	3.07	3.17	4.68	5.38	4.79	15.78
Ult. Sulphur	.62	.52	.54	.66	.60	.47	.33	.31	.57	.88
Ult. Hydrogen	5.41	4.74	5.37	5.05	5.76	5.68	......	......	5.41	......
Ult. Carbon	71.18	71.93	75.31	76.81	73.22	74.08	......	......	68.76	......
Ult. Nitrogen	1.59	1.18	1.31	1.28	1.22	1.36	......	......	1.41	......
Ult. Oxygene	12.68	11.56	13.20	10.99	16.13	15.24	......	......	19.06	......
Calories	7,238	7,020	7,556	7,516	7,343	7,358	4,372	4,871	6,837	6,815
British thermal units	13,028	12,636	13,601	13,529	13,217	13,244	7,870	8,768	12,307	12,267
Loss of moisture on air drying	.80	1.40	1.10	1.70	2.00	2.70	9.80	10.10	1.70	3.20
Air-dried sample:										
Prox. Moisture	2.59	1.03	1.25	.96	3.56	3.35	12.91	10.16	7.37	1.06
Prox. Volatile matter	35.37	29.55	35.36	29.34	36.38	24.58	32.29	34.53	34.82	4.11
Prox. Fixed carbon	53.45	59.21	59.07	64.40	56.93	68.81	49.61	49.33	52.94	78.53
Prox. Ash	8.59	10.21	4.32	5.30	3.13	3.26	5.19	5.98	4.87	16.30
Ult. Sulphur	.63	.53	.55	.67	.61	.48	.37	.34	.58	.91
Ult. Hydrogen	5.36	4.64	5.31	4.94	5.65	5.53	......	......	5.31	......
Ult. Carbon	71.75	72.95	76.15	78.14	74.72	76.13	......	......	69.95	......
Ult. Nitrogen	1.60	1.20	1.32	1.30	1.25	1.40	......	......	1.44	......
Ult. Oxygen	12.07	10.47	12.35	9.65	14.64	13.20	......	......	17.85	......
Calories	7,296	7,120	7,640	7,646	7,493	7,562	4,847	5,418	6,955	7,040
British thermal units	13,133	12,815	13,752	13,763	13,487	13,612	8,725	9,753	12,520	12,673
Thickness of part of bed sampled	*Ft. in.* 4 5	*Ft. in.* 4 9	*Ft. in.* 6 4	*Ft. in.* 6 4	*Ft. in.* 5 10	*Ft. in.* 5	*Ft. in.* 7	*Ft. in.* 7	*Ft. in.* 7	*Ft. in.* 5 6

5530.[a] Sec. 26, T. 1 S., R. 1 W. (Ute principal méridian), 80 feet from mouth of opening in deserted mine.
5534.[b] Sec. 18, T. 4 S., R. 3 E. (Ute principal meridian), 160 feet from mouth of opening.
5724.[c] NW. ¼ SE. ¼ sec. 34, T. 10 S., R. 98 W., 165 feet from mouth of opening.
5535.[a] Sec. 17, T. 12 S., R. 97 W., 125 feet from mouth of opening.
5541.[c] SE. ¼ SE. ¼ sec. 34, T. 13 S., R. 96 W., 2,000 feet from mouth of opening.
5542.[c] NW. ¼ NW. ¼ sec. 35, T. 13 S., R. 96 W., 285 feet from mouth of opening.
5540.[c] Sec. 19, T. 13 S., R. 95 W., 800 feet from mouth of opening.
5522.[c] Sec. 16, T. 13 S., R. 95 W.; upper bench, 500 feet from mouth of opening.
5539.[c] Sec. 16, T. 13 S., R. 95 W.; lower bench, 500 feet from mouth of opening.
5521.[c] SW. ¼ SE. ¼ sec. 11, T. 13 S., R. 95 W., 200 feet from mouth of opening.
5523.[c] NE. ¼ NE. ¼ sec. 13, T. 13 S., R. 95 W., 110 feet from mouth of opening.
5524.[a] Sec. 15, T. 13 S., R. 94 W., 250 feet from mouth of opening.
5538.[a] Sec. 12, T. 13 S., R. 94 W., 200 feet from mouth of opening.
5525.[c] SW. ¼ NW. ¼ sec. 23, T. 13 S., R. 93 W., 50 feet from mouth of opening.
5537.[c] SE. ¼ NW. ¼ sec. 26, T. 13 S., R. 93 W., 240 feet from mouth of opening.
5536.[c] Sec. 30, T. 13 S., R. 92 W., 800 feet from mouth of opening.
5552.[b] Sec. 21, T. 13 S., R. 92 W.
5551.[c] NW. ¼ SE. ¼ sec. 24, T. 13 S., R. 92 W.; upper bench, 300 feet from mouth of opening.
5526.[c] NW. ¼ SE. ¼ sec. 24, T. 13 S., R. 92 W.; lower bench, 300 feet from mouth of opening.
5527.[c] SW. ¼ SW ¼ sec. 17, T. 13 S., R. 91 W., 300 feet from mouth of opening.
5760.[c] NE. ¼ NW. ¼ sec. 15, T. 13 S., R. 91 W., 700 feet from mouth of opening.
5533.[c] NE. ¼ NE. ¼ sec. 15, T. 13 S., R. 91 W.; upper bench, 700 feet from mouth of opening.
5531.[c] NE. ¼ NE. ¼ sec. 15, T. 13 S., R. 91 W.; lower bench, 700 feet from mouth of opening.
5532[c]. NE. ¼ NE. ¼ sec. 15, T. 13 S., R. 91 W.; lower bench, 500 feet feet from mouth of opening. Coal said to be "dead."
5406.[a] Sec. 11, T. 13 S., R. 90 W., 70 feet from mouth of opening.
5405.[a] Sec. 32, T. 13 S., R. 90 W., 100 feet from mouth of opening.
5529.[b] Sec. 22, T. 14 S., R. 90 W.
5344.[c] Sec. 10(?), T. 13 S., R. 89 W., 60 feet from mouth of opening.
5528.[c] Prospect south of Mount Gunnison.

[a] Samples represent coal from freshly cleared sections in abandoned mines.
[b] Samples represent weathered coal.
[c] Samples represent fresh coal.

THE COAL FIELD BETWEEN GALLINA AND RATON SPRING, NEW MEXICO, IN THE SAN JUAN COAL REGION.

By James H. Gardner.

INTRODUCTION.

The San Juan coal region (Durango-Gallup coal field)[a] is a basin of more or less circular outline, with an area of about 13,500 square miles, about one-seventh of which lies in Colorado and the remainder in New Mexico. The region receives its name from San Juan River. The two chief coal-producing localities are Durango, in the extreme southwestern part of Colorado, on the Denver and Rio Grande Railroad, and Gallup, in New Mexico, on the Atchison, Topeka and Santa Fe Railway. The San Juan coal region is the inner coal-bearing portion of the San Juan Basin.

During the season of 1905 a reconnaissance survey around the east side of this region was made by F. C. Schrader, assisted by M. K. Shaler. Work was begun at Durango, Colo., and carried in an easterly direction to Monero, N. Mex.; thence southward in New Mexico via Elvado, Gallina, and Cuba, to Cabezon; and thence westward to Gallup.

In the season of 1906 M. K. Shaler, assisted by the writer, conducted a reconnaissance survey around the opposite side of the region. Work was tied to that of the previous season at Durango, and the outcrop of the coal formations was mapped around the west side of the region and connected with that of Schrader at Gallup. The coal-bearing formations mapped in each survey are the Mesaverde and Laramie, of Upper Cretaceous age, as classified by Cross[b] in the vicinity of Durango.

In the reconnaissance of Schrader in 1905 the outcrops of the Mesaverde and Laramie formations were found to be roughly parallel,

[a] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258. Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 316, 1907, pp. 376-426.

[b] Cross, Whitman, La Plata folio (No. 60), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

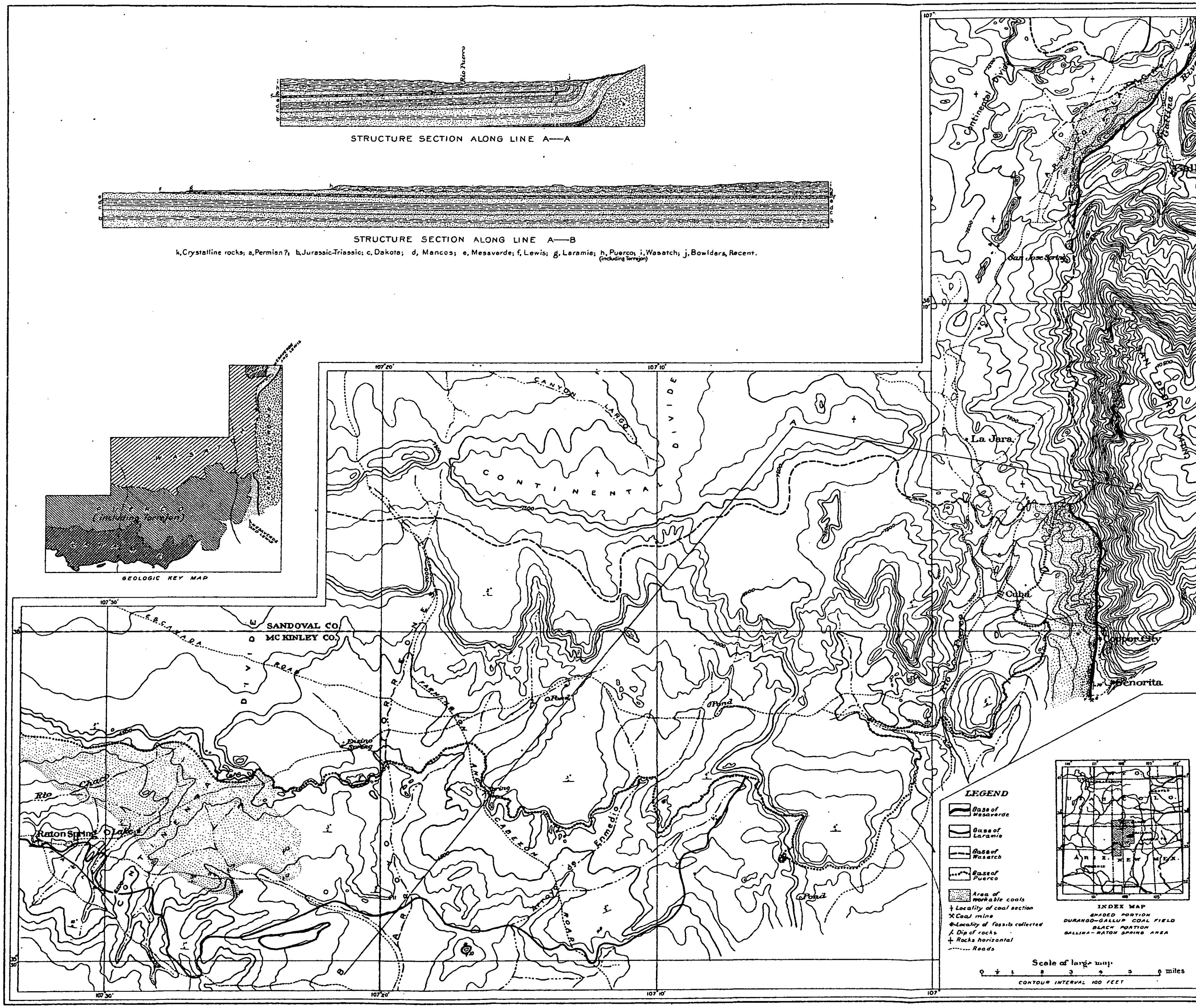
and to be represented by more or less eroded hogbacks, with intervening valleys of softer Lewis shale. This relationship extends from Durango eastward to Monero, and thence southward to the vicinity of Gallina, where the Laramie was found to be no longer marked by a prominent hogback, but to be more or less covered by overlapping Tertiary rocks. This complexity of structure, together with lack of time, compelled the party to discontinue the mapping of the Laramie at this place, and it was not recognized beyond this point. The Mesaverde formation, being more resistant and covered to a less extent by unconformable shale, was easily followed southward.

In Shaler's reconnaissance in 1906 the Mesaverde and Laramie formations were recognized in similar relationship around the west side of the basin to the vicinity of Sulphur Spring, on the drainage of Rio Chaco. Here the Mesaverde and Laramie boundaries were found to diverge, the former continuing southward, the latter bearing off to the east a short distance north of Rio Chaco. The Laramie was traced and mapped as far east as Raton Spring, about 35 miles west of Gallina. At this point the examination of the Laramie was abandoned, but it appeared to continue eastward to the region near Gallina, where Schrader last recognized it a year previous.

The present report covers the area between Gallina and Raton Spring. The field work was carried on from July 20 to August 26, inclusive, 1907, by the writer, assisted by William J. Reed and Albert L. Beekly. To these gentlemen acknowledgments are due for valuable assistance in the field and office. The map (Pl. XXII) presented in connection with this report was prepared by Mr. Reed.

GEOGRAPHY AND TOPOGRAPHY.

Gallina, N. Mex., is a small Mexican settlement of about 100 people, located approximately in latitude 36° 15′ and longitude 106° 50′, at the point where Gallina River emerges from the Sierra Nacimiento. About 14½ miles south-southwest is the old Mexican town of Nacimiento, known to the post-office officials as Cuba. This village contains about 200 inhabitants, and is located in a small fertile valley at the foot of San Pedro Mountain, near the point where Nacimiento Creek joins Rio Puerco. Lajara, Copper City, and Senorito are settlements of less importance. About 34 miles south of west from Cuba is Raton Spring, where there are two Mexican stores and a few dwelling houses. Raton Spring is known also as Pueblo Pintado, a name formerly applied to the Aztec ruins, which are still evident at this place. The spring itself is a deep pool of somewhat alkaline water, which flows as a mere seep. At Ensino Spring, between Cuba and Raton, 11 miles north of east from Raton, there are some Indian stone huts, but the spring is known as a watering place for miles over



ANDREW. B. GRAHAM CO., PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

MAP OF THE COAL FIELD BETWEEN GALLINA AND RATON SPRING, NEW MEXICO, IN THE SAN JUAN COAL REGION

By James H. Gardner, William J. Reed, and Albert L. Beekly the surrounding desert country. The water issues from beneath a massive sandstone, and the flow in August, 1907, was about 1 gallon per minute. These are the only localities worthy of individual mention here, but there are numerous Mexican ranches along the west foot of the Sierra Nacimiento between Gallina and Cuba.

The Sierra Nacimiento is a more or less continuous north-south mountain ridge, with an average elevation of about 9,500 feet, or about 2,500 feet above the surface of the plateau country to the west. Northeast of Cuba the ridge rises to an elevation of 10,162 feet, and is known as San Pedro Mountain. An abundant supply of pure water flows perennially from the slopes of this mountain, the drainage on the north passing down as the source of Gallina River and on the southwest as the source of Rio Puerco. Gallina River flows northward for about 16 miles, then turns eastward to Rio Chama, a tributary of the Rio Grande. Rio Puerco flows southward and is also a tributary of the Rio Grande. On the west the mountain presents a bold front, and along its slopes the sedimentary rocks are steeply inclined and form hogbacks. At some places the slopes are extensively covered by bowlders and wash, principally granite and granite porphyry from the mountain mass. In the vicinity of Gallina the Tertiary beds overlap the Cretaceous and lower sedimentary strata, and in places rest against the crystalline rocks of San Pedro Mountain. These Tertiary beds include the Puerco, Torrejon, and Wasatch formations, which cover the broad plateau country, stretching westward to San Juan River. This region is a dry, barren expanse of highly colored mesas and badlands, known as the Nacimiento Desert. The high portion of the plateau along the Continental Divide west of Gallina and east of Canyon Largo is named on the Wheeler map "Los Altos del Utah."[a] The country between Cuba and Raton Spring presents a series of Laramie and Tertiary escarpments that have receded to varying distances northward. These escarpments have been dissected into numerous outliers and mesas with gentle, intervening dip slopes in the form of sage-covered plains. Interspersed with these features are numerous canyons and deep arroyos. The principal drainage way of this area is the Arroyo Torrejon. This stream heads along the Atlantic side of the Continental Divide, which crosses the territory in a northeast-southwest direction. In times of heavy rainfall there are numerous small lakes in the area, which are readily soaked up or dry away in the periods of drought that follow. There are no ranches in the area west of Cuba, but only scattered tents of Mexican sheep herders or hogans of a few nonreservation Navajoes.

The area is not subdivided by land lines; however, some surveying is at present being done in the vicinity of Cuba.

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[a] U. S. Geog Surveys W. 100th Mer., Atlas sheet No. 69.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The formations known to occur within the area included in this report are as follows:

Generalized section of rocks in coal field between Gallina and Raton Spring, N. Mex.

System.	Series or formation.	Thickness in feet.
Quaternary	Recent	0-50
Tertiary	Wasatch formation	(?)1,000
	Unconformity.	
	Torrejon formation	110
	Unconformity (?).	
	Puerco formation	690
Cretaceous	Unconformity.	
	Laramie formation	900
	Lewis shale	250-2,000
	Mesaverde formation	200-900
	Mancos shale	500-1,000
	Dakota sandstone.	

CRETACEOUS ROCKS.

Dakota sandstone.—The Dakota, or basal formation of the Cretaceous throughout the San Juan region, is exposed in a prominent hogback along the west slope of the Sierra Nacimiento. It consists chiefly of hard quartzite with intercalated shale toward the top, but near the base is made up of reddish sandstone and yellowish shale that grade gradually into the Jurassic-Triassic rocks below. No signs of coal beds were observed in the Dakota, but they are known to occur in other parts of the basin.

Mancos shale.—The Mancos shale rests conformably upon the Dakota. In the type locality at Mancos, Colo., the formation is all shale, but in New Mexico there are transitional sandy beds toward the top. At a point 10 miles north of Gallina a part of the formation becomes arenaceous and forms a hogback in the shale valley. This sandy bed is about 30 feet thick and about 275 feet below the top of the formation. It is no doubt the beginning of the sandstone and shale formation that increases in thickness toward the south and is coal bearing on the south side of the basin.[a] The siliceous phase is continuous along the foot of the Sierra Nacimiento, but is prominent only south of Cuba. In the vicinity of San Miguel, 12 miles down Rio Puerco from Cuba, the writer observed a thickness of 300 feet of argillaceous sandstone and sandy shale in the Mancos, grading upward through a transition zone to the Mesaverde.

Mesaverde formation.—The Mesaverde is the most important coal-bearing formation in the area, as well as throughout the San Juan

[a] See reports of Schrader and Shaler, already cited.

region. It forms a prominent hogback across the east side of the Gallina-Raton Spring field. The outcrop of the formation enters this field at a point 5½ miles N. 8° E. from Gallina, follows along the foot of the Sierra Nacimiento in a north-south direction, and passes from the area mapped near Copper City. Coal beds occur at varying intervals between a prominent basal and a capping sandstone. The main coal bed of the area is just below the top sandstone.

Lewis shale.—The Lewis is much like the Mancos in appearance. The only point worthy of mention here regarding this formation is its notable change in thickness across the field. From about 2,000 feet north of Gallina it thins to 250 feet on the Arroyo Torrejon and in the vicinity of Raton Spring. It may be, however, that the lower part of the shale in that region is replaced by sandstone which has heretofore been considered Mesaverde.

Laramie formation.—The Laramie is without workable coal beds at the north limit of the field. In fact, Schrader[a] maps the entire area northward to the Colorado State line as barren. West of Gallina the Laramie and underlying Lewis shale disappear beneath unconformable Eocene beds. The next point to the south at which the Laramie shows is where it emerges from beneath the Puerco, about 10½ miles southwest of Cuba. The Laramie strata exposed between this point and Raton Spring are coal bearing, the coal beds increasing in thickness and number toward the west.

TERTIARY ROCKS.

In the vicinity of Gallina and to the south beyond Lajara the variegated shales of the Wasatch rest horizontally against the foot of the Sierra Nacimiento, covering the highly inclined strata of the Cretaceous and lower sedimentary rocks. The Wasatch bears many fragments of vertebrates, and collections were sufficient to permit its positive identification.

In the southern portion of the area, along the mountain foot northeast of Cuba and along the headwaters of Rio Puerco, the Wasatch is underlain by a mass of variegated and bituminous shale, with two beds of massive sandstone. The sandstones form prominent escarpments, the upper immediately west and the lower about 10 miles southwest of Cuba. The entire thickness of these beds is about 800 feet. They are highly inclined along the mountains, and northeast of Cuba they are overturned and dip toward the mountains at about 70°. The high dips of the massive sandstones are in marked contrast to the unconformable horizontal shale of the overlying Wasatch. The prominent sandstone escarpments swing westward from Cuba, the lower being traced across the area beyond the limits of the present

[a] Op. cit., p. 243.

mapping. The upper escarpment could not be traced with certainty. The prominent escarpment of the Wasatch to the north follows in a general way parallel to these escarpments. Near a small pond, about 7 miles N. 76° E. of Ensino Spring, vertebrate fossils were collected from 25 feet of dark and gray argillaceous sand and shale immediately overlying the basal escarpment sandstone. A careful study of these fossils has been made by J. W. Gidley, of the United States National Museum, and the specimens have been compared with original material in the American Museum of Natural History, New York. This comparison definitely places them in the Torrejon formation.[a] The Laramie reappears from beneath the lower escarpment, striking almost at right angles with it, thus bringing out a marked unconformity between the two. It does not follow from the fossils that the lower escarpment is of Torrejon age. It is probable that there is an unconformity between the Puerco and the Torrejon. This accounts for the Torrejon fossils immediately above the basal escarpment sandstone, which is in all probability the lowest member of the Puerco. It is certainly at the base of an 800-foot mass below the Wasatch, exposed along the headwaters of Rio Puerco, as originally described by Cope.[b] Along Rio Puerco the base of the Wasatch is 750 feet above the top of the basal Puerco sandstone. At the point where the Torrejon fossils were collected the base of the Wasatch, as determined by both stratigraphic relationship and fossil evidence, is only 135 feet above the top of the same sandstone. Hence the 800 feet of the original Puerco is represented by only the basal sandstone, from 30 to 50 feet thick, unconformably overlying the Laramie. This sandstone is unconformably overlain by 110 feet of Torrejon, above which, also unconformably, lies the Wasatch. Space does not permit a detailed discussion of the Tertiary rocks in this preliminary report, but such a discussion will appear as a chapter in the report on the entire field, to be published as a separate bulletin of the Survey.

QUATERNARY DEPOSITS.

The local terrace deposits, granite wash, etc., occurring between Gallina and Cuba and resting in places upon the Wasatch beds, also the alluvium and adobe clays along the present drainage ways, used as building materials by the natives, are classed as Quaternary.

STRUCTURE.

Mention has been made of the hogbacks composed of steeply dipping strata along the crystalline rocks of the Sierra Nacimiento. The Cretaceous rocks in the vicinity of Gallina dip to the west at an angle of 60°; farther south the dips are steeper, reaching 90° near

[a] Torrejon is a name proposed by J. L. Wortman (Bull. Am. Mus. Nat. Hist., vol. 9, 1897, pp. 260–261) for a fossil zone at the top of the original Puerco of Cope.

[b] Cope, E. D., Rept. Chief Eng., 1875, pt. 2, p. 1008.

Lajara; and along the foot of San Pedro Mountain east of Cuba the rocks are overturned and dip 70° E. The highly tilted Puerco and Torrejon indicate an elevation of the Sierra Nacimiento after their deposition. This elevation took place at the close of Torrejon time, as shown by the fact that the superjacent Wasatch beds lie apparently level against the mountain.

There are two prominent unconformities by overlap in the beds above the Laramie—one at the base of the Puerco, the other at the base of the Wasatch. The relation of these unconformities, dips, etc., may be obtained from the accompanying map (Pl. XXII). In the vicinity of Ensino Spring and of the lake 7 miles north of east from the spring there are local domes in the strata. Such local changes in dips prevent an accurate estimate of thickness by topographic lines on the map. As discussed under the heading "Tertiary rocks," there is also very strong evidence of an unconformity between the Puerco and the overlying Torrejon.

There are few faults aside from local displacements along the east side of the field adjacent to the mountains. Many such minor dislocations occur along the strike of the sedimentary beds where they rest in close proximity to the crystalline rocks, but they are not of sufficient importance for discussion here. The only fault deserving mention is the one at Raton Spring. This is a tension fault with a stratigraphic throw of 60 feet. The strike is inconstant, but averages about S. 50° E. from the spring for a distance of several miles, the downthrow being on the northeast side. The spring issues near the fault and doubtless has its source along the fault plane.

THE COAL.

COAL-BEARING FORMATIONS.

The two coal-bearing formations are the Mesaverde and the Laramie. Coal has been mined in this field from the former only, and that to a very slight extent in one locality. One mile southwest of Senorito the upper bed of the Mesaverde has been opened and mined for local use by the Juratrias and other copper companies, which have now discontinued operations. The coal was used for steaming and smelting as well as for domestic purposes, and is reported to have given general satisfaction.

The Laramie is covered by the overlap of the Tertiary in the vicinity of Gallina, on the north side of the field. At this point it is barren of workable coal beds. Its boundary beneath the Tertiary diverges from that of the north-south line of the Mesaverde, and at its reappearance on the south side of the field is about 12 miles west of the Mesaverde boundary. From this point the strike turns westward and the formations begin to show thin coal beds which increase in thickness and number toward Raton Spring.

DETAILED DESCRIPTION.

The coals of the area are here described by two districts. One is along the exposure of the Mesaverde in a north-south direction across the east side of the field, and is designated the Gallina-Cuba district. The other includes the Laramie area in the vicinity of Raton Spring, and is termed the Raton Spring district.

GALLINA-CUBA DISTRICT.

Locality No. 1:[a] The following is a general section of the Mesaverde formation at locality No. 1, 5½ miles N. 8° E. of Gallina, where the rocks dip N. 75° W. at an angle of 36°.

Section of Mesaverde formation 5½ miles N. 8° E. of Gallina (No. 1).

	Ft.	in.
Sandstone, brownish, massive, coarse grained	35	
Shale	20	
Coal		7
Shale	8	
Sandstone		8
Coal		2
Sandstone	8	
Shale	5	
Coal		1
Shale	12	
Sandstone	4	
Coal	1	1
Shale	8	
Sandstone, carbonaceous		1
Coal, resinous	1	2
Sandstone and shale	2	
Sandstone, carbonaceous	1	
Shale	2	
Coal		4
Shale	3	
Sandstone and shale	3	
Coal		2
Shale	5	
Sandstone	21	
Coal		4
Shale, brown, lignitic		3
Coal	1	4
Shale	13	
Coal	1	
Shale, brown, lignitic	5	
Coal		1
Shale, brown, lignitic	1	3
Coal		11
Shale, brown, lignitic		4
Coal	1	10
Shale, brown, lignitic	1	4
Coal		2

[a] These numbers correspond to numbers on the map. Pl. XXII.

	Ft.	in.
Shale with selenite	1	8
Shale and thin beds of sandstone, good roof	4	
Coal	3	
Sandstone	1	
Shale, grayish	1	
Sandstone, carbonaceous		2
Sandstone, brown, massive	35	
	214	

It will be observed that in this section there are fourteen coal beds that are not of workable thickness, and only one—the 3-foot bed just above the basal sandstone—that is more than 2 feet thick. The coal of this bed is apparently a good grade of subbituminous [a] coal.

Locality No. 2: About 2½ miles northwest of Gallina the Mesaverde formation shows two workable beds which are probably identical with some of the thin beds farther north. The lowest coal horizon is covered in this vicinity. The following is a section of these beds; the strata dip 45° N. 45° W.

Section of Mesaverde coal-bearing rocks 2½ miles northwest of Gallina (No. 2).

	Ft.	in.
Sandstone, massive	50	
Sandstone, shale, and thin coal beds	100	
Shale	10	
Coal	3	2
Shale	3	
Sandstone and shale	50	
Shale	20	
Coal	2	8
Shale	10	
Shale, sandstone, and traces of coal	120	
Sandstone, massive	50	
	418	10

Locality No. 3: South of Gallina no workable coals were observed in the Mesaverde, although the bed occurring elsewhere immediately above the basal sandstone may be present here. This coal bed is associated with over 100 feet of thin sandstone and shale, and along the steep hogback a valley is formed at this horizon; as a result the talus from the protruding basal sandstone, together with dwarf vegetation, completely covers the beds in this vicinity. The two workable beds that are present at locality No. 2, northwest of Gallina, have probably thinned very much or disappeared.

Inasmuch as there are several thin beds in the upper portion which on the surface show a considerable quantity of loose coal, it seems well to give a general section of the Mesaverde coal beds in this locality.

[a] The term subbituminous has been adopted by the Geological Survey for that class of coal commonly known as "black lignite."

The higher beds are covered by unconformable Tertiary shale. The following is a section at this place, where the strata dip 60° W.:

Section of Mesaverde formation 3½ miles S. 65° W. of Gallina (No. 3).

	Ft.	in.
Sandstone	2	
Shale, brown	10	
Coal	1	4
Shale, brown	15	
Shale, gray	3	
Shale, drab	50	
Coal	1	3
Shale, brown	3	
Coal, bony		4
Shale, gray	2	6
Coal	1	
Shale	16	
Sandstone and shale	8	
Coal, bony		4
Shale	12	
Coal, bony		6
Shale	12	
Sandstone	2	
Covered; probably contains coal bed	120	
Sandstone, basal, massive	55	
	315	3

Locality No. 4: At a point S. 50° W. of Gallina the Mesaverde disappears beneath unconformable Tertiary and granite wash. Between this point and the hogback, 3½ miles N. 40° E. of Cuba, the formation is covered except for a small outcrop of resistant sandstone here and there. Where the hogback reappears northeast of Cuba the formations from Triassic up to Puerco, inclusive, are overturned and dip 70° E. At this point the following section was taken in the Mesaverde:

Section of Mesaverde formation 3½ miles N. 40° E. of Cuba (No. 4).

	Ft.	in.
Sandstone, gray	25	
Coal		6
Shale, carbonaceous	3	
Coal, bony		7
Shale, drab, hard	1	7
Coal	4	3
Shale, carbonaceous	10	
Sandstone	2	
Shale, carbonaceous	15	
Covered by granite wash.		
	61	11

The coal bed in this section is apparently made up of excellent coal, so far as physical appearances show. This is the bed which has been locally mined at Senorito, 6 miles farther south.

Locality No. 5: The following is a section of the Mesaverde rocks at a prominent cirque 1 mile north of Copper City. The local dip here is 60° S. 30° E.

Section of Mesaverde formation 1 mile north of Copper City (No. 5).

	Ft.	in.
Sandstone, top escarpment	45	
Covered; signs of coal	10	
Shale, dark; some sandstone and thin coal streaks	110	
Coal	1	
Shale	12	
Coal	1	
Shale, drab, and thin sandstone	200	
Coal		6
Shale, carbonaceous	3	
Coal	2	2
Shale, drab		6
Coal		3
Shale		6
Coal	1	10
Shale		6
Coal	1	6
Shale, carbonaceous	1	
Shale, drab	5	
Sandstone, gray	4	
Shale, carbonaceous	4	
Coal	1	
Shale, carbonaceous	5	
Coal	2	
Shale, carbonaceous	1	
Shales, dark and drab	30	
Shale, carbonaceous, and thin sandstone	20	
Sandstone, massive, gray, resistant	30	
Covered; largely shale	40	
Sandstone, gray, soft	40	
Shales, drab and yellowish	15	
Sandstone, gray, soft, massive	100	
Sandstone, fossiliferous	1	6
Sandstone, thin bedded	5	
Shale, drab	3	
Sandstone, gray, soft, argillaceous	20	
Sandstone, brown, ferruginous	2	
Shale, Mancos.		
	719	3

Locality No. 6: Another exposure of Mesaverde coal beds occurs in the hogback at Copper City. The rocks are overturned, dipping at an angle of 70° S. 70° E., toward San Pedro Mountain. A massive resistant sandstone 50 feet thick caps the formation, and a similar one lies at the base. Between the two is a series of alternating thin sandstones and shales with small intercalated coal beds. These coal beds are scarcely more than traces with the exception of the bed stratigraphically near the top, which shows a thickness of 5½ feet of clear coal. This bed occurs also at locality No. 4, and carries good coal in the vicinity of Senorito. The following is a detailed section of Mesaverde at this locality:

Section of Mesaverde formation at Copper City (No. 6).

	Ft.	in.
Sandstone, massive	50	
Sandstone, thin-bedded	5	
Shale, carbonaceous	2	
Coal	5	6
Shale, brown	2	
Coal	1	
Shale and thin sandstone	32	
Shale, brown, carbonaceous	6	
Coal		2
Sandstone, grayish, soft	12	
Coal		6
Shales, drab and brown	13	
Coal		4
Sandstones, with drab and brown shales	50	
Shale, brown, carbonaceous		6
Coal		2
Shales, drab and dark, with thin sandstones	80	
Coal		4
Sandstone, thin, and shale	10	
Coal		4
Shale, brown	4	
Coal	1	
Shale, dark	10	
Coal		4
Shale, dark	5	
Coal		3
Shale, brown	1	
Coal		9
Sandstone, thin, and shale	12	
Coal		6
Shale, carbonaceous	8	
Sandstone, massive, basal	50	
	363	8

Locality No. 7: At locality No. 7, three-fourths of a mile west of Senorito, the Senorito bed is exposed, dipping 70° E., showing the following section:

Section of Senorito coal bed three-fourths of a mile west of Senorito (No. 7).

	Ft.	in.
Sandstone, massive; top of Mesaverde	50	
Shale, brown, carbonaceous, slickensided	4	
Coal, clear	4	6
Shale, brown, carboneceous	10	
Covered.		
	68	6

Locality No. 8: One mile southwest of Senorito, near the Cuba-San Miguel road, the top coal bed of the Mesaverde has been mined to some extent for local purposes. At this locality the strata are overturned, as at points farther north, the rocks dipping east at an angle of 70°. Mining is reported to have been done by the Juratrias and other copper companies formerly operating local smelters at Copper City. The chief developments at the coal mine are a well-timbered 20-foot shaft following the dip of the coal and a small head frame with a windlass hoist. In the overturned rocks the brown arenaceous shale stratigraphically overlying the coal becomes the floor; the brown shale below becomes the roof. The bed at this point is 6 feet thick and is composed of clear coal. The coal has a black, shiny luster and is apparently a high-grade subbituminous coal, but unfortunately a good sample for analysis could not be obtained from the partly filled shaft. The coal is reported on good authority to have given general satisfaction as a steam and domestic fuel.

From this locality to the limit of the field here described the Mesaverde formation is steeply inclined eastward toward the Sierra Nacimiento. Farther south the beds assume a normal attitude, dipping steeply westward toward the interior of the basin.

RATON SPRING DISTRICT.

The Laramie emerges from beneath the Puerco 12½ miles S. 70° W. from Senorito, and then turns westward toward Raton Spring. This formation is apparently without workable coal beds in this vicinity, but thin beds make their appearance within a short distance and become more prominent to the west. The formation dips slightly northward and does not stand in bold escarpments. Coal exposures are few and occur in small outliers irregularly over the district. Near Raton Spring there are three beds, two averaging 3 feet and the other 2 feet in thickness. Locally they show thicknesses of 3½ or 4 feet.

Locality No. 9: The first coal exposure noted west of the point of emergence is 1 mile east of the Farmington and Cabezon road. Here the following section was taken, the rocks dipping 3° N.:

Section of Laramie coal beds 1 mile east of Farmington-Cabezon road (No. 9).

	Ft.	in.
Sandstone, brown, hard	2	
Shale, very compact, sandy	20	
Coal	1	1
Coal, bony		5
Coal		5
Shale, carbonaceous		6
Shale, brown	1	6
Shale, gray, sandy	20	
Covered.		
	45	11

This bed is near the top of the basal Laramie sandstone, which at this place is largely covered.

Locality No. 10: The next indication of coal is 4½ miles S. 80° W. from locality No. 9. Here the following section was taken of a small outlier at the base of the Laramie:

Section at base of Laramie, locality No. 10.

	Ft.	in.
Sandstone, brown, massive	15	
Coal		6
Shale, gray, sandy	90.	
	105	6

At this horizon farther west a workable bed makes its appearance.

Locality No. 11: At locality No. 11, 3¼ miles N. 53° W. of locality No. 10, the following section was obtained on Arroyo Torrejon at practically the same horizon. The rocks here dip N. 5° W.

Section of Laramie coal beds at locality No. 11.

	Ft.	in.
Sandstone, brown, massive	20	
Sandstone, carbonaceous		8
Coal		3
Sandstone	1	
Coal		2
Sandstone, gray	35	
Sandstone, carbonaceous	3	
Shale, drab	4	
Coal		8
Shale	5	
Sandstone, soft, grayish	40	
	109	9

It will be noted that the coal beds of this section are too thin to work, but the section is given in order to indicate the gradual increase westward in the thickness and number of the coal beds.

Locality No. 12: The next locality of coal exposure is 3½ miles N. 80° W. of locality No. 11, and at this point the first section of clear coal of workable thickness was obtained. This is the lowest workable bed of the area, and is designated coal bed A. The rocks here dip 3° N.

Section of coal bed A at locality No. 12.

	Ft.	in.
Covered; mostly shale	30	
Shale, black, carbonaceous	4	
Shale, brown	5	
Shale, drab	10	
Sandstone, grayish	4	
Coal A	2	6
Shale, carbonaceous	10	
Sandstone, grayish	20	
	85	6

The coal of this section has a very black, glossy luster, and apparently does not alter rapidly on exposure.

Locality No. 13: At locality No. 13, 1 mile north of No. 12, the following section was obtained. The bed in this section is designated B, being next above coal bed A of locality No. 12:

Section of coal bed B at locality No. 13.

		Ft.	in.
Sandstone, gray, thin bedded		3	
Shale, drab		6	
Shale, brown		1	
Bed B	Coal	1	
	Shale, carbonaceous	1	
	Coal		10
Covered.			
		12	10

Locality No. 14: At locality No. 14, 3 miles N. 30° W. from No. 13, a coal bed 2 feet thick is exposed about 20 feet stratigraphically above bed B. This bed is designated C. A section taken at a small outlier shows the following relations:

Section of coal bed C at locality No. 14.

	Ft.	in.
Sandstones, thin, and shale	6	
Shale, carbonaceous	1	
Coal bed C	2	2
Shale, carbonaceous	3	
Covered.		
	12	2

Locality No. 15: At locality No. 15, about 2¼ miles S. 5° W. from No. 14, there is a northward-facing escarpment which shows complete sections of beds A and B, together with part of bed C. The coal-bearing section is as follows:

Section of Laramie coal beds at locality No. 15.

		Ft.	in.
Shale and coal, bed C.			
Covered		20	
Bed B	Coal	1	8
	Shale, sandy		1
	Coal		10
	Shale, sandy		1
	Coal	1	6
Shale, carbonaceous		2	
Shale, gray, sandy		15	
Sandstone, grayish, brown		3	
Shale, drab		15	
Coal streak.			
Shale, carbonaceous		3	
Bed A	Coal	1	
	Shale, sandy		2
	Coal	2	
Shale		3	
Covered.			
		68	4

Locality No. 16: At locality No. 16, 1 mile S. 20° E. from No. 15, the following section was taken immediately above the basal sandstone, showing coal bed A and small related beds:

Section of Laramie coal-bearing rocks at locality No. 16.

	Ft.	in.
Sandstone, gray, massive	15	
Shale, carbonaceous	18	
Coal		4
Shale, carbonaceous	1	8
Coal		6
Shale		8
Coal		4
Shale, drab	3	
Coal, bed A	2	6
Shale, carbonaceous	10	
Sandstone, gray, soft	20	
Covered.		
	72	

Locality No. 17: One mile N. 52° W. from locality No. 16, bed A shows a thickness of 4 feet 7 inches, with a sandy shale parting toward the top varying from 1 to 2 inches. The following is the section at this place:

Section of coal bed A at locality No. 17.

	Ft.	in.
Covered.		
Shale, sandy		7
Coal	1	5
Shale, sandy		½
Coal	3	2
Shale, dark	3	
Covered.		
	8	2½

Locality No. 18: At locality No. 18, about 3¼ miles north of east of Raton Spring, beds B and C are exposed. These beds are much burned in the vicinity, and the red baked shale stands out in marked contrast to the surrounding rocks, affording a reliable guide in tracing the coal beds. A section was measured at the head of an arroyo, where erosion has removed the greater part of the burned material. The relations at this point are as follows:

Section of Laramie rocks at locality No. 18.

		Ft.	in.
Sandstone, gray		3	
Coal, bed C		2	
Shale, carbonaceous		3	
Shales, drab		25	
Shale, carbonaceous		1	
Bed B	Coal		6
	Shale		3
	Coal	3	7
Shale, dark		3	
Covered.			
		41	4

Westward from this locality the coal boundaries were traced beyond the limit of the area mapped, but no sections were obtained. The beds are much burned and covered along the head drainage of Rio Chaco north of Raton Spring. In the immediate vicinity of Raton the geologic mapping connects with that of Shaler[a] in 1906.

DEVELOPMENT AND TRANSPORTATION.

The only coal mining in the Gallina-Raton Spring field has been done in connection with the operations of local copper companies at Copper City, in the Gallina-Cuba area. A mine was worked here for a brief time on the upper coal bed of the Mesaverde, but was discontinued with the closing of the smelters. The coal gave good satisfaction and is evidently a high-grade coal of the subbituminous class. The coals in the Raton Spring area have not been prospected and little can be said regarding their quality. They resist weathering fairly well, however, and from all appearances are similar to the best Laramie beds throughout the San Juan region. The topography of the region is such that practicable railroad routes may be found to any part of the field. The nearest railroad points at present are on the Denver and Rio Grande, 45 miles north of Gallina; the Farmington branch of the same line, 55 miles N. 35° W. from Raton Spring; and the Atchison, Topeka and Santa Fe, 48 miles S. 35° W. from Raton Spring.

[a] Op. cit.

THE COAL FIELD BETWEEN DURANGO, COLORADO, AND MONERO, NEW MEXICO.

By JAMES H. GARDNER.

INTRODUCTION.

In 1905 a reconnaissance survey of the area between Durango, Colo., and Monero, N. Mex., was conducted by F. C. Schrader,[a] assisted by M. K. Shaler. The work of that season was carried on too rapidly to permit the location of coal boundaries with reference to land lines, the chief object being a hasty determination of the extent and value of the entire San Juan coal region (Durango-Gallup field).[b] Since that time the outcrops of the coal beds from Durango to Rio Florida have been carefully surveyed by Joseph A. Taff.[c]

During the season of 1907 the writer, assisted by William J. Reed and Albert L. Beekly, conducted a resurvey of the field eastward from Durango to Monero, N. Mex. It seems desirable to publish a brief review of this area in connection with a map (Pl. XXIII) showing more accurately the boundaries of the coal-bearing formations.

GEOLOGY.

STRATIGRAPHY.

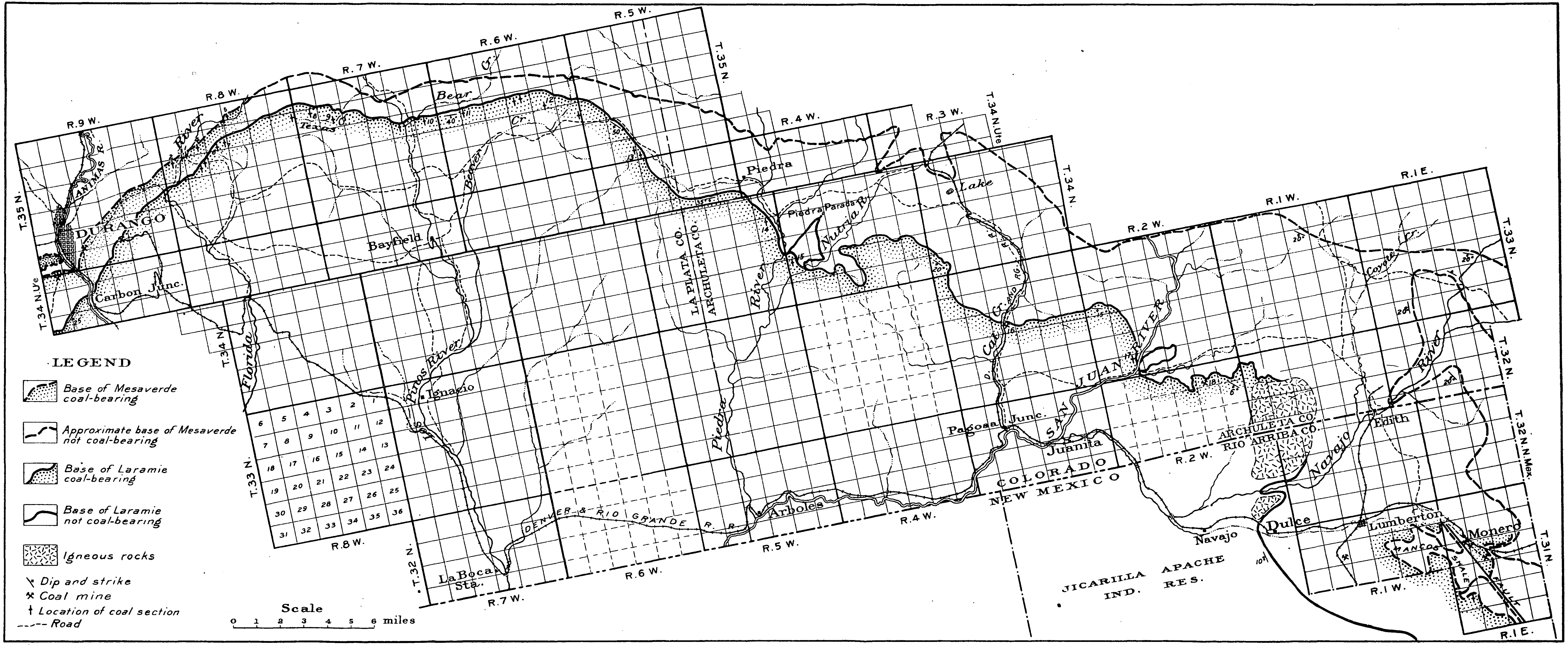
The Cretaceous formations in this area, from the base upward, are as follows: Dakota sandstone, 300 (?) feet; Mancos shale, 1,200 feet; Mesaverde formation, 1,000 feet; Lewis shale, 1,600 feet; and Laramie formation, 700 feet. Of these the Dakota, Mesaverde, and Laramie contain workable coal beds in certain regions. In the area considered, however, the Dakota coal is not known to be of commercial value.

The Mesaverde is the most important of the coal-bearing formations in the Durango district, containing three or four workable beds of excellent bituminous coal, some beds locally being suitable for the

[a] The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, pp. 241–258.

[b] For a description of the west side of the field, see Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field: Bull. U. S. Geol. Survey No. 316, 1907, pp. 376–426.

[c] The Durango coal district, Colorado: Bull. U. S. Geol. Survey No. 316, 1907, pp. 321–337.



MAP OF THE COAL FIELD BETWEEN DURANGO, COLORADO, AND MONERO, NEW MEXICO

By James H. Gardner, William J. Reed, and Albert L. Beekly

ANDREW B. GRAHAM CO., PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

manufacture of good coke. However, the Mesaverde is barren of workable coal in the northeastern part of T. 35 N., R. 8 W., and is not known to contain a single workable bed around the northeast side of the basin for a distance of more than 60 miles along the outcrop. In this distance the formation shows remarkable thinning, and along Piedra River it is less than 400 feet thick. The next occurrence of workable Mesaverde coal beds is in the vicinity of Monero, N. Mex., and to the south on the Apache Indian reservation and the Tierra Amarilla grant.

The Laramie formation, on the other hand, contains coals of lesser value than the Mesaverde in the Durango district, and shows workable beds along its entire line of outcrop from Durango to the Apache reservation. The Laramie coal is of medium grade over most of the area, and is classed as subbituminous ("black lignite"), though an analysis of Laramie coal along upper Beaver Creek, in T. 35 N., R. 6 W., closely approaches that of a bituminous coal.

The outcrops of the Mesaverde and Laramie formations are represented by hogbacks and bold escarpments, with intervening valleys of Lewis shale. The two escarpments are roughly parallel and extend eastward to the southern part of T. 35 N., R. 5 W. From this vicinity eastward the boundaries separate, being at some points as much as 8 miles apart.

The Dakota at most places forms a broad dip slope, from which the Mancos shale has been entirely eroded, along with the Mesaverde toward the interior of the basin.

Overlying the Laramie are the Tertiary rocks, having a thickness of about 2,500 feet and at places forming a line of high hills near the Laramie escarpment. In the vicinity of Durango a series of conglomerate beds about 300 feet thick at the base of the Tertiary were named by Cross[a] the Animas formation. These are well exposed on Animas River at Carbon Junction, below Durango, but they were not recognized east of Piedra River and apparently are locally developed in the vicinity of the type locality. Toward the interior of the basin the Tertiary forms high broken hills of smooth outline, covered largely by pine and piñon trees.

STRUCTURE.

The dips of the rocks around this side of the San Juan Basin differ considerably in different areas, in both direction and degree. The general direction, however, is south and west of south, away from the San Juan Mountains and toward the interior of the basin. From T. 35 N., R. 8 W., to T. 35 N., R. 5 W., the dips increase from 30° to 50°. Farther east the dips decrease slightly, and gradually change to west of south on the east side of the basin.

[a] Cross, Whitman, La Plata folio (No. 60), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

Along the Laramie outcrop on San Juan River, above Juanita, in T. 33 N., R. 2 W., there are several faults of small longitudinal extent but considerable throw. The largest fault that was observed in the upper part of the Laramie is in the SW. ¼ SW. ¼ sec. 32. This fault trends N. 25° W. and shows a downthrow of about 125 feet to the southwest. A fault is evident also in the west side of Archuleta Mountain. The only other fault worthy of mention is the one at Monero, N. Mex. This fault strikes S. 26° E. from the northwest corner of sec. 7 to the southern part of sec. 33, T. 31 N., R. 1 E. The displacement amounts to more than 200 feet, the downthrow being on the north side. The disturbance of the rocks in this area has facilitated erosion, and thus the area of workable coal beds is considerably reduced.

THE COAL.

MESAVERDE COAL BEDS IN T. 35 N., R. 8 W.

Locality No. 1: [a] In T. 35 N., R. 8 W., the Mesaverde formation contains six beds. The following section, reading down in stratigraphic order from the upper sandstones, was measured by Joseph A. Taff in the southwestern part of sec. 8:

Section of Mesaverde coal beds in sec. 8, T. 35 N., R. 8 W. (No. 1).

	Ft.	in.
Sandstone, massive	30–40	
Sandstone, shaly	3	
Coal	1	6
Shale and shaly sandstone	28	
Coal	1	8
Shale	12	
Coal	2	
Shale	8	
Coal	1	3
Shale and shaly sandstone	12	
Coal	1	4
Shale, sandy		1
Coal	2	
Coal, bony		3
Coal		10
Shale	11	
Coal	1	
Sandstone, massive.		
	115–125	11

Locality No. 2: The coal beds given in the section at locality No. 1 can not be definitely identified in other parts of the same township. It is probable, however, that the bed exposed at an old prospect near the center of the north side of sec. 18 is the same as the top bed at

[a] These numbers correspond to those on Pl. XXIII.

locality No. 1. The following section was measured by Mr. Taff at the exposure just mentioned:

Section of Mesaverde coal bed in sec. 18, T. 35 N., R. 8 W. (No. 2).

	Ft.	in.
Sandstone, massive	35	
Shale		6
Coal		4
Shale		6
Coal	1	10
Shale, sandy		4
Coal		9
Total coal bed	3	9

Locality No. 3: In the SE. ¼ sec. 7, T. 35 N., R. 8 W., one of the Mesaverde coal beds has been opened at what was formerly known as the Perkins & Rookwood mine. On account of water, a section of the coal bed could not be procured in the abandoned slope, but Mr. Taff gives the following section of another bed 80 feet or more stratigraphically above it:

Section of Mesaverde coal bed in sec. 7, T. 35 N., R. 8 W. (No. 3).

	Ft.	in.
Coal		4
Shale	1	6
Coal	1	6
Shale, carbonaceous		4
Coal	1	3
Shale and sandstone	80	
Covered.		
Total coal bed	4	11

Locality No. 4: In the southeastern part of sec. 8, T. 35 N., R. 8 W., one of the Mesaverde coal beds has been exposed by a drift 25 feet in length. No coal is at present being mined at this point. Mr. Taff gives the following section taken at the face of the drift:

Section of Mesaverde coal bed in sec. 8, T. 35 N., R. 8 W. (No. 4).

	Ft.	in.
Sandstone.		
Shale		6
Coal	2	9
Shale		3
Coal		3
Coal, bony		1
Coal	2	8
Shale.		
Total coal bed	6	

Locality No. 5: Toward the northeast part of T. 35 N., R. 8 W., the coal beds of the Mesaverde apparently thin suddenly and disappear. However, the last bed observed in passing eastward along the outcrop of the Mesaverde shows a thickness of more than 6 feet. The section was measured at a prospect just north of the Durango wagon road, in the southwest part of sec. 3, T. 35 N., R. 8 W.:

Section of Mesaverde coal bed in sec. 3, T. 35 N., R. 8 W. (No. 5).

	Ft.	in.
Shale, sandy.		
Coal	4	
Shale		3
Coal		6
Shale		2
Coal	2	
Shale.		
	6	11

It is the writer's opinion that the bed shown above represents a local thickening.

LARAMIE COAL BEDS.

Locality No. 6: In the Laramie of the Florida River district there are two important coal beds in the shales and thin sandstones immediately above the basal sandstone. These coal beds are usually made up of thin benches of coal separated by shale partings. They are exposed at several places in the southern part of sec. 9, T. 35 N., R. 8 W., at which the following section was measured by Mr. Taff:

Section of coal bed of the upper Laramie in sec. 9, T. 35 N., R. 8 W. (No. 6).

	Ft.	
Sandstone.		
Coal	8	
Shale	4	6
Coal	2	
Shale, carbonaceous.		
	14	6

Locality No. 7: Near the southeast corner of sec. 9, T. 35 N., R. 8 W., the lower coal bed of the Laramie is exposed in natural outcrop. The section here furnished by Mr. Taff is as follows:

Section of coal bed of the lower Laramie in sec. 9, T. 35 N., R. 8 W. (No. 7).

	Ft.	in.
Shale.		
Coal	2	6
Shale	3	
Coal	2	
Shale	1	6
Coal	6	
Shale	1	
Coal	5	
Shale.		
	21	

Locality No. 8: Below is given a section of a Laramie coal bed in the northern part of sec. 7, T. 35 N., R. 7 W.:

Section of a Laramie coal bed in sec. 7, T. 35 N., R. 7 W. (No. 8).

	Ft.	in.
Shale, carbonaceous, and bone.		
Coal	1	2
Shale	1	8
Coal		8
Shale		8
Coal	1	2
Covered; possibly more coal.		
	5	4

There have been local prospects in this vicinity, but no coal is being mined at the present time.

Locality No. 9: Near the center of sec. 8, T. 35 N., R. 7 W., the following section was taken of the upper coal bed of the Laramie:

Section of the upper coal bed of the Laramie in sec. 8, T. 35 N., R. 8 W. (No. 9).

	Ft.	in.
Shale.		
Coal, with thin shale partings	3	
Coal, bony		5
Coal, with bony streaks	3	
Shale.		
	6	5

Locality No. 10: Near the center of sec. 13, T. 35 N., R. 7 W., a great quantity of Laramie coal is exposed in an old prospect. The identity of this bed could not be determined. The following section was measured in this pit:

Section of Laramie coal bed in sec. 13, T. 35 N., R. 7 W. (No. 10).

	Ft.	in.
Shale, carbonaceous.		
Coal with thin partings	14	
Shale, soft	4	
Coal, bony	3	
Coal	5	6
Shale.		
	26	6

In the upper bed of the above section the coal is apparently of low grade; the thin partings are too numerous and irregular to permit a detailed section. The lower bed, however, is made up of clear coal.

Locality No. 11: In the western part of sec. 17, T. 35 N., R. 6 W., the following section of a Laramie coal bed was obtained:

Section of a Laramie coal bed in sec. 17, T. 35 N., R. 6 W. (No. 11).

	Ft.	in.
Sandstone	5	
Shale	1	
Coal	5	
Coal, bony		6
Coal	2	4
Sandstone.		
	13	10

Locality No. 12: There have been several prospects and local coal mines along the Laramie boundary in the eastern part of T. 35 N., R. 6 W. The bed in this vicinity is represented by the following section, taken along the south line of sec. 14:

Section of Laramie coal beds in sec. 14, T. 35 N., R. 6 W. (No. 12).

	Ft.	in.
Shale.		
Coal	2	
Shale	15	
Coal	4	8
Coal, bony		1
Coal		5
Shale.		
	22	2

A sample of the coal bed shown above was taken for analysis by F. C. Schrader in 1905. The sample was obtained by making a cut across the coal bed exclusive of the bony-coal parting. The moisture content is less than in many of the coals in the San Juan region (Durango-Gallup field), but the percentage of ash is far above the average.

Locality No. 13: Along the line between secs. 32 and 33, T. 35 N., R. 5 W., the Laramie coal beds are exposed at several places. There has been some local prospecting in the vicinity. Two beds are exposed, with signs of a third, as shown in the following section, taken at the central part of the east line of sec. 32:

Section of Laramie coal beds in sec. 32, T. 35 N., R. 5 W. (No. 13).

	Ft.	in.
Shale	10	
Coal	3–6	
Shale		2
Coal		1
Shale		1
Coal	1	6
Shale		1
Coal	7	
Shale	25	
Sandstone	2	
Coal signs, possibly workable bed.		
Sandstone	2	
Shale	25	
Sandstone	4	
Coal	6	
Sandstone, massive, base of Laramie	60	
	145–148	11

Locality No. 14: In T. 34 N., R. 5 W., there appears to be much coal at the base of the Laramie, but a large amount of it contains hard argillaceous streaks, commonly known as "bone coal." In this region the Tertiary escarpment is near the Laramie outcrop; the intervening valley shows natural exposures of the coal at several localities. The following section was taken in the northwestern part of sec. 12:

Section of Laramie coal beds in sec. 12, T. 34 N., R. 5 W. (No. 14).

	Ft.	in.
Shale, much burnt	4	
Coal	2	6
Shale	6	
Coal with bony streaks	12	
Shale, drab	10	
Shale, carbonaceous	8	
Sandstone, massive.		
	42	6

Locality No. 15: About 1¼ miles southwest of Piedra Parada Peak, in T. 34 N., R. 4 W., there are two beds exposed above the basal Laramie sandstone. The total thickness of the Laramie as measured in this vicinity is 650 feet. The following is a section of the basal portion, including the coal beds:

Section of Laramie coal beds in sec. 30, T. 34 N., R. 4 W. (No. 15).

	Ft.	in.
Shale	12	
Limestone, argillaceous, bearing fossil shells		6
Shale, argillaceous, bearing fossil shells at base	2	
Coal	7	
Shale	5	
Sandstone	4	
Shale, bearing some fossil shells	7	
Limestone, argillaceous, bearing fossil shells		7
Shale, with fragments of silicified wood	5	
Coal	2	2
Shale	15	
Sandstone, massive, base of Laramie	100	
	160	3

Locality No. 16: Near the center of sec. 16, T. 33 N., R. 3 W., one of the Laramie coal beds is being worked at the Talian mine, on a branch of the Denver and Rio Grande Railroad running from Pagosa Springs to Pagosa Junction. The following is a section of the coal at this mine:

Section of coal beds at Talian mine, in sec. 16, T. 33 N., R. 3 W. (No. 16).

	Ft.	in.
Shale, arenaceous.		
Coal	4	
Sandstone, thin-bedded	16	
Sandstone	3	
Shale, arenaceous		6
Coal	3	
	26	6

The upper bed in the above section is the one being mined and is reported to be good coal for steam and domestic purposes. The output of this mine goes largely to the Denver and Rio Grande Railroad, Pagosa Springs, and lumber camps in adjacent portions of the State.

Locality No. 17: Across San Juan River from Montezuma Mountain two workable coal beds are exposed above the basal Laramie sandstone. In the NE. ¼ sec. 32, T. 33 N., R. 2 W., the following section was measured:

Section of Laramie coal beds in sec. 32, T. 33 N., R. 2 W. (No. 17).

	Ft.	in.
Shale, sandy	25	
Coal, bony	1	8
Shale	1	
Coal	5	4
Shale	7	
Coal	3	
Shale	1	
Sandstone, massive, base of Laramie	90	
	134	

Locality No. 18: In the southern part of sec. 2, T. 32 N., R. 2 W., the lowest Laramie coal bed was mined several years ago at what was known as the Archuleta mine. A drift which was run in on the bed, trending S. 50° W. at a very slight dip, is now filled by débris. Schrader[a] reports the coal to be of good quality and 11 feet thick, with two thin partings. Shale occurs above and below the coal bed.

MONERO COAL DISTRICT.

The outcrop of the Laramie formation striking east of south across the Jicarilla Apache Indian reservation from Dulce is apparently barren of workable coal beds. The Mesaverde, however, in the vicinity of Monero, N. Mex., contains three workable beds of excellent quality. Monero is located on the Denver and Rio Grande Railroad, in the SE. ¼ sec. 7, T. 31 N., R. 1 E. Three companies are operating mines near this place—the Monero Coal Company, the Rio Arriba Coal Company, and the George W. Kutz Company. Most of the coal is sold to the Denver and Rio Grande Railroad, but a small portion goes to the San Luis Valley and some to Santa Fe, N. Mex. The total output for the year 1906 was 43,000 tons, valued at $69,500.

[a] Op. cit., p. 247.

The following is a generalized section from the base of the Mesaverde up to and including the Monero coal beds:

Section of Mesaverde coal group in Monero district, T. 31 N., R. 1 E.

		Ft.	in.
Covered.			
Sandstone, brown		4	
Bed No. 3	Coal	1	6
	Shale		7
	Coal	1	6
Shale		3	
Coal		1	
Shale and thin sandstones		10	
Sandstone, brown		1	6
Shale		10	
Sandstone, thin bedded		30	
Bed No. 2	Bone		2
	Sandstone		6
	Coal	3	4
Shale		5	
Sandstone		15	
Bed No. 1	Coal	1	8
	Shale		9
	Coal	1	4
Sandstone and shale		15	
Sandstone, massive, base of Mesaverde		50	
		155	10

Two analyses of coal from bed No. 2 of this district, as made at the fuel-testing plant, St. Louis, Mo., are given on page 363, Nos. 2121 and 2122. The samples were collected by F. C. Schrader[a] in the usual manner, by making a cut across the face of the bed, quartering the sample to convenient size, and sealing it in an air-tight can.

A new mine has recently been opened southwest of Lumberton, in the SE. ¼ sec. 8, T. 31 N., R. 1 W. This mine is on a branch line from Lumberton to Elvado and was opened in 1906 by the Burns-Biggs Lumber Company. The thickness of this bed is 3 feet, with sandstone above and shale below.

COAL NORTHEAST OF PAGOSA SPRINGS, COLO.

During the present examination the writer had occasion to visit an area of reported coal about 10 miles northeast of Pagosa Springs, Colo. A prospect from which a small amount of coal has been taken is located in the NE. ¼ sec. 36, T. 36 N., R. 1 W. of the New Mexico

[a] Op. cit., p. 258.

principal meridian. The following is a section of the horizontal coal-bearing rocks at the prospect:

Section of coal-bearing rocks in sec. 36, T. 36 N., R. 1 W.

	Ft.	in.
Sandstone and shale, largely covered.		
Coal bed, burnt.		
Shale, brown, carbonaceous	6	
Covered	15	
Shale, carbonaceous	14	
Coal	5	6
Shale, brown, carbonaceous	9	
Coal	1	
Shale, carbonaceous	1	
Coal	1	3
Sandstone, carbonaceous	2	
Sandstone, massive, white	50	
	104	9

Two coal beds 3 feet or more in thickness are reported by J. E. Chapson, of Pagosa Springs, as occurring above the 5½-foot bed shown in the above section. Possibly one of these beds is represented by the burned zone at the top and the other in the covered area of 15 feet near the top of the section. Coal has been mined for local use at the prospect.

In the eastern part of the SW. ¼ sec. 31, T. 36 N., R. 1 E., there has been some local mining. The bed at this point measures 10½ feet, with shale above and below. The coal has a black, shiny luster, and mines out in rather thin layers.

It is the writer's opinion that the coal beds in the region under discussion are Laramie and have been preserved by block faulting adjacent to the San Juan Mountains. The exposures are within 1 mile of the igneous peaks and 1,000 feet above San Juan River. The coal-bearing rocks are largely covered by talus and spruce. There is evidence of a fault in the vicinity, but no attempt was made to trace the sedimentary boundaries or to map the structure. The coal sections with the massive white sandstone at the base are closely similar to sections on the north side of the main Laramie outcrop, and on this basis alone the identification is made.

For purposes of comparison the analyses of three other samples from the vicinity of Durango are given on page 363. Sample No. 2092 is from bed No. 3, at Porter, and No. 3552 from Perrine Peak. Both of these samples are from coal in the Mesaverde formation. Sample No. 3551 was obtained 3 miles southeast of Durango and is representative of the Laramie coal in this district.

ANALYSES.

The following analyses represent the character of the coal in this field:

Analyses of coal samples from the Durango-Monero coal field, Colorado-New Mexico.

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

Name of formation	Laramie.		Laramie(?).	Mesaverde.				
Locality	Beaver Creek.	Durango.	12 miles northeast of Pagosa Springs	Monero.		Lumberton.	Porter.	Durango.
Laboratory No.	2094.	3551.	4175.	2121.	2122.	5761.	2092.	3552.
Sample as received:								
Prox. Moisture	4.79	3.05	9.50	3.04	3.99	1.71	2.73	3.64
Prox. Volatile matter	35.04	32.70	34.78	39.02	39.03	36.26	36.05	37.79
Prox. Fixed carbon	45.45	47.47	45.75	48.28	51.04	55.11	54.48	53.35
Prox. Ash	14.72	16.78	9.97	9.66	5.94	6.92	6.74	5.22
Ult. Sulphur	.77	1.30	1.14	3.52	1.01	.65	.53	1.36
Ult. Hydrogen	....	4.73	....	5.57	....	5.21	....	5.39
Ult. Carbon	....	64.21	....	70.72	....	75.38	....	75.40
Ult. Nitrogen	....	1.43	....	1.48	....	1.56	....	1.48
Ult. Oxygen	....	11.55	....	9.05	....	10.28	....	11.15
Calories	....	6,611	....	7,185	....	7,625	7,730	7,553
British thermal units	....	11,900	....	12,933	....	13,725	13,914	13,595
Loss of moisture on air drying	2.20	.90	2.20	.90	1.50	....	1.30	1.60
Air-dried sample:								
Prox. Moisture	2.65	2.17	7.46	2.16	2.53	1.32	1.45	2.07
Prox. Volatile matter	35.83	33.00	35.56	39.37	39.62	36.40	36.52	38.40
Prox. Fixed carbon	46.47	47.90	46.78	48.72	51.82	55.33	55.20	54.22
Prox. Ash	15.05	16.93	10.20	9.75	6.03	6.95	6.83	5.31
Ult. Sulphur	.79	1.31	1.17	3.55	1.03	.65	.54	1.38
Ult. Hydrogen	....	4.67	....	5.52	....	5.19	....	5.29
Ult. Carbon	....	64.79	....	71.36	....	75.68	....	76.63
Ult. Nitrogen	....	1.44	....	1.49	....	1.57	....	1.50
Ult. Oxygen	....	10.86	....	8.33	....	9.96	....	9.89
Calories	....	6,671	....	7,250	....	7,656	7,832	7,676
British thermal units	....	12,008	....	13,050	....	13,780	14,098	13,816
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of coal bed	3 2½	7 3	5 6	3 5	3 4	2 6	3	6 10

THE COAL FIELD BETWEEN GALLUP AND SAN MATEO, NEW MEXICO.

By James H. Gardner.

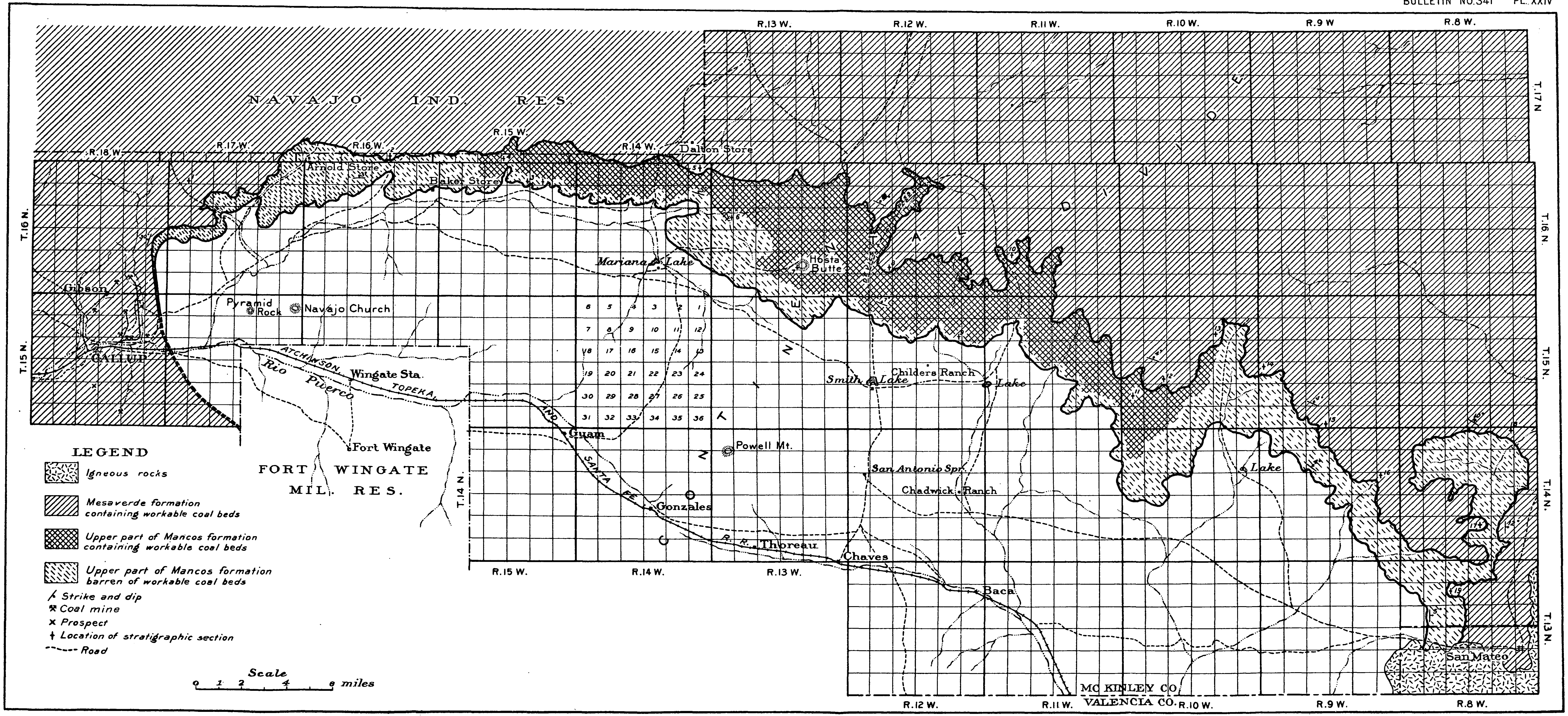
INTRODUCTION.

The coal-bearing rocks between Gallup and San Mateo, N. Mex., are included in a portion of the area covered by the hasty reconnaissance of Schrader[a] in 1905. Because of the brief time available for work during the season of 1905, Schrader's party was unable to trace boundaries in detail. The matter of land lines was necessarily ignored to a large extent, as in other parts of the region. The field work of the last season included a resurvey of the area in greater detail and relative to land lines. The map here presented (Pl. XXIV) was prepared by W. J. Reed. Acknowledgment is due also to A. L. Beekly for valuable assistance in the field.

Work was begun at the northeast corner of T. 15 N., R. 18 W., of the New Mexico principal meridian, the township in which Gallup is located, and continued eastward to San Mateo, in T. 13 N., R. 8 W., including a resurvey of that township. The report given here is a brief review of this portion of the San Juan coal region (Durango-Gallup coal field). A full report on the entire field is in preparation, to be published later as a bulletin of the Survey.

The region under discussion is one of sparse population. The lack of permanent streams for irrigating purposes leaves the country practically void of agricultural development. During the fall and spring months there is usually a fair growth of grass over the area and stock may be grazed with profit, but as the grazing season does not continue throughout the entire year and is inconstant in its occurrence, little capital has been invested. There are a few small springs near which are located trading posts, supported largely by Mexicans and Navajo Indians.

[a] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258.



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MAP OF THE COAL FIELD BETWEEN GALLUP AND SAN MATEO, NEW MEXICO

By James H. Gardner, William J. Reed, and Albert L. Beekly

TOPOGRAPHY AND GEOLOGY.

The topographic features are comparatively simple, and the same may be said of the geology. The boundary of the Cretaceous system is expressed in a general way in the topography, which is shown on the Fort Wingate and Mount Taylor topographic sheets of the Geological Survey. On the Fort Wingate sheet a narrow ridge is represented as running in a north-south direction about 2¾ miles east of Gallup. The bold portion of this ridge or hogback marks the boundary of the Cretaceous rocks, which dip steeply westward. This hogback stands in bold relief for a few miles northward from the Atchison, Topeka and Santa Fe Railway. Beyond this stretch it swings to the east and is continuous with an escarpment trending in a southeasterly direction by way of Hosta Butte to and beyond the vicinity of San Mateo, in the Mount Taylor quadrangle.

The relation of the coal-bearing formations of this region to those in the northern part of the San Juan River region was not determined in the work of 1905. Schrader classified the rocks in three divisions—upper Montana, lower Montana, and Colorado.

Regarding the Hosta Butte district, Schrader[a] says:

> The upper coal group [upper Montana] was observed only in the northwestern part of the district, in the southeast corner of the Navajo Indian Reservation, where it has an extent of about 30 miles in an east-west direction. * * * The middle and lower coal groups enter the Hosta Butte district from the direction of Mount Taylor, and after extending northwestward across the district, curve southward and form the hogback, which crosses the railroad 3 miles east of Gallup. Their geologic age is not definitely determined, but from the evidence of a few fossils collected in each of them it is probable that the middle group represents the lower part of the Montana formation and that the lower group represents a part of the Colorado formation.

Schrader shows the three divisions on his map, stating in connection with it that the relation of the upper and lower Montana to the Mesaverde was at that time unknown. However, in Shaler's reconnaissance in 1906,[b] the true Mesaverde was traced southward from its type locality in the Mesa Verde, on the Rio Mancos in Colorado, and found to be continuous, though possibly not identical in entirety with the coal groups at Gallup. As a result, Shaler mapped the coal-bearing strata on the south side of the field on a new basis, substituting Mesaverde for the upper and lower Montana of Schrader.

The Colorado formation of Schrader, subjacent to the Mesaverde, consisting of clay and arenaceous shale, and bearing coal beds, was mapped by Shaler, on the basis of fossil evidence, as coal-bearing Mancos. The lower portion of the Mancos is Colorado and the upper portion Montana.[c] Consequently Shaler[d] shows only two groups of

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[a] Op. cit., p. 252.

[b] Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 316, 1907, pp. 376–426.

[c] Cross, Whitman, La Plata folio (No. 60), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

[d] Op. cit., Pl. XXII.

coal beds between Gallup and San Mateo, the Mancos and the Mesaverde. All the fossils so far collected by previous parties and by the writer during the last season confirm Shaler's determination that the coal beds of the Mancos are limited to the lower part, and consequently are of Colorado age.

Only the lower part of the Mesaverde formation is present in the escarpment between Gallup and San Mateo. The upper portion is eroded for a distance of 40 miles to the north, and forms an escarpment along Rio Chaco roughly parallel with the margin of the field and in close proximity to the outcrops of the Lewis and Laramie formations.

The following table includes the formations of the Cretaceous system exposed between Gallup and San Mateo:

Generalized section of a portion of the Cretaceous rocks between Gallup and San Mateo, N. Mex.

Mesaverde formation, lower part (1,000 feet): Massive sandstone, alternating with thin clay and argillaceous shales and bearing workable coal beds.

Mancos shale (800 feet):

Massive sandstone, arenaceous shale, and coal beds, workable in central part of the area (500 feet).

Drab clay shale and thin sandstones (300 feet).

Dakota sandstone (200 feet): Light-gray, hard sandstone at top and bottom. Alternating thin beds of sandstone and shale, with some bituminous shale and a few irregular coal beds of no commercial importance.

It is probable that the upper part of the Mesaverde, corresponding to the formation along Rio Chaco, is present in the Gallup district and farther southward in the Zuñi Basin. Further work will doubtless be necessary before the exact correlation of these rocks can be made.

Regarding the Dakota coal, it seems well to quote the following paragraph of Shaler's report relative to the Gallup district:[a]

The coals of the Gallup district represent three formations—the Dakota, Mancos, and Mesaverde. Those of the Mesaverde are the most valuable and the only ones at present mined. The Dakota coal was examined east of Gallup in the southward-facing escarpment north of the railroad, but was found to be thin and full of partings and consequently not of present commercial value.

This character appears to hold for the Dakota throughout the Gallup-San Mateo field.

THE COAL.

There has been no development of the coal beds in most of the field under present discussion, mining being confined entirely to the vicinity of Gallup. For a description of the mines and sections at Gallup, the reader is referred to the Schrader and Shaler reports,

[a] Op. cit., p. 410.

previously cited. The present lack of demand for subbituminous noncoking coals in this portion of the country and the recent adoption of fuel oil on the Pacific coast railroads has had a tendency to prevent any marked increase in production in this part of the field. The sections given in the following pages show the number of workable coal beds in the escarpment between Gallup and San Mateo.

Locality No. 1:[a] The following section represents the coal-bearing strata, beginning at the base of the Mancos transitional rocks in the central part of sec. 16, T. 16 N., R. 17 W., and extending to the top of the Mesaverde escarpment, at the southeast corner of sec. 6 of the same township:

Section of coal-bearing rocks from sec. 16 to sec. 6, T. 16 N., R. 17 W. (No. 1).

	Ft.	in.
Sandstone, brown, massive	30	
Shale and shaly sandstone	40	
Sandstone, massive	6	
Shale, carbonaceous	2	
Coal	3	
Shale, carbonaceous	3	
Coal		6
Shale, carbonaceous	6	
Coal	2	2
Shale, carbonaceous	10	
Shale, drab	5	
Coal		6
Shale, carbonaceous	2	
Shale and thin sandstone	15	
Coal		6
Shale	25	
Sandstone	3	
Shale, drab	5	
Shale, carbonaceous	20	
Shale and thin brownish sandstone	150	
Sandstone, gray, massive	50	
Shale, carbonaceous	10	
Sandstone and shale	40	
Sandstone, brown, massive	35	
Shale	20	
Sandstone, massive	20	
Shale and sandstone	50	
Shale	5	
Coal	1	8
Shale	10	
Sandstone	1	
Shale, carbonaceous	1	
Sandstone, gray	10	
Coal	2	
Shale and sandstone	15	

[a] These numbers correspond to those on Pl. XXIV.

	Ft.	in.
Sandstone, thin-bedded	20	
Shale, carbonaceous	1	
Coal	2	
Shale, carbonaceous	10	
Sandstone, thin, and shale	50	
Sandstone, brown, massive	20	
Coal	1	4
Shale		8
Coal		8
Shale	28	
Sandstone, brown, massive; base of Mesaverde	60–100	
Shale, drab	20	
Sandstone, massive	15	
Shale	20	
Sandstone	15	
Shale, sandy	18	
Sandstone, brown, massive, argillaceous	15	
Shale and thin sandstone	60	
Sandstone, ferruginous, fossiliferous	1	
	957–997	

Locality No. 2: The following is a section of the Mesaverde coal-bearing rocks near the southwest corner of sec. 35, T. 17 N., R. 16 W.:

Section of Mesaverde coal-bearing rocks in sec. 35, T. 17 N., R. 16 W. (No. 2).

	Ft.	in.
Sandstone, brown, massive	70	
Shale, carbonaceous	25	
Sandstone, massive, soft	30	
Shale	1	
Coal		5
Shale	5	
Sandstone, whitish, massive	50	
Shale, drab, hard	10	
Coal	3	9
Shale, carbonaceous	3	
Sandstone	60	
Shale, hard, carbonaceous	1	8
Coal	3	
Shale, drab	4	
Coal	4	
Shale	1	
Coal		8
Shale, drab	2	
Sandstone, massive	4	
Shale	1	
Coal	1	2
Coal, bony		9
Coal		4
Shale		5
Coal	2	1
Shale	30	

	Ft.	in.
Sandstone, whitish, massive	20	
Coal	1	8
Shale		2
Coal	1	6
Shale		3
Coal		10
Shale	12	
Coal	3	4
Shale, drab	3	
Covered.		
	357	

The section given above includes only that portion of the Mesaverde which contains workable coal beds. A series of sandstones, shales, and very thin coal beds occurs below the section given above, continuing on down to and including the upper part of the Mancos.

Locality No. 3: The following is a section of the coal-bearing rocks in the Mancos shale below the Mesaverde, taken at the southeast corner of sec. 3, T. 16 N., R. 15 W.:

Section of Mancos coal-bearing rocks in sec. 3, T. 16 N., R. 15 W. (No. 3).

	Ft.	in.
Sandstone, brown, massive	30	
Shale, yellowish, arenaceous	30	
Shale, tan colored	50	
Sandstone, yellowish	6	
Shale and thin sandstone	50	
Coal	1	2
Shale, dark		4
Coal		8
Shale, hard, sandy	3	
Coal		10
Coal, bony		4
Coal	1	4
Sandstone, gray, argillaceous	3	
Shale, carbonaceous	2	
Coal, bony		8
Shale, drab, and thin sandstone	40	
Sandstone	15	
Shale	12	
Sandstone, massive	10	
Coal	3	
Coal, bony		8
Coal	1	
Shale, drab	10	
Sandstone	1	
Coal, bony	1	
Shale	15	
Coal	2	
Shale, carbonaceous	2	
Sandstone	1	

	Ft.	in.
Shale, carbonaceous	1	
Coal	2	6
Shale		1
Coal	1	1
Shale, sandy	3	
Coal		8
Shale	19	
Sandstone, gray	6	
Sandstone, massive	40	
Covered	100	
Sandstone, massive, soft	30	
	496	4

The detailed section given above represents the entire sandstone and coal zone of the Mancos formation. From this place the Mancos is coal bearing eastward to the center of T. 15 N., R. 10 W.

Locality No. 4: The following section of the Mesaverde coal-bearing rocks was measured in the southwest corner of sec. 34, T. 17 N., R. 15 W.:

Section of Mesaverde coal-bearing rocks in sec. 34, T. 17 N., R. 15 W. (No. 4).

	Ft.	in.
Sandstone, brown, massive	60	
Shale, gray, and thin sandstone	7	
Sandstone, yellowish, soft	5	
Shale, gray	20	
Sandstone, gray, soft	8	
Shale	2	
Coal		8
Shale	4	
Sandstone, white		3
Coal	1	4
Sandstone, white, soft	3	
Sandstone	8	
Shale, drab, hard	7	
Sandstone, brown	4	
Shale, brown	10	
Coal	3	6
Shale, brown	6	
Sandstone, locally burned red	15	
Coal	7	6
Shale, gray, sandy	11	
Coal	7	
Shale, gray	4	
Coal	1	3
Shale, gray	4	
Coal	6	
Shale, brown	4	
Sandstone, massive	6	
Shale, brown	3	
Coal	1	
Shale, gray	10	
Sandstone	4	

	Ft.	in.
Shale, gray	3	
Coal	1	3
Shale	3	
Sandstone	50	
Coal	2	
Shale, gray	4	
Coal		2
Shale, brown and yellow	35	
Coal		7
Shale, brown	1	4
Coal		5
Shale, brown	25	
Coal	1	4
Shale	1	
Coal		4
Sandstone	10	
Coal	2	
Sandstone and sandy shale	35	
Coal	2	
Shale and thin sandstone	55	
Sandstone, white, massive	14	
Shale, brown	3	
Coal	2	3
Shale	12	
	497	2

The three workable beds in the upper part of this section, with an average thickness of 6 feet, apparently contain a good grade of subbituminous coal, free from partings.

Locality No. 5: In the northern part of sec. 1, T. 16 N., R. 14 W., there are four beds of workable thickness in the upper or Mesaverde formation, as shown in the following section of the coal-bearing portion:

Section of Mesaverde coal-bearing rocks in sec. 1, T. 16 N., R. 14 W. (No. 5).

	Ft.	in.
Sandstone, gray, and shale	20	
Shale	3	
Coal	3	4
Shale, drab	40	
Sandstone, gray, soft	40	
Coal	3	6
Shale, sandy	15	
Coal	1	
Shale, carbonaceous	3	
Sandstone and shale, with thin beds of coal	50	
Shale, drab, hard	5	
Shale, carbonaceous	2	
Coal	2	
Shale, sandy	20	
Coal with bony streaks	4	
Shale, sandy, carbonaceous	20	
Covered.		
	231	10

The coal beds of this section are free from partings and resist weathering fairly well. The 4-foot bed near the base of the section does not present a favorable appearance at the surface exposure. It evidently contains a large percentage of hard, argillaceous material.

Locality No. 6: The following section represents a part of the Mancos shale in the east part of sec. 18, T. 16 N., R. 13 W.:

Section of Mancos coal beds in sec. 18, T. 16 N., R. 13 W. (No. 6).

	Ft.	in.
Top covered.		
Sandstone, massive	5	
Shale, carbonaceous	10	
Coal		6
Shale, carbonaceous	1	6
Coal	2	2
Shale, carbonaceous	2	
Sandstone and shale	6	
Coal	1	
Sandstone and thin coals	90	
Covered.		
	118	2

This section shows only one coal bed more than 2 feet in thickness, but it is probable that other beds occur above the section given here, although their outcrop is so covered as to be indistinguishable.

Locality No. 7: Hosta Butte is located on the line between secs. 26 and 27, T. 16 N., R. 13 W. The main portion of this butte is composed of an outlier of the upper or Mesaverde coal group, and the Mancos coal rocks form the escarpment about 1 mile south of the butte. The base of the main butte has an elevation of about 8,000 feet; the top of the escarpment, at a triangulation point used in the survey of the Wingate quadrangle, is at an elevation of 8,837 feet. Just below the 8,000-foot level is a coal bed 2 feet thick, with massive sandstone above and shale beneath. The bed is in the Mancos shale and apparently contains good coal. At an elevation of 8,550 feet occurs a bed 3 feet thick, with carbonaceous shale roof and floor. At 8,600 feet is a bed 5 feet thick, of clear coal, with shale above and below. The two latter coal beds belong in the Mesaverde formation. They are clear of partings or any apparent injurious constituents.

Locality No. 8: Devils Pass is a deep canyon cut through the Mesaverde rocks from sec. 20 to sec. 3, T. 16 N., R. 12 W. The following is a general section taken in the southeast corner of sec. 29 of this township:

Section of Mesaverde coal-bearing rocks in sec. 29, T. 16 N., R. 12 W. (No. 8).

	Ft.	in.
Sandstone, massive.		
Shale	10	
Coal	3	6
Sandstones and shale (shale at base)	25	
Coal	3	6
Shale and sandstone	10	

	Ft.	in.
Shale	8	
Coal	1	
Shale and sandstone	20	
Coal	1	6
Shale	1	
Coal	1	6
Shale and sandstone	100	
Shale, brown, carbonaceous	1	
Coal	2	
Shale	3	
Coal	2	
Shale, brown, carbonaceous	1	
Shale	2	
Shale, brown, carbonaceous	1	
Shale and sandstone	100	
Shale, brown, carbonaceous	1	
Coal	1	
Shale, brown, carbonaceous	1	
Shale	2	
Coal containing much fossil resin	2	
Shale, brown, carbonaceous	1	
	1	
	306	

Locality No. 9: Near the southeast corner of sec. 11, T. 15 N., R. 12 W., there is one workable bed in the Mancos showing the following section:

Section of Mancos coal bed in sec. 11, T. 15 N., R. 12 W. (No. 9).

	Ft.	in.
Sandstone with intercalated sandy shale	4	
Coal	3	2
Shale, sandy		2
Coal		10
Shale, carbonaceous	10	
	18	2

A section of this bed measured 3 or 4 miles west of the locality noted above is given in the report of Shaler, who describes it as follows:[a]

A typical section of the Mancos coal is exposed in the escarpment south of the entrance to Devils Pass, about 12 miles east of north of Thoreau. The coal compares well in quality with the sample collected in 1905 from the same bed in the Tiejen prospect,[b] 10 miles east of north from Baca. The analysis shows a good subbituminous coal. It contains considerable fossil resin, which causes it to ignite readily. The strata * * * dip east of north at an angle of 7°. The section of the coal is as follows:

Section of Mancos coal bed south of Devils Pass.

	Ft.	in.
Shale, drab.		
Coal	2	6
Shale		3
Coal		10
Shale, brown, carbonaceous.		
	3	7

[a] Op. cit., p. 410.

[b] See No. 11 of this report, p. 374.

Locality No. 10: The following is a general section of the Mesaverde or upper coal-bearing rocks, measured in the northwest corner of sec. 29, T. 16 N., R. 11 W.:

Section of Mesaverde coal-bearing rocks in sec. 29, T. 16 N., R. 11 W. (No. 10).

	Ft.	in.
Sandstone, yellow, massive	55	
Shale, gray	20	
Shale, black, with streaks of bony coal	7	
Coal		10
Shale, gray	5	
Coal	2	6
Shale, gray	2	
Sandstone, white, soft	4	
Shale, brown	4	
Coal	2	3
Shale, brown	2	
Sandstone, white, soft	2	
Shale, brown	30	
Coal	4	
Sandstone, pinkish, soft	3	
Shale, soft	12	
Sandstone, hard	2	
Sandstone, soft, and shale	25	
Sandstone, brown, hard	3	
Shale, brown	4	
Coal	1	4
Shale, dark	3	
Shale, gray	3	
Coal	5	2
Shale	4	
Coal		4
Shale	7	
Coal	2	
Sandstone, thin bedded	3	
Shale, sandy	8	
Sandstone	18	
Shale, brown	8	
Coal		10
Coal, bony	2	
Sandstone, yellowish	4	
Shale, gray	3	
Coal	2	
Sandstone, thin bedded	6	
Shale and soft sandstone	38	
Coal	2	2
Shale and sandstone, soft	32	
Sandstone, tan colored, hard	25	
Sandstone, brown, massive, hard	35	
Shale, Mancos.		
	402	5

Locality No. 11: The principal coal bed of the Mancos shale is the Tiejen bed, so named from a small prospect made several years ago by J. E. Tiejen, of Bluewater, N. Mex. The location of this prospect as given by Mr. Tiejen is in the center of sec. 30, T. 15 N., R. 10 W. A section of the bed follows:

Section of coal bed at Tiejen prospect, sec. 30, T. 15 N., R. 10 W. (No. 11).

	Ft.	in.
Shale, carbonaceous	1	
Coal	1	3
Shale, arenaceous		1¼
Coal	3	6
Shale, carbonaceous.		
Total coal bed	4	10¼

Schrader[a] makes the following statement relative to this coal:

The coal is a good black lignite[b] and contains much fossil resin, resembling in this respect the Monero coal. A sample was taken from the Tiejen prospect for analysis. The material was secured by making a cut across the face of the coal, exclusive of the parting 1¼ inches in thickness. * * * With the exception of the heavy percentage of water, this analysis compares favorably with the analyses of other coals of the field.

The analysis of this coal as made at the St. Louis laboratory follows:

Analysis of coal from the Tiejen bed.

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

	As received.	Air dried.
Air-drying loss	5.20	
Total moisture, including air-drying loss	15.03	10.37
Volatile matter	37.26	39.30
Fixed carbon	41.97	44.27
Ash	5.74	6.06
Sulphur	.57	.60

In the central portion of T. 15 N., R. 10 W., shown by the broken-lined area on the accompanying map (Pl. XXIV), the Mancos is barren of workable coal beds. Thin beds, however, occur throughout the length of the Mancos exposure. From this vicinity eastward the workable coals are confined to the Mesaverde, which is exposed in a bold, well-marked escarpment striking in a northwest-southeast direction.

Locality No. 12: The following section includes the workable coal beds of the escarpment in sec. 20, T. 15 N., R. 10 W.:

Section of Mesaverde coal beds in sec. 20, T. 15 N., R. 10 W. (No. 12).

	Ft.	in.
Sandstone and shale	40	
Shale, brown, hard	10	
Coal	3	
Shale, brown	3	
Coal	1	8
Shale	8	

[a] Op. cit., p. 254.

[b] The term "subbituminous" was later adopted by the Survey for this class of coal.

	Ft.	in.
Shale, black, arenaceous	3	
Coal		6
Shale, drab, hard	9	
Coal	1	
Shale	3	
Sandstone	4	
Shale	1	
Coal	3	6
Shale.		
	90	8

Locality No. 13: At the southwest corner of sec. 11, T. 15 N., R. 10 W., the coal beds exposed are as follows:

Section of Mesaverde coal beds in sec. 11, T. 15 N., R. 10 W. (No. 13).

	Ft.	in.
Shale, carbonaceous	10	
Coal	3	3
Shale, carbonaceous	15	
Coal	2	
Shale, carbonaceous	6	
Shale and thin-bedded sandstone	100	
Shale, carbonaceous	2	
Coal	2	
Shale	2	
Coal	2	
Covered.		
	144	3

Locality No. 14: In the southwestern part of sec. 19, T. 15 N., R. 9 W., the Mesaverde contains several coal beds which show along the face of the escarpment. These beds vary remarkably, as a comparison of the sections will indicate. Within a few miles thin beds undoubtedly thicken to valuable proportions, and thicker beds thin to mere traces. The following is a section of the coal beds exposed at locality No. 14:

Section of Mesaverde coal beds in sec. 19, T. 15 N., R. 9 W. (No. 14).

	Ft.	in.
Shale, carbonaceous	20	
Coal	2	3
Shale, carbonaceous	15	
Coal	1	10
Shale and sandstone	12	
Coal	1	2
Shale	2	
Coal	3	1
Shale, carbonaceous	4	
Sandstone, brown	10	
Shale, drab	15	
Coal	1	

	Ft.	in.
Shale, carbonaceous	10	
Coal containing fossil resin	3	
Shale, carbonaceous	1	
Coal	1	6
Shale		2
Coal		5
Shale	2	
Sandstone and shale	25	
Coal	2	
Shale, carbonaceous	6	
Coal		8
Covered.		
	139	1

Locality No. 15: A section was made in the southeastern part of sec. 33 of the same township and shows about an equal quantity of coal, although the relations of one bed to another are somewhat different.

Locality No. 16: In sec. 13, T. 14 N., R. 9 W., there are three beds in the escarpment of the Mesaverde worthy of mention. They are shown in the following section:

Section of Mesaverde coal beds in sec. 13, T. 14 N., R. 9 W. (No. 16).

	Ft.	in.
Sandstone.		
Shale, carbonaceous	1	
Coal	3	2
Shale, carbonaceous	1	
Sandstone, massive	10	
Shale, drab	4	
Coal	3	
Shale, carbonaceous	10	
Sandstone, gray	18	
Coal	2	2
Shale, carbonaceous	2	6
Coal		10
Shale, carbonaceous.		
	55	8

Locality No. 17: In T. 14 N., R. 8 W., the outcrop of the Mesaverde formation makes a decided northward swing; from the east side of sec. 34 it encircles a wide area covering several square miles to the north and returns to the west side of sec. 35 in the same township. From this point the boundary passes westward, showing as a mesa in sec. 9, and thence southward to the point of disappearance beneath the lava surrounding Mount Taylor.

In the central part of sec. 27, T. 14 N., R. 8 W., a coal bed 4 feet 2 inches thick was observed in the Mesaverde formation. The bed is about 20 feet below a massive sandstone, 60 to 100 feet thick, which caps the escarpment at that place.

Locality No. 18: The same bed was observed in the northeastern part of sec. 2, T. 14 N., R. 8 W., where the section is as follows:

Section of Mesaverde coal bed in sec. 2, T. 14 N., R. 8 W. (No. 18).

	Ft.	in.
Shale, sandy	10	
Coal	2	6
Shale		6
Coal	1	8
Shale	4	
Covered.		
	18	8

Locality No. 19: In the mesa in sec. 9, T. 13 N., R. 8 W., there is only one workable coal bed. This is 3 feet thick, with a carbonaceous shale above and below, and it occurs about 100 feet below the top of the mesa, on the west face. Other thin coal beds are associated with the shales and sandstones above the massive sandstone at the base of the mesa which represents the bottom of the Mesaverde formation.

In the vicinity of San Mateo the dips change from north to east, and as a result the outcrops of the Mancos and Mesaverde formations turn to the south. West of San Mateo the outcrops of these formations pass beneath a lava flow which covers a broad expanse of country to the south and east. It is probable that to the northeast, toward Cabezon, the upper Montana coal group of Schrader is identical with the upper Mesaverde of Rio Chaco and with the highest coal-bearing strata at Gallup.

THE HARMONY, COLOB, AND KANAB COAL FIELDS, SOUTHERN UTAH.

By G. B. RICHARDSON.

INTRODUCTION.

The existence of coal beds of workable thickness in the southern part of Utah has been known since the country was settled by the Mormons in the middle of the last century, but the isolation of the area has prevented development and the southern Utah coal region is the least known in the United States. Only a few small mines have been opened, in the vicinity of settlements that are located contiguous to the coal outcrop, and practically the entire region is unprospected. The recent completion of the San Pedro, Los Angeles and Salt Lake Railroad, however, has aroused interest in this area, and, although the road is 40 miles from the nearest coal, a branch line can easily be constructed across the Escalante Desert between Lund and Cedar City, near the west end of the coal deposits. (See Pl. XXV.)

Very little has been published concerning the coal in southern Utah. Several analyses of samples from the vicinity of Cedar City and Kanarraville were printed in 1883,[a] and a number of references [b] to the occurrence of the coal have appeared, but the first systematic study was not undertaken until 1906, when Lee [c] made a preliminary examination of the deposits in Iron County. In the summer of 1907 the writer, assisted by Leon J. Pepperberg, Herbert Graff, and C. D. Perrin, surveyed the Harmony, Colob, and Kanab fields in the western part of the southern Utah coal region; and the present paper is an abstract of a more complete report of this investigation which will be published later.

LOCATION AND TOPOGRAPHY.

That part of the southern Utah coal region which is the subject of the present report is situated in eastern Iron and Washington counties

[a] Daggett, E., Analyses and calorific values of some Utah coals: Mineral Resources U. S., U. S. Geol. Survey, 1883, pp. 76-79.

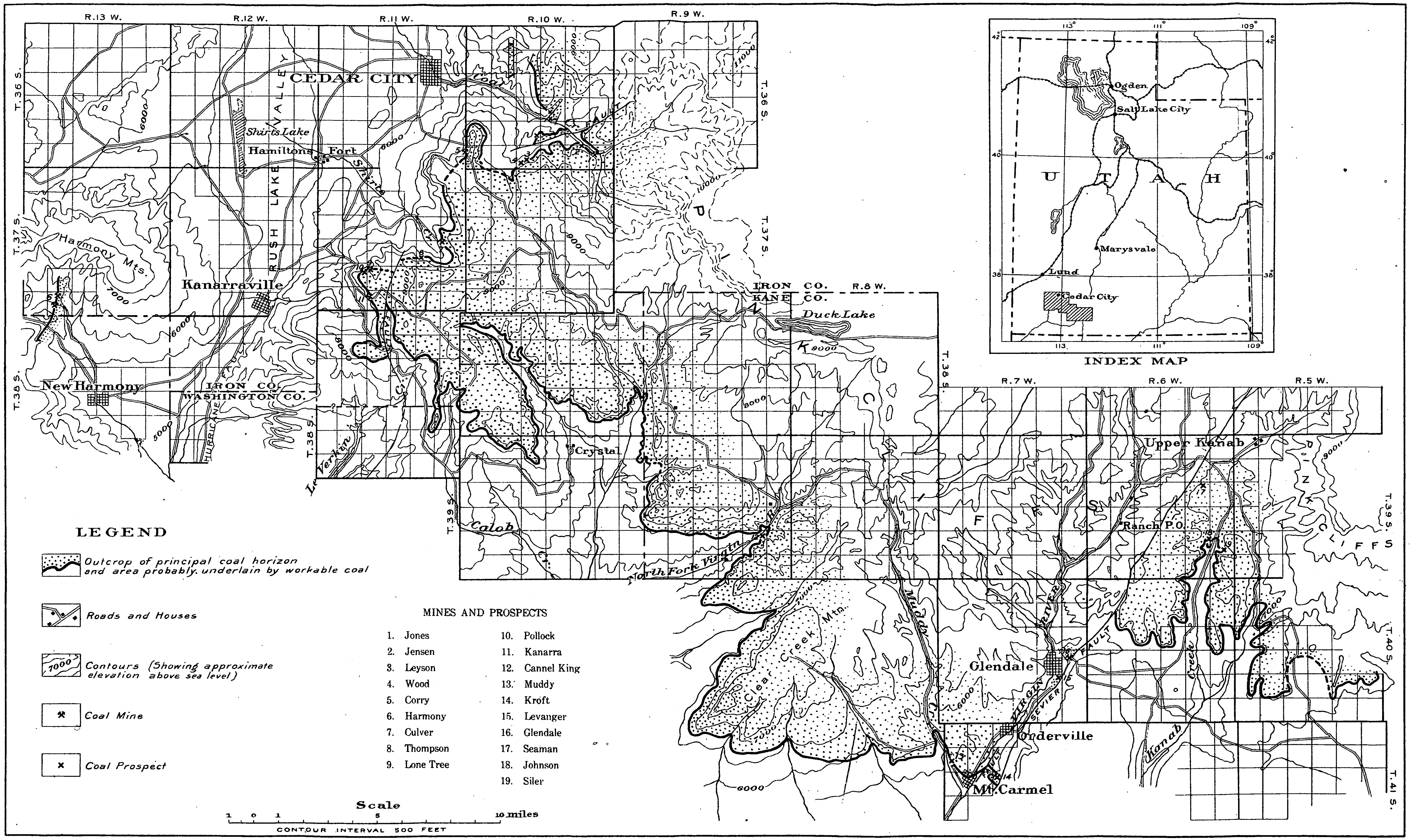
[b] Dutton, C. E., Geology of the High Plateaus of Utah, 1880, p. 155. Forrester, R., Coal fields of Utah: Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 519. Stanton, T. W., The Colorado formation: Bull. U. S. Geol. Survey No. 106, 1893, pp. 34-37. Storrs, L. S., Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, pp. 455-456.

[c] Lee, W. T., The Iron County coal field, Utah: Bull. U. S. Geol. Survey No. 316, 1907, pp. 359-375.

and western Kane County, and extends from the vicinity of Rush Lake Valley on the west to the Kanab Creek valley on the east. The west end of the region lies at the border of the Basin Range and Plateau provinces, but with the exception of the small Harmony field, the entire coal area is situated in the Plateau Province. The surface of the country ranges in elevation from 5,000 to 11,000 feet above sea level, the general altitude of the country decreasing southward by a series of benches which descend step like from the top of the highest plateaus. In the area under consideration the prominent escarpment known as the Pink Cliffs separates the crest of the High Plateaus, here known as the Markagunt and Paunsagunt, from the next lower bench; and another escarpment, less conspicuous, marks off this from the succeeding platform, the Colob Plateau, which is terminated by the bold escarpment known as White Cliffs. In the western part of the region, toward the border of the plateaus, the White Cliffs fade away and the plateau that is underlain by coal-bearing rocks rises directly above Rush Lake Valley. West of Rush Lake Valley the Harmony Mountains, outliers of the Pine Valley Mountains, form the limit of the area under consideration.

The extreme western portion of the region drains into the Great Basin and has no outlet to the sea; but the larger part is drained by the headwaters of the Virgin River and by Kanab Creek, both of which are tributary to the Colorado. These streams occupy deep valleys, some of them flowing in canyons more than a thousand feet deep, and the region is characterized by some of the grandest scenery on the continent. A large part of the region, consequently, is difficult of access, and much of it is unsuited for settlement; but the relatively broad and low valleys in the eastern and western extremities of the area examined in 1907 are occupied by prosperous towns. Intensive farming is successfully practiced in the valleys, and parts of the Colob Plateau are used as a summer range for sheep and cattle. Snow remains until summer on the highlands, which consequently are well watered and support a forest growth of pine, fir, aspen, cottonwood, etc., so that there is a good supply of timber for mine purposes.

Cedar City, Kanarraville, and New Harmony are situated in or near Rush Lake Valley. Cedar City, with a population of about 1,000, is the largest town in the region and is 33 miles distant from Lund, the nearest station on the San Pedro, Los Angeles and Salt Lake Railroad. Near the east end of the area are the towns of Mount Carmel, Orderville, and Glendale, situated in Long Valley at the head of Virgin River, and Upper Kanab, at the head of Kanab Creek. These towns are most conveniently reached from Marysvale, about 90 miles north of Glendale, at the terminus of the San Pete and Sevier branch of the Rio Grande Western Railway. (See Pl. XXV.)



ANDREW B. GRAHAM CO. PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

MAP OF THE HARMONY, COLOB, AND KANAB COAL FIELDS, UTAH

By G. B. Richardson and Leon J. Pepperberg

GEOLOGY.

GENERAL OUTLINE.

A large part of the High Plateaus of Utah is composed of an igneous complex consisting of lava sheets, beds of tuff and volcanic conglomerate, and intrusive masses of various types. These rocks in general overlie an eroded surface of Eocene strata which outcrop at lower elevations around the igneous uplands. Beneath the Tertiary rocks there are several thousand feet of practically horizontal Mesozoic and Paleozoic strata which outcrop at successive lower elevations in a series of benches that extend southward from the High Plateaus to the platform in which Colorado River has cut the Grand Canyon. The Markagunt and Paunsagunt plateaus are underlain by Eocene beds, the southernmost extent of which is marked by their outcrop in the Pink Cliffs. The next succeeding bench is underlain by Cretaceous strata; rocks of Jurassic age underlie the Colob Plateau; and older rocks down to the Carboniferous are exposed along the western base of the plateau. Coal occurs in the lower part of the Cretaceous system and is of Colorado age.

STRATIGRAPHY.

In the southern Utah coal region the rocks are chiefly sedimentary, ranging in age from Carboniferous to Eocene. There are also local intrusive masses and lava flows. As is general throughout the Rocky Mountain province, the coal-bearing rocks are of Cretaceous age, and in the present preliminary report it will suffice to limit the description to the coal measures and to the immediately overlying and underlying formations, which are outlined in the following table:

Outline of coal-bearing and associated rocks in the southern Utah coal region.

System.	Series.	Formation.	Character.	Thickness in feet.
Tertiary	Eocene	Wasatch	Varicolored shale, limestone, sandstone, and conglomerate.	500+
		Unconformity.		
Cretaceous	Upper Cretaceous	Montana (?)	Buff sandstone and drab shale.	500±
		Colorado	Buff sandstone and drab shale, including workable beds of coal in the lower part.	2,500±
		Unconformity.		
Jurassic			Varicolored shale and sandstone, with lenses of limestone and gypsum overlying massive marine limestone.	800±

The coal-bearing strata are underlain by about 800 feet of generally soft rocks, which outcrop in a lowland belt below the Cretaceous platform. These lower rocks are composed of reddish and varicolored shale and thin-bedded sandstone, with intercalated beds and lenses of gray limestone and white gypsum, and about 400 feet of massive gray limestone at the base. Marine Jurassic fossils occur abundantly in the lower limestone, but no remains of life have yet been found in the upper strata. The lithology and stratigraphic relations of these upper rocks suggest, however, their equivalence to the fresh-water Jurassic beds (Morrison) that are well developed in other parts of the Rocky Mountain region. These rocks are delimited above by an erosional unconformity, marked by the varying thickness of the Jurassic and by a basal Cretaceous conglomerate.

Throughout the Plateau Province Lower Cretaceous time is unrepresented by rocks, and Upper Cretaceous strata lie directly upon beds of Jurassic age. In the area under consideration the Upper Cretaceous rocks consist of about 3,000 feet of buff sandstone and drab shale, in the lower part of which coal beds of workable thickness occur. No Dakota fossils have been found in this area, although possibly the thin bed of conglomerate at the base of the Cretaceous is of that age. The greater part of the Cretaceous rocks, including the coal, are assigned to the Colorado, but the upper few hundred feet contains fresh-water shells and plants of undetermined age, which may possibly belong to the Montana. The succession of Cretaceous strata in the southern Utah region is unlike that in western Colorado and northeastern Utah, so that the formation names used in the coal fields of those areas can not be applied to the rocks in the area under consideration. The coal in southern Utah is older than that in the Uinta Basin region, which includes the Book Cliffs field, the largest and most important in the State. The southern Utah coal belongs to the same group as that in the Weber River field.

The Cretaceous rocks are unconformably overlain by Eocene strata, which, as already stated, outcrop in the Pink Cliffs and underlie the Markagunt and Paunsagunt plateaus. The unconformity, marked by a basal conglomerate containing pebbles of the underlying rocks, is emphasized by the absence of the upper members of the Cretaceous system, which are well developed in other parts of the Plateau province. The Eocene rocks consist of a variable succession of shale, limestone, sandstone, and conglomerate that are characteristically varicolored. Shades of red and white predominate and are beautifully developed in the Pink Cliffs. Fossils are extremely rare in these rocks, and only a few fragments of *Vivipara* and *Unio* have been obtained in this area; but the characteristic peculiarities of stratigraphy and coloring of the rocks leave little room for doubt that, except possibly a few feet of basal beds containing conglomerate of doubtful significance, they belong to the Wasatch formation of the Eocene series, which is so largely developed in the High Plateaus of Utah and from which characteristic fossils have been obtained in a number of places.

Igneous rocks cover a large part of the surface of the High Plateaus north of the coal fields, but in the area under consideration they are comparatively rare. The common type is basalt, which occurs in lava flows on an eroded surface of the sedimentary rocks from those of Eocene age downward. Over most of the area these igneous rocks apparently have had no effect on the coal, but in the Harmony field an intrusive mass of andesite has accomplished considerable metamorphism.

STRUCTURE.

Throughout the greater part of the area included in the present report the rocks dip between 1° and 2° NE.; but along the western margin of the Plateau Province the structure is complex and the strata are steeply tilted, and north of New Harmony the coal measures adjacent to a mass of intrusive igneous rock dip eastward at high angles. The continuity of the strata is interrupted by a number of normal faults of large displacement. One of these, the Hurricane fault, extends along the western border of the plateau and has been traced southward as far as the Grand Canyon in Arizona. In consequence of this fault the coal in the Colob field occurs about 2,000 feet higher than that in the Harmony field. Several displacements, in general parallel to the Hurricane fault, occur east of it, and in the vicinity of Cedar City especially the rocks are much disturbed. Another important fault is the Sevier, which extends along the upper valley of Virgin River east of Orderville and Glendale. This displacement has been traced for many miles, both north and south, beyond the limits of the area represented by the map (Pl. XXV). Within the region here discussed the throw of the Sevier fault amounts to about 2,000 feet, the downthrow, as is common throughout the plateau region, being on the west. This fault causes a lateral offset of the coal outcrop of 9 miles, extending from the vicinity of Mount Carmel to a point north of Glendale.

THE COAL.

OUTLINE OF OCCURRENCE.

Coal occurs throughout the area examined in the lower part of the Cretaceous system between 50 and 500 feet above the top of the Jurassic rocks. In general, in any one section only one bed of workable coal has been found, but in places six are present. The beds of coal thicken and thin out like lenses, and no single bed has been found to be continuous for more than a few miles. In the absence of prospecting, however, many facts relating to the occurrence of the coal are unknown. It is estimated, on the assumption that the workable limit of the coal is 4 miles back from the outcrop, that there are 295 square miles of coal land in the area examined in 1907.

If the entire thickness of coal may be represented by a single bed 8 feet thick, the total amount in this area is 2,672,803,840 short tons.

The present development of the western part of the southern Utah coal region is limited to the few small mines and prospects shown on the map. The mines are worked only during the fall and winter months, to supply the local demand, and the entire output is only a few hundred tons a year. When a railroad enters the field, this coal may compete with others in the southern California market, with the advantage of being the nearest of the Rocky Mountain fields.

That part of the southern Utah coal region with which the present report is concerned is divided into the Harmony, Colob, and Kanab fields, which are distinctly separated topographically.

HARMONY FIELD.

The Harmony coal field is the best known though smallest in the southern Utah region. The coal outcrop is only about 3 miles long, and the field has been prospected by a number of pits, tunnels, and shafts.

LOCATION.

The Harmony field lies partly in Iron County and partly in Washington County, in secs. 29 and 32, T. 37 S., R. 13 W., and in unsurveyed land in the adjoining township to the south. This area is a hilly country between the Pine Valley Mountains on the southwest and the Harmony Mountains on the northeast, and is drained by branches of Harmony Creek. The coal in the Harmony field is as accessible as any other in the entire region and is much more easily reached than the coal in the greater part of the region. The principal prospects are situated 4 miles northwest of New Harmony, at an elevation of about 6,000 feet, and are reached by a wagon road up Pace Creek. New Harmony is connected with Cedar City, 20 miles to the northeast, by a good wagon road across a broad wash-covered area.

OCCURRENCE AND THICKNESS OF COAL.

The coal in the Harmony field occurs in a narrow belt of Cretaceous strata which outcrop along the eastern base of a low range of hills composed of andesite. The coal-bearing rocks contain abundant fossils of Colorado age and are correlated with the coal measures on the Colob Plateau, but neither the fossils nor the rocks are sufficiently distinctive to determine the exact horizon that is here represented as compared with the section on the plateau. Only about 600 feet of Cretaceous rocks, consisting of alternating layers of drab shale, buff sandstone, lenses of gray limestone, and several beds of coal, are exposed in the Harmony field. These rocks are unconformably overlain by Eocene rocks and they are delimited below by an intrusive mass of andesite which has tilted the strata and metamorphosed the coal.

The rocks adjacent to the andesite and extending eastward from it for about half a mile dip to the east at angles ranging from 45° to 80°. East of this steeply tilted zone the dips become less, and in the Harmony Mountains the strata lie almost flat. In the valley of Pace Creek, where the change in dip occurs, the relations are concealed by abundant vegetation and by accumulations of rock débris, but a few exposures show disturbed conditions, and it is probable that faulting has occurred. Whether the coal continues but little disturbed east of the Pace Creek valley or has been cut off by a considerable fault can best be determined by drilling.

The following section of coal-bearing rocks in the Harmony field was measured during the past summer:

Section of coal-bearing rocks in the Harmony field, Utah.

	Feet.
Shale, buff	65
Sandstone, buff	4
Shale, buff	50
Coal and shale (No. 1)	7
Shale, drab	36
Coal and shale (No. 2)	11
Sandstone, buff	1
Covered (shale?)	30
Shale, drab	8
Coal and shale (No. 3)	6
Shale, drab	10
Covered (shale?)	25
Limestone, fossiliferous	5
Coal and shale (No. 4)	11
Sandstone, buff	2
Shale, drab	25
Sandstone, buff	3
Covered (shale?)	35
Shale, drab	18
Sandstone, buff	5
Shale, drab	18
Covered (shale?)	25
Sandstone, buff	10
Shale, drab	16
Coal and shale (No. 5)	17
Limestone, gray	5
Sandstone, buff	3
Shale, carbonaceous	10
Coal and shale (No. 6)	6
Shale, drab	15
Sandstone	8
Shale, carbonaceous	20
Concealed	50
Intrusive andesite.	
	560

R. A. Kirker, who has spent several years in prospecting this field, numbers the coal beds from 1 to 6, the latter being at the base of the section, and states that the coal ranges from 4 to 7 feet in thickness, as follows:

Thickness of coal beds in the Harmony field, Utah.

[Measured by R. A. Kirker.]

	Ft.	in
Bed 1	4	
Bed 2	5	
Bed 3	4	8
Bed 4	4	4
Bed 5	7	
Bed 6	4	

The measurements for beds 3 and 4 were confirmed by the writer, but the conditions of the workings were such that the other beds could not be measured with accuracy.

The steep dip of the coal-bearing rocks and the close proximity of the ground-water level to the surface will cause trouble in developing this field, but apparently the chief drawback is the dirty condition of the coal, as shown by the large amount of ash in the analyses. Although considerable prospecting has been done in the Harmony field, active mining has not yet begun. It is reported, however, that a Los Angeles company plans soon to develop the property.

QUALITY OF THE COAL.

The coal in the Harmony field has been metamorphosed by the intrusion of a large mass of andesite into the coal-bearing rocks. The andesite occupies an area of many square miles west of the coal field, and its intrusion has steeply tilted the strata adjacent to the contact, as already mentioned. In the SW. ¼ sec. 32, T. 37 S., R. 13 W., the intrusive rock is in close proximity to the coal, but the actual contact was not seen nor was any evidence obtained that the coal has been coked. In other places the outcrop of the andesite is several hundred feet distant from the nearest coal bed. The analyses show that considerable alteration of the coal has occurred, and, as would be expected, that the beds which are farthest away from the andesite are the least altered. Unless the intrusive rock extends eastward beneath the surface, it is probable that the higher grades do not extend far from the outcrop.

The coal in the Harmony field is deep black in color and has a brilliant luster. It breaks both with a semiconchoidal and a cubical fracture, and is fairly hard, though it can be crushed in the hands. The coal is streaked with seams of bone and shale in intimate association, and, at least locally, much foreign matter is present. Films of iron pyrite occur, irregularly disseminated. The coal burns with but little smoke and with a faint blue flame.

The composition of coal from the Harmony field is shown by the analyses on page 388, made at the fuel-testing plant of the United States Geological Survey at Pittsburg, Pa., by uniform methods,[a] under the direction of N. W. Lord and F. M. Stanton.

The analysis of each sample is tabulated in two forms, showing the analysis of the sample as received and that of the air-dried sample. The two sets of figures show the composition of the same sample under different conditions, and the difference in the figures emphasizes the necessity of stating with each coal analysis exactly what it represents. The analysis of the "sample as received" shows the percentage of the several constituents in the coal, including the amount of water contained by the coal as mined. The analysis of the "air-dried sample" shows the percentage of the several constituents in the coal after it has been powdered and allowed to lose the moisture that evaporates on exposure in an oven heated to a temperature slightly above that of the laboratory until a constant weight results, the percentage of air-drying loss being shown in the table. For general purposes the figures for the air-dried sample are best for comparison with other analyses.

The analyses show an extremely high percentage of ash, ranging from 22.89 to 33.96 per cent in the air-dried samples. These high values are due to the intimate association of shale and foreign matter with the coal. Better results are obtained from picked samples. Three small samples selected by Mr. Kirker and analyzed by Herman Harms, State chemist of Utah, showed respectively 11.65, 12.61, and 13.83 per cent of ash, and two small lumps of coal from bed 6, chosen to show low ash values, were found to contain 8.90 and 9.46 per cent of ash by G. O. Spitler, of the United States Geological Survey. The amount of coal containing such relatively low proportions of ash has not been determined. If by washing or by other means the product of this field can be put on the market with a much lower percentage of ash than shown by the analyses on page 388, the Harmony coal will rank as a high-grade fuel. The high ash content is the cause of the low heating values, which range from 8,569 to 10,796 British thermal units, as shown in the table.

Bed 6, the one nearest the andesite, has a fuel ratio of 13.16, which on that basis classes the coal as an anthracite. The fuel ratios of beds 3 and 4 range from 5.88 to 3.39, which would class them from low-grade semianthracite to semibituminous coals. The high percentages of carbon (82.06 to 88.53) in the ultimate analyses calculated on an ash-free, moisture-free basis emphasize the metamorphosed condition of the Harmony coals.

[a] Prof. Paper U. S. Geol. Survey No. 48, 1906, pp. 174 et seq.

Analyses of coal samples from the Harmony coal field, southern Utah.

No. of coal bed	Bed 6.	Bed 4.	Bed 3 (picked sample).	Bed 3.
Laboratory No.	5311	5312	5310	5309
Sample as received:				
Prox. Moisture	8.21	7.02	9.50	8.29
Prox. Volatile matter	4.41	10.30	13.22	13.44
Prox. Fixed carbon	58.02	60.61	49.22	45.64
Prox. Ash	29.36	22.07	28.06	32.63
Ult. Sulphur	2.28	4.06	3.55	3.17
Ult. Hydrogen	2.98	3.32	3.44	3.55
Ult. Carbon	53.31	62.77	51.44	48.48
Ult. Nitrogen	.90	.92	.85	.85
Ult. Oxygen	11.17	6.86	12.66	11.32
Calories	4,949	5,782	4,922	4,575
British thermal units	8,908	10,408	8,860	8,235
Loss of moisture on air drying	5.20	3.60	5.70	3.90
Air-dried sample:				
Prox. Moisture	3.17	3.55	4.03	4.57
Prox. Volatile matter	4.65	10.69	14.02	13.99
Prox. Fixed carbon	61.21	62.87	52.19	47.49
Prox. Ash	30.97	22.89	29.76	33.95
Ult. Sulphur	2.41	4.21	3.76	3.30
Ult. Hydrogen	2.53	3.03	2.98	3.25
Ult. Carbon	56.23	65.12	54.55	50.45
Ult. Nitrogen	.95	.95	.90	.88
Ult. Oxygen	6.91	3.80	8.05	8.17
Calories	5,220	5,998	5,219	4,761
British thermal units	9,397	10,796	9,395	8,569

COLOB FIELD.

LOCATION.

The Colob coal field includes the coal on the bench immediately above the Colob Plateau. It extends from the vicinity of Cedar City and Kanarraville, at the west end of the plateau, southeastward to the Sevier fault in the vicinity of Glendale and Mount Carmel, in the upper Virgin Valley. The outcrop of the coal beds follows a tortuous course around the dissected margin of the plateau and throughout the larger part of the area occurs in the face of steep cliffs and is difficult of approach, but where the coal passes beneath the surface in the valleys of the larger streams it is more easily accessible. In the eastern part of the field, especially, and locally at the extreme west the coal can be conveniently reached. In the central part of the Colob field, however, the problem of transporting the coal from its outcrop in the face of cliffs across the dissected upland presents many difficulties.

OCCURRENCE AND THICKNESS OF COAL.

The coal in the Colob field occurs in the lower few hundred feet of the Cretaceous section in rocks of Colorado age. Several beds have been found at different horizons, but the field has been prospected in only a few places and much remains to be learned concerning the occurrence of the coal. The work of the last season demonstrated, however, that no bed can be traced continuously throughout the field, and that the coal occurs in beds of variable extent which are lenslike in their development. Coal has been found near the base of the Cretaceous rocks wherever sections have been made, and it is probable that the entire area marked on the map by stippling is underlain by one or more beds of coal. In prospecting it will be convenient to bear in mind that the coal occurs in the lower part of the buff and drab sandstone and shale series, usually within 200 feet of the underlying red and varicolored shales and gypsum.

The rocks on the Colob Plateau lie almost flat, dipping northeastward at an angle of only 1° or 2°. Along the margins of the field the rocks are traversed by normal faults of large displacement. The Sevier fault, at the east end, is of such magnitude that it causes a lateral displacement of the coal of about 9 miles, and forms the boundary between the Colob and Kanab fields.

The following measurements of the coal in the Colob field begin in the vicinity of Cedar City and proceed southeastward, following the crop around the field. (See Pl. XXV.) Several layers of thin-bedded, marly shale and limestone are associated with the coal, both above and below. They contain numerous small gasteropods, popularly known as screw shells, which serve as a guide in prospecting.

No successful coal mines have been located on the north side of Coal Creek, and apparently beds of workable thickness do not extend north of this stream. Two prospects near the mouth of Maple Creek, in sec. 22, T. 36 S., R. 10 W., show that the coal has many partings, and it is probably too "dirty" to be worked with profit. A section at the prospect on the west side of the creek is as follows:

Section at prospect in the SW. ¼ sec. 22, T. 36 S., R. 10 W.

	Ft.	in.
Limestone, fossiliferous.		
Coal		8
Shale		3
Coal	1	2
Bone		1
Coal		10
Shale		2
Coal		11
Shale		1
Coal		7
Shale		6
Coal	2	
Total coal	6	2

At the head of and south of Coal Creek, however, coal occurs in workable thickness, and a number of prospect pits and small mines have been opened to supply the demand for domestic coal in Cedar City.

The Jones mine (No. 1[a]) is situated in the NW. ¼ sec. 36, T. 36 S., R. 10 W., about 25 feet above Coal Creek and adjacent to a good wagon road. Like all the workings in this field, this mine consists of a tunnel driven in on the outcrop for 100 feet, more or less. The following section was measured in the mine:

Section of coal bed at Jones mine.

	Ft.	in.
Limestone, fossiliferous.		
Shale, carbonaceous	1	
Coal	1	8–12
Bone		1– 4
Coal	2	3–12
Shale, carbonaceous		3
Limestone, fossiliferous.		
Total coal	5±	

The Jensen mine (No. 2) is an abandoned drift about three-fourths of a mile northwest of the Jones property, in the NE. ¼ sec. 35, T. 36 S., R. 10 W. The workings were inaccessible in the summer of 1907, and the thickness of the coal was not determined.

A fault apparently causes an offset of the coal in secs. 27 and 28, as shown on the map, where the vertical displacement between two beds of coal, presumably the same, is indicated as about 700 feet. At a prospect in the downthrown block in the SE. ¼ sec. 28, T. 36 S., R. 10 W., the following section was measured:

Section of coal bed in prospect south of Coal Creek.

	Ft.	in.
Shale.		
Coal		6
Bone		4
Coal	3	
Bone	1	
Coal		10
Limestone, fossiliferous.		
Total coal and bone	5	8

A number of prospects have been opened on the coal in sec. 33, T. 36 S., R. 10 W. The abandoned Leyson mine (No. 3) is reported to have been the earliest opened in this field, and to have been worked between 1854 and 1890. Daggett[b] states that the bed in this mine is split by a clay parting into an upper bench 2 feet thick and a lower one 4 feet thick.

At the Wood prospect (No. 4), about half a mile to the south, the following section was measured by W. T. Lee:

[a] The numbers refer to location of mines and prospects on Pl. XXV.

[b] Daggett, E., Analyses and calorific values of some Utah coals: Mineral Resources U. S., U. S. Geol. Survey, 1883, p. 77.

Section of coal bed in Wood mine.

	Ft.	in.
Limestone, fossiliferous.		
Coal, bony	2	
Clay		5
Coal		10½
Shale, carbonaceous		1
Coal		6
Clay		3½
Coal	2	1
Clay		1
Coal	2	1
Limestone.		
Total coal	7	6½

These two mines are situated about 2,000 feet above Cedar City, and consequently are difficult of approach.

The Corry mine (No. 5) is situated on the west side of Mount Henry about 4 miles southeast of Cedar City, at an elevation of about 2,700 feet above the town, and is one of the main sources of supply. The following section was measured here:

Section of coal bed in Corry mine.

	Ft.	in.
Limestone, shaly, fossiliferous.		
Coal	3	3
Bone		9
Coal	2	4
Clay		6
Coal		10
Limestone, shaly, fossiliferous.		
Total coal and bone	7	2

South of the Corry mine the coal is covered by a mass of basaltic lava, but the bed outcrops again in the amphitheater at the head of Shirtz Creek. Several old prospect holes are situated there, but only one opening, the Culver mine (No. 7), is now accessible. The coal is about 10 miles distant from Cedar City and nearly 3,000 feet above it, and is reached by a steep road. The following section was measured in this mine:

Section of coal bed in Culver mine.

	Ft.	in.
Limestone, fossiliferous.		
Shale, carbonaceous		4
Coal	2	3
Bone		2
Coal	4	11
Clay		7
Coal		9
Limestone, fossiliferous.		
Total coal and bone	8	1

South of Shirtz Creek the coal outcrop is also covered by a sheet of lava, and where it next appears, east of Kanarraville, a fault probably divides the coal measures and causes an apparent repetition of the coal. The dislocation is suggested by the occurrence of two beds of coal with fossiliferous limestone above each, in secs. 8 and 10, T. 38 S., R. 11 W., but the actual existence of the fault has not been demonstrated. However, 5 miles farther south, at the end of the area mapped, a fault which causes an estimated displacement of 500 feet in the massive red sandstone and overlying Jurassic limestone is plainly visible, and the suspected fault in the coal measures appears to be the northward continuation of this displacement.

Several prospect pits and small mines have been opened on the plateau east of Kanarraville, where the coal is at an elevation of about 3,000 feet above the town. Two old mines, known as the Lone Tree (No. 9) and Pollock (No. 10), were caved in when visited in 1907. Daggett[a] reported in 1883 that 8 feet of coal was exposed in the Lone Tree mine, and 14 feet 3 inches in the Pollock mine. At present the Kanarra mine (No. 11) is the only one that is worked. This is located on the road from Kanarraville across the plateau, and consists of a drift about 200 feet long, with several rooms off the main entry which are now caved in. The following section was measured at the mouth of the entry:

Section of coal bed at Kanarra mine.

	Ft.	in.
Limestone, shaly, fossiliferous	4	
Shale, carbonaceous		2
Coal	8	9
Shale, carbonaceous		7
Sandstone, buff.		

Between the Kanarra mine and North Fork of the Virgin, an air-line distance of 18 miles and a distance along the outcrop of more than 40 miles, the coal is unprospected and very little is known regarding it. Throughout this distance the coal outcrops for the most part in the face of steep cliffs and is difficult of approach. Wherever sections were measured during the survey in 1907 one or more beds of coal were encountered, the indications being that the coal occurs in lenses which thicken and thin. No single bed could be recognized as such for any considerable distance.

The following measurements show general conditions:

Section of coal beds in sec. 8, T. 38 S., R. 11 W.

	Ft.	in.
Coal	4	
Covered	15	
Sandstone, massive, buff	35	
Sandstone, thin bedded	10	

[a] Op. cit., pp. 77-78.

	Ft.	in.
Shale, calcareous and carbonaceous	15	
Limestone, fossiliferous	6	
Coal	4	
Shale		4
Coal	1	6
Shale		4
Coal	3	8
Shale		4
Limestone, fossiliferous	1	4
Coal	1	6
Shale		4
Coal	1	
Shale.		
Total coal	15	8

Section of coal beds in sec. 13, T. 38 S., R. 11 W., at the head of Colob Creek.

	Ft.	in.
Shale, sandy.		
Limestone, thin bedded, fossiliferous		10
Coal	4	2
Shale, drab		½
Coal	1	5
Shale	1	3
Coal		1
Sandstone	10	
Total coal	5	8

Section of coal beds in sec. 14, T. 38 S., R. 11 W.

	Ft.	in.
Shale, carbonaceous	12	
Limestone, fossiliferous	1	
Coal	4	
Shale	2	2
Sandstone, buff	35	
Shale, sandy	6	
Sandstone, buff	12	
Shale, carbonaceous	10	
Limestone, fossiliferous	10	
Coal	1	6
Shale		3
Coal	4	11
Shale, carbonaceous		6
Sandstone, fossiliferous	2	6
Coal		11
Shale, carbonaceous	4	
Total coal	11	4

Section of coal bed in sec. 5, T. 39 S., R. 10 W.

	Ft.	in.
Limestone, fossiliferous.		
Coal	3	4
Shale, carbonaceous.		

Section of coal bed in sec. 7, T. 39 S., R. 9 W.

	Ft.	in.
Sandstone.		
Coal	1	2
Shale	1	
Sandstone, buff	30	
Covered (probably shale)	35	
Shale, carbonaceous	45	
Coal	6	2
Shale, drab	6	
Total coal	7	4

A bed of cannel coal has recently been found in the valley of North Fork of Virgin River, and in the fall of 1907 a prospect, known as the Cannel King (No. 12), was opened in sec. 26, T. 39 S., R. 9 W., where the following section was measured:

Section of coal bed in Cannel King prospect.

	Ft.	in.
Shale, carbonaceous, fossiliferous.		
Coal, bituminous	2	5
Coal, cannel	5	6
Shale, drab.		
Total coal	7	11

The cannel-coal bed occurs about 100 feet above the conglomerate at the base of the Cretaceous section, and 160 feet below a prominent bed of white sandstone which will serve as a guide in prospecting. As yet little work has been done here and the extent of the bed has not been determined. It has not been discovered in sections made several miles northwest and southeast of the Cannel King property, and it is probable that this coal is not of great extent.

In Orderville Gulch, north of Clear Creek Mountain, the following section was measured:

Section of coal beds in Orderville Gulch.

	Ft.	in.
Shale, carbonaceous	2	3
Coal, bituminous	5	4
Shale, carbonaceous	1	3
Coal, bituminous	4	7
Shale and sandstone	250	
Coal, bituminous	2	2
Coal, cannel	5	6
Shale, carbonaceous.		
Total coal	17	7

In Long Valley, at the east end of the Colob field, several openings have been made on the coal, which is conveniently located and easy of access. But the quality is inferior to that of the coal farther northwest, and locally the bed is disturbed by faults. The following sections were measured in this vicinity:

Section of coal-bearing rocks 2 miles southwest of Orderville.

	Ft.	in.
Shale, drab, fossiliferous.		
Coal and bone	5	
Shale, drab	2	
Coal	2	6
Shale, carbonaceous	5	
Sandstone, thin bedded	5	
Sandstone, massive	21	
Concealed (probably shale)	17	
Shale, carbonaceous	10	
Coal	1	3
Concealed (probably shale)	11	
Sandstone, massive	27	
Concealed (probably shale)	60	
Sandstone, white	50	
Shale, drab	11	
Coal and bone	10	
Shale, carbonaceous	5	
Clay	7	
Sandstone, massive	37	
Conglomerate, pebbles of quartzite and limestone (base of Cretaceous)	15	
Total coal and bone	18	9

At the Muddy prospect (No. 13), in sec. 7, T. 41 S., R. 7 W., a mile northwest of Mount Carmel, the following section was measured:

Section of coal bed at Muddy prospect.

	Ft.	in.
Sandstone	1	
Coal	2	2
Bone		7
Coal		7
Bone		2
Coal	3	5
Clay		2
Coal	1	5
Bone		7
Coal	1	11
Clay		3
Coal		10
Shale, carbonaceous.		
Total coal	10	4

At the Kroft mine (No. 14), in sec. 16, T. 41 S., R. 7 W., 2 miles south of Orderville, the following measurements were made:

Section of coal bed in Kroft mine.

	Ft.	in.
Shale, sandy, carbonaceous.		
Coal	4	2
Parting		4
Coal	3	4
Parting		½
Coal	1	8
Shale.		
Total coal	9	2

In the vicinity of Glendale coal occurs in the upper part of the rocks of Colorado age, and prospects have been opened northeast and southeast of the town, adjacent to the Sevier fault.

C. Levanger has opened a prospect (No. 15), in sec. 26, T. 40 S., R. 7 W., in which the following section was measured, the base of the coal not being exposed:

Section of coal bed in sec. 26, T. 40 S., R. 7 W.

	Ft.	in.
Shale.		
Coal	2	2
Bone		3
Coal	4	1
Total coal and bone	6	6

In the Glendale mine (No. 16), in sec. 24, T. 40 S., R. 7 W., one-half mile northeast of Glendale, the following section was measured:

Section of coal bed in Glendale mine.

	Ft.	in.
Shale, fossiliferous.		
Coal	3	2
Bone		3
Coal	4	
Shale, carbonaceous.		
Total coal	7	2

QUALITY OF THE COAL.

The Colob coals are deep black and have a shiny luster. They are slick and do not soil the hands like better grades of bituminous coal. Their fracture generally is irregular, with a tendency to split along bedding planes. Some of the coals have two well-developed planes of fracture at right angles, but fine prismatic cleavage is notably absent.

The composition of several samples of coal from the Colob field is shown in the following table. The samples were taken from the working faces of the mines and prospects and represent as fresh coal as could be obtained, but as the working faces are not far from the outcrop, and as active mining was not in progress when the samples were collected, they probably represent slightly weathered coal.

Analyses of coal samples from the Colob field, southern Utah.

Location	NW. ¼ sec. 36, T. 36 S., R. 10 W.	NW. ¼ sec. 31, T. 36 S., R. 10 W.	NW. ¼ sec. 24, T. 37 S., R. 11 W.	NW. ¼ sec. 33, T. 37 S., R. 11 W.	NW. ¼ sec. 16, T. 41 S., R. 7 W.	NW. ¼ sec. 24, T. 40 S., R. 7 W.	NE. ¼ sec. 26, T. 39 S., R. 9 W.	
Laboratory No	5304	5494	5305	5307	5314	5341	[a] 5306	[b] 5308
Sample as received:								
Prox. Moisture	10.35	4.93	14.19	12.56	16.59	20.56	15.74	7.35
Prox. Volatile matter	36.33	37.24	33.39	36.43	32.59	32.43	41.92	46.93
Prox. Fixed carbon	43.70	44.79	42.50	46.21	37.38	40.79	28.00	22.48
Prox./Ult. Ash	9.62	13.04	9.92	4.80	13.44	6.22	14.34	23.24
Ult. Sulphur	5.82	6.72	5.39	5.24	3.41	1.19	1.32	1.61
Ult. Hydrogen	5.13	5.11	5.20	5.67	5.39	6.08	6.11	6.18
Ult. Carbon	61.24	63.01	55.27	62.13	46.66	57.11	51.96	51.88
Ult. Nitrogen	.95	.93	.85	.93	.85	1.01	1.16	1.06
Ult. Oxygen	17.24	11.19	23.37	21.23	30.25	28.39	25.11	16.03
Calories	6,041	6,340	5,515	6,079	4,379	5,441	5,282	5,753
British thermal units	10,874	11,412	9,927	10,942	7,882	9,794	9,508	10,355
Loss of moisture on air drying	1.80	1.40	2.80	1.60	3.90	4.70	4.50	1.10
Air-dried sample:								
Prox. Moisture	8.71	3.58	11.72	11.14	13.20	16.64	11.77	6.32
Prox. Volatile matter	37.00	37.78	34.35	37.02	33.91	34.03	43.89	47.45
Prox. Fixed carbon	44.50	45.42	43.72	46.96	38.90	42.80	29.32	22.73
Prox./Ult. Ash	9.80	13.22	10.21	4.88	13.99	6.53	15.02	23.50
Ult. Sulphur	5.93	6.82	5.55	5.32	3.55	1.25	1.38	1.63
Ult. Hydrogen	5.02	5.02	5.03	5.58	5.16	5.83	5.87	6.13
Ult. Carbon	62.35	63.91	56.86	63.14	48.55	59.93	54.41	52.46
Ult. Nitrogen	.97	.94	.87	.94	.88	1.06	1.21	1.07
Ult. Oxygen	15.93	10.09	21.48	20.14	27.87	25.40	22.11	15.21
Calories	6,152	6,430	5,674	6,178	4,557	5,709	5,531	5,817
British thermal units	11,073	11,574	10,213	11,120	8,202	10,277	9,956	10,470

[a] Upper 2 feet. [b] Lower 3½ feet.

The coal contains considerable moisture, and in general a large amount of ash, though in some samples the ash is only medium; sulphur, too, is high, especially for coals of the Rocky Mountain region. The analyses show that in addition to carrying these impurities the coals are intrinsically of medium low grade, the change from the original vegetable matter from which the coal is derived having progressed only moderately in the process of transformation to pure carbon. Calculated on an ash-free and moisture-free basis, the carbon in the ultimate analyses ranges from 66 to 76 per cent. The carbon-hydrogen ratios of the air-dried samples, ranging from 12.42 to 9.40, and the heating values, which range from 8,202 to 11,120 British thermal units, also indicate that the coal is of medium to low grade. It should be noted that the samples from the western part of the field, east of Cedar City and Kanarraville, show better results than those from the eastern part, in the vicinity of Mount Carmel and Glendale. Judged from the analyses, therefore, the coal of the Colob field ranges from low-grade bituminous to subbituminous.

In view of its possible future use in reducing the iron ores in the Iron Springs district, which is only 10 miles northwest of Cedar City, the coking quality of this coal is an important consideration. The iron ore is still undeveloped, but so far as known it is the largest deposit west of Mississippi River, and sooner or later it will be mined. Unfortunately, no satisfactory coking tests have been made of the southern Utah coal, although it is reported that a number of years ago an inferior quality of coke was produced in the Coal Creek valley. Laboratory tests in a small crucible show that the Colob coals fuse to a slightly coherent mass in which grains of coal are distinctly visible, but only tests on a practical scale can determine whether commercial coke can be made from the southern Utah coal. The high sulphur content of the Colob coal renders it an undesirable metallurgical fuel.

The cannel coal is massive bedded, of a brownish-black color, and has a dull greasy luster. Its fracture is conchoidal and the coal also tends to break along bedding planes, although it is notably tough compared with the other coals. The analyses clearly show that the coal found in the valley of North Fork of Virgin River possesses the peculiar properties of cannel. The volatile matter is high, from one and one-half times to twice as great as the fixed carbon; and the hydrogen in the analyses of dry coal is more than 5 per cent, being practically double that in the other coal beds of the Colob Plateau. The characteristic peculiarity of cannel is due to the fact that its original ingredients are largely different from those composing most coals. Thin sections of this cannel coal have been examined by David White, of the United States Geological Survey, who reports as follows:

> The fuel contains very little in the way of vestiges of the cell structures of higher plants, being made up largely of russet and lemon-yellow, more or less lenticular, or globular, translucent bodies embedded in a brownish-black groundmass of somewhat flocculent aspect. Some of this translucent matter is probably resinous, while it is possible that some of the lemon-yellow substance, less in quantity, may be gelatinous, though that is not at all certain. On the whole, the microscopical composition of the coal is essentially that of a high-grade cannel.

The heating value of the cannel coal is low, 9,956 British thermal units in one specimen and 10,470 in the other, figured on an air-dried basis. These low figures, however, are largely due to the considerable amount of ash in the coals. The high content of volatile constituents makes cannel coal a valuable gas producer.

KANAB FIELD.

LOCATION.

The Kanab coal field is the eastern continuation of the Colob field, and is named from Kanab Creek. This field is bounded by the Sevier fault on the west, and extends northeastward toward Paria River, the present work ending at range 5 of the Land Office survey. The coal in the Kanab field in general is more accessible than in the Colob field; a number of roads cross the area, and the outcrop of the coal measures in most places is easily reached. But, on the other hand, this field is far distant from an immediately prospective market of any consequence.

OCCURRENCE AND THICKNESS OF COAL.

In the Kanab as in the Colob field, coal occurs in the lower part of the Cretaceous section, and the same buff sandstone-shale series, within a hundred feet or so above the basal Cretaceous conglomerate which overlies the Jurassic varicolored shale and gypsum, can be used as a guide in prospecting. In addition to the lower coal, another bed 4 feet 5 inches thick occurs several hundred feet higher, on which a prospect pit (No. 17) has been opened about 3 miles southwest of Upper Kanab.

The main coal horizon in many places can be easily traced by the dark streak caused by the outcrop along the hillsides, but very little prospecting has been done. Two openings have been made on the coal in the valley of Kanab Creek, about 5 miles south of Upper Kanab. At the old Siler prospect (No. 19), in sec. 25, T. 39 S., R. 6 W., the drift had caved in, but in the Johnson prospect (No. 18), about one-half mile to the northwest, the following section was measured:

Section of coal beds in Johnson prospect (No. 18).

	Ft.	in.
Shale, drab.		
Coal	1	6
Bone		3
Coal	1	
Bone		1
Coal		7
Limestone		3
Coal	3	11
Shale, carbonaceous.		
Total coal	7	

No other test pits were found in the Kanab field within the area studied in 1907. Apparently the coal thins out east of Kanab Creek, and there is an area of barren rocks that extends an indefinite distance beyond the limits of the region mapped (Pl. XXV), in which coal of workable thickness has not been found. The following section, measured near the east end of the area studied, shows the greatest thickness of coal found in that vicinity:

Section of coal beds in the NW. ¼ sec. 35, T. 40 S., R. 5 W.

	Ft.	in.
Shale, carbonaceous.		
Coal and bone	1	9
Shale, carbonaceous	3	
Coal	1	6
Shale, carbonaceous	2	3
Total coal and bone	3	3

QUALITY OF THE COAL.

Fresh samples from the Kanab field could not be obtained, and no analyses have been made of this coal. It resembles that from the eastern part of the Colob field, of which it is a continuation, and probably the analyses of the coal from Tps. 40 and 41 S., R. 7 W., indicate the general composition of the coal in the Kanab field. It should be noted, however, that the cover of the coal in a considerable part of the field, for 2 or 3 miles back from the outcrop, is generally slight—in many places less than 100 feet—and doubtless in such places, on account of weathering, the coal is of inferior quality.

THE ROGUE RIVER VALLEY COAL FIELD, OREGON.

By J. S. Diller.

LOCATION.

Coal occurs at numerous localities in the Rogue River valley of southwestern Oregon, between the Cascade Mountains on the east

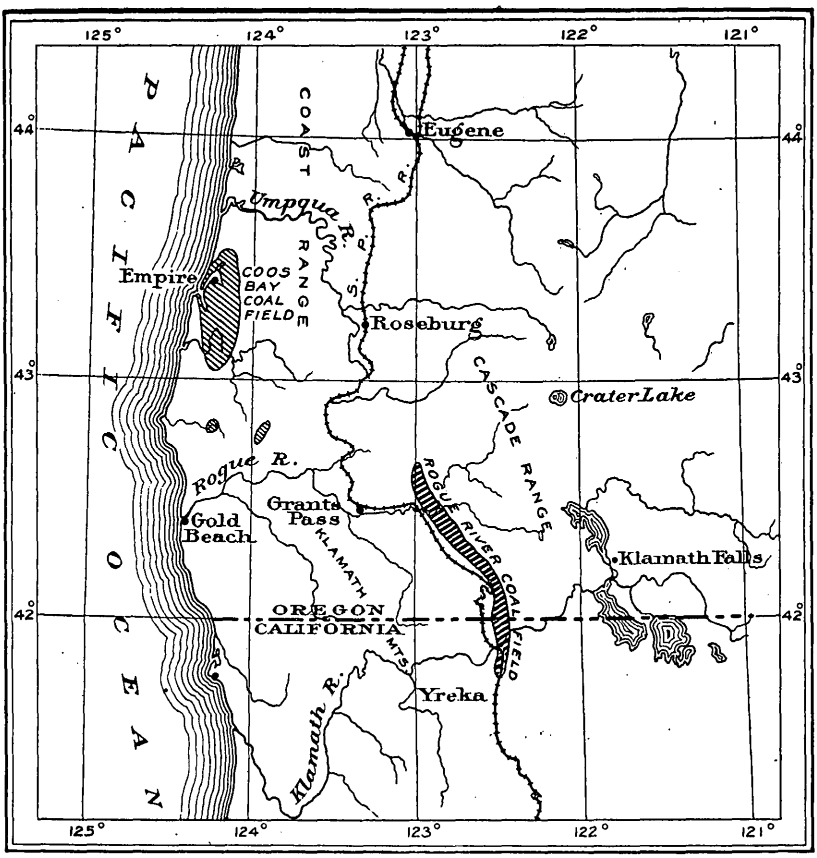


Fig. 6.—Map of Rogue River valley and other coal fields of southwestern Oregon.

and the Klamath Mountains, locally called the Siskiyou Mountains, on the west. The long, narrow coal belt, as outlined in fig. 6, begins at the north on Evans Creek in T. 33 S., R. 2. W. of the Willamette principal meridian, stretches to the south and southeast in the Rogue River Valley east of Medford and Ashland, and continues through the Siskiyou Mountain divide into California, a total distance of nearly 100 miles.

STRUCTURE OF COAL BELT.

The Cascade Range, east of the coal belt, is made up mainly of Tertiary lavas; the Klamath Mountains, on the west, are composed of granular igneous rocks and a smaller proportion of pre-Cretaceous sediments.

The soft rocks in which the Rogue River valley has been cut are sandstones, shales, and conglomerates. They dip generally eastward, extending beneath the greater portion of the lava fields of the Cascade Range. The older sediments along the western border of the valley, by Bear Creek from the Toll House to Ashland, Phoenix, and Jacksonville, are Cretaceous in age and do not contain coal. The coal-bearing rocks lie east of Bear Creek as far north as Medford, but beyond that point they overlap the Cretaceous rocks and occupy the whole northern portion of the Rogue River valley.

THE COAL.

The principal prospects have been made near Medford and Ashland, but others occur on Evans Creek, to the north, and near Ager, in California, to the south.

PROSPECTS ON EVANS CREEK.

On Evans Creek the strata dip locally to the northwest, but at the time of examination the incline by which the coal was prospected was full of water, so that the available exposures were unsatisfactory. However, there appear to be 8 feet, if not more, of coal, some of which is of fair quality, but most of which is impure and shaly. The coal bed has, besides a number of small clay partings, two prominent partings of sandstone, one 12 inches and the other 6 inches thick. The shaly coal has been sheared so that much of it is slickensided and goes to pieces on exposure. The immediate vicinity does not show a large body of coal above drainage level. The coal at this point appears to lie within a few hundred feet of the base of the coal-bearing rocks.

Coal is reported from the meadows on Evans Creek and also from Table Mountain on Rogue River, but as there was no active prospecting at either locality they were not specially examined.

COAL NEAR MEDFORD.

The coal 6 miles east of Medford lies along the foot of the steeper slope, which rises from the edge of the valley, 600 feet above the town, to the bold front of the Cascade Range. Some years ago the Southern Pacific Company prospected a coal bed at this point, and the size of the dump indicates that the trial drift must have been about 100 feet in length. Since then R. P. Little has discovered a number of other coal beds a short distance farther up on the same hillside and opened two of them by slopes, tunnels, and drifts aggregating nearly 900 feet in length. Drainage is effected by a lateral tunnel into an adjacent ravine. Considerable coal has been hauled to Medford and sold at $8 per ton.

The principal bed prospected is about 12 feet thick, and the striking feature at the entrance of the gentle slope is the large number of clay and sand partings with very little coal between them. The partings weathering whitish are strongly contrasted with the darker bands. As the slope is descended along the bed there appears a decided increase in the quantity and improvement in the quality of the coal toward the northeast. The bands of black lustrous coal, generally not over 6 to 8 inches thick, locally swell to more than a foot and furnish the source of supply for the local demand. The intermediate shaly coal and coaly shale is abundant and requires much picking to obtain satisfactory results. Several faults striking N. 40° E. and dipping 26° to 42° SE. have been encountered in the tunnels. The direction of movement and the amount of displacement could not be definitely determined. No lavas were seen in the mine, but they appear higher up, overlying the whole succession of coal beds. The decided improvement in the coal down the dip suggested that as the most favorable direction in which to prospect.

Since the examination on which the foregoing statement is based was made the Pacific Coal Company has purchased this mine and has developed the openings to the northeast along the dip of the coal bed for more than 1,000 feet. The prediction that the coal would be found of better quality and in larger quantity has been confirmed. A few small faults have been encountered, but these are all of the normal type and easily overcome. The mine is now producing coal and supplies the local market. The development of this mine has greatly stimulated prospecting in other parts of the field.

J. A. Holmes, of the Geological Survey, collected a sample of coal at this locality last summer and has kindly furnished the following results of an analysis made in the laboratory of the Survey fuel-testing plant:

Analysis of sample of coal obtained near Medford, Oreg.

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

	As received.	Air dried.
Laboratory No	5346.	5346.
Loss of moisture on air drying	....	2.00
Moisture	11.30	9.49
Volatile matter	23.39	23.87
Fixed carbon	31.89	32.54
Ash	33.42	34.10
Sulphur	1.16	1.18
Calories	4,183	4,268
British thermal units	7,529	7,683

The sample taken is a complete section of the coal bed exposed and represents what has to be removed in working the coal. It contains not only the good coal, but all the shaly partings. The high percentage of ash indicates that the bed contains much that would have to be thrown away in mining. The ash is about four times as great as that of the bed mined at Libby, in the Coos Bay region.

In prospecting the region systematically the entire coal-bearing series should be drilled from top to bottom to determine the number, position, and relative value of the beds, and then they should be worked at the top first. If the lower beds are worked out first, those next above may be rendered unworkable by caving and thus lost.

It is not to be expected that the coal beds extend to a very great distance beneath the Cascade Range before being disturbed by the rising lavas of the range, but it may well be that they continue far enough to give a considerable body of coal of various grades that will supply for the present, in some measure, local demands for fuel and that will in the future, when producers and gas engines are perfected, furnish an important source of power.

Several other prospects have been opened to the north and also to the south of those of Mr. Little, but nowhere are the works extensive enough to show continuity of the beds.

COAL NEAR ASHLAND.

Four miles north of Ashland several coal beds have been faced up in short slopes by D. P. Greninger. A striking feature of this coal, as of that near Medford, is the decided increase in the amount and improvement in the quality of the coal to the northeast, but the workings are not extensive enough to afford a fair opportunity of estimating their value. Neither lavas nor faults were encountered here. The beds are not so large as those farther north. They have furnished a few tons of coal for the local market.

Greater activity is shown 4 miles east of Ashland, near the "Gillett Lithia Springs," where the Ashland Coal Company has run slopes into two coal beds, the upper 12 feet and the lower 5½ feet thick, separated by 50 feet of slippery shale and shaly sandstone. The coal beds are made up of streaks of good coal locally 6 inches thick and separated by coaly shale. The coal breaks out in blocks and contains a considerable percentage of sulphur. The disturbing features at this prospect are irregular masses of old lavas, which appear not only in all the entries, but at various levels on the surface and in bluffs near by along the creek. Where the coal is in contact with the lava the latter appears to be the older. The abundance and irregularity of these lava masses render the extent of the coal beds a matter of doubt.

COAL NEAR AGER, CAL.

As already stated, the coal belt extends south through the Siskiyou Mountains into California, where several coal beds have been reported near Ager and one of them prospected to a considerable depth on an incline of 45°.

SUMMARY.

Although coal beds have been prospected, as noted above, at six localities between Evans Creek and Ashland, a distance of 40 miles, the evidence thus far available does not indicate the continuity of the same coal beds throughout that distance, but rather the development of small beds a few miles in greatest extent parallel to the coal belt and to the old shore line along which the vegetation accumulated in swamps to form coal. The swamps lay at the base of the Klamath Mountains when the coal-bearing beds were deposited over the low flats and the shallow body of water extending to the northeast.

The most impressive feature at all the localities examined is the improvement in the coal toward the northeast, down the dip of the coal beds into the hill. This is not simply a matter of weathering, but a decided increase in the amount of coal present and a decrease in the amount of fine sediment washed into the original swamp where the vegetal matter was accumulating. The farther northeast in the swamp the deposits lie, the farther from the source of the wash from the slopes of the Klamath Mountains and to a certain extent the thicker and purer the coal.

The age of the coal-bearing rocks of the Rogue River valley is not yet fully determined. They contain numerous fossil leaves which are now regarded by Doctor Knowlton as Eocene, although the latest collections from that region have not yet been studied. It is probable, however, that they are Eocene and of approximately the same age as the coal of Coos Bay.

For the present the coal beds from Ager to Evans Creek are only of local interest as a source of fuel, but detailed examinations in the future may show these coals to be more extensive than they are now supposed. If so, they may become, with the improvement of gas producers, important sources of power.

A COAL PROSPECT ON WILLOW CREEK, MORROW COUNTY, OREGON.

By W. C. Mendenhall.

The coal prospect here described is on Willow Creek, about 22 miles above Heppner, the county seat of Morrow County, Oreg., in a rather mountainous region just west of the divide between the Willow Creek and the John Day River drainage. The coal property is in secs. 33, 34, 35, and 36, T. 4 S., R. 28 E. Willow Creek, a tributary of Columbia River, flows through a canyon from its source to its mouth, but this canyon deepens toward the head of the stream because the general level of the surrounding country is higher in this direction. The elevation of the bed of the creek in the vicinity of the coal prospect is about 4,400 or 4,500 feet above sea level. That of the highest summits near by is perhaps 7,000 feet.

The walls of the lower portion of Willow Creek canyon reveal sections of basalts exclusively. These rocks underlie the central portion of the Columbia River valley, and are probably to be correlated with the Yakima basalt of central Washington. Eighteen or 20 miles above Heppner the geology changes abruptly and older, altered rocks, including basic plutonics and granitic and diabasic intrusives, appear in the canyon walls. These rocks clearly represent a part of the basement upon which the lavas were poured out and their abrupt appearance is probably to be explained by the presence of a sharp fault of perhaps a few thousand feet throw, with the uplift on the eastern side of the fracture. Just below the coal mines coarse feldspathic sandstone outcrops, overlying the older basement rocks and dipping in general 20° or 25° SE., the strike of the sedimentary beds being northeast and southwest with local variations in attitude. This belt of sediments is reported to have been explored for 15 or 20 miles along the strike and to extend, therefore, to the southwest across the divide into the John Day drainage basin. Overlying the sedimentary beds the basalts appear again, capping the neighboring ridges. The total thickness of the sedimentary section here was not measured, but by combining the apparent exposed section above the creek bed with the reported record of a diamond-drill hole 602 feet deep, bored in the vicinity of the prospects, the conclusion is reached that the sedimentary rocks are probably less than 2,000 feet thick. The beds exposed in the neighborhood of the coal mines are sandstones of varying degrees of coarseness, but softer shale is reported higher up on the slopes. A few poor specimens of fossil plants were collected from the roof of one of the drifts and submitted to F. H. Knowlton for determination. He reports, in part, as follows:

> This material contains the following species:
>
> Monocotyledonous plant (unknown to me).
> Glypostrobus cf. G. europæus Heer.
> Quercus consimilis? Newberry.
> Populus sp.?
>
> I am uncertain about the age of this material, but from the presence of what appears to be *Quercus consimilis* I incline to regard it as * * * upper Clarno [upper Eocene].

The coal was discovered some years ago by Willard Herron, by following up float found in the creek bed. The property is now reported to be owned by D. A. Herron, C. A. Redfield, and George Conser jointly, and the statement is made that about $82,000 has been expended in exploitation and development. Five drifts have been carried into the sides of the canyon. No. 1 is only a few feet long, No. 2 about 50 feet, No. 3 about 150 feet, No. 4 about 380 feet, and No. 5, known as the "Conser tunnel," 290 feet. No. 4 is in the best condition for examination at present and is the only one explored at the time of the writer's visit, November 7, 1907. It has been driven into the west side of the canyon wall in a nearly westerly direction, following the local strike. Near its entrance the drift is timbered, and near the heading, which has been chambered out into rooms 15 or 20 feet long, 10 or 12 feet wide, and 8 or 10 feet high, some props have been placed. The immediate floor and roof of the coal bed are of that variety of black, homogeneous, nonfissile, and highly carbonaceous shale usually characterized as bone. These shale bands are only a few inches thick and above and below them appears the sandstone which makes up the major part of the inclosing formation. The sandstones, both above and below the coal, are rolling and irregular, so that the thickness of the coal is variable. The coal bed where measured is about 53 inches thick and consists of an intimate interbedding of bands and lenses of pure coal, apparently bituminous in its nature, with bands of bone similar to that forming the roof and floor. These materials are interbedded in such thin bands as to make it difficult to separate the coal from the bone commercially. Selected pieces of coal can be taken which would yield a low percentage of ash and would probably give high-grade tests, but such sampling would not yield practical results.

So far as known all the drifts are on one coal bed, but the 602-foot diamond-drill hole bored in the creek bed opposite the mouth of one of these drifts and starting perhaps 25 or 30 feet below its level is reported to have passed through six beds of coal. The thicknesses of the upper two, whose positions are not given in the section, are reported at 8 feet 4 inches and 7 feet 6 inches; the other four are very much thinner. No accurate idea could be gained of the quality of the coals passed through by the drill. No effort has been made thus far to sink shafts to these beds, so that it may be assumed that their quality was not sufficiently good to justify this expenditure.

The owners of the prospects report that selected samples of the coal have yielded from 51 to 71 per cent of fixed carbon by analysis; that the average moisture content is about 8 per cent, and that samples yielding as low as 5 per cent of ash have been analyzed. It is stated that a fair sample across the face of one of the drifts has yielded about 26 per cent of commercial coal, and that in other places the coal forms from 12 to 40 per cent of the total thickness of the bed.

It will be evident from the above account that the coals thus far revealed by developments are not usable in the ordinary commercial way because of their very high percentage of ash, due to the intimate intermingling of coal and bone. It is possible, however, that as they occur in a region remote from other sources of hydrocarbon fuels, they may prove to be suitable for use in producer-gas engines, when this means of developing power has become more general.

THE POCKET COAL DISTRICT, VIRGINIA, IN THE LITTLE BLACK MOUNTAIN COAL FIELD.

By Cassius A. Fisher.

INTRODUCTION.

During the early part of June, 1908, the writer made a brief examination of the coal deposits in the vicinity of Pennington Gap, Virginia. Considerable exploitation and development work has been done in this district during the last three years, and as a result a large amount of valuable information concerning the stratigraphic position and distribution of the various workable coal beds has been obtained. This information, which was kindly furnished by the persons interested, together with additional data collected during a brief examination of the area, is regarded as sufficient to warrant the present publication.

LOCATION AND EXTENT.

The Pocket coal district is located in Lee County, in the southwest corner of Virginia, between Cumberland and Little Black mountains, mainly on the southern slope of the latter. It constitutes a part of the Black Mountain coal field, which extends along the northwestern side of Cumberland Mountain throughout southwestern Virginia into eastern Kentucky. The name "Pocket" has been applied to this district owing to the fact that it is a topographic depression surrounded on three sides by high ridges. It is about 9 miles long and 4 to 5 miles wide, comprising about 40 square miles. It lies just north of Pennington Gap, Virginia, and is reached by a branch of the Louisville and Nashville Railroad from Pennington station and also by a branch of the Southern Railway from Appalachia. Above the junction at the upper end of the gap a line extends up Straight Creek, from which branches have been built up Baley Trace, Fawn Branch, and Gin Creek to the various coal mines. These lines are used jointly by the two railroad systems, and they extend to all the operations in the district. (See fig. 7.)

TOPOGRAPHY.

The district is one of hilly topography, with very little level land, being made up mainly of steep-sided, narrow-topped, irregular ridges that rise to the northwest, culminating in Little Black Mountain, which has an altitude of about 3,500 feet.[a] This ridge marks the State boundary line between Kentucky and Virginia. Along the southern border of the district Stone Mountain extends as a high, narrow ridge,

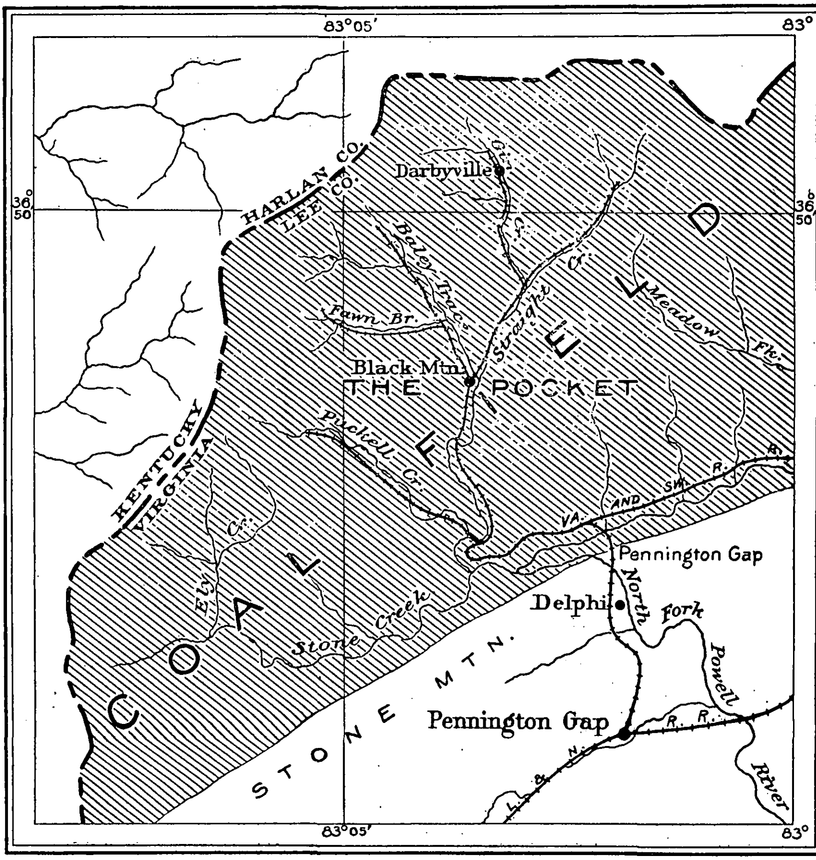


FIG. 7.—Sketch map of the Pocket coal district, Virginia, in the Little Black Mountain coal field.

rising about 1,200 feet above the river at Pennington Gap. The district is heavily wooded and thinly populated except along the narrow stream valleys.

DRAINAGE.

The principal stream of the district is Straight Creek, which rises high on the slope of Little Black Mountain and, flowing southward, empties into North Fork of Powell River, at the head of Pennington

[a] This altitude was taken from a reconnaissance topographic map which can be regarded only as approximate.

Gap. Its principal tributaries are Gin Creek, Baley Trace, Puckell Creek, and Stone Creek, all entering from the west. Fawn Branch and Ely Creek, tributaries of Baley Trace and Stone Creek, respectively, also drain small areas in the western part of the district. These are all vigorous mountain streams, carrying considerable water except in very dry seasons.

STRUCTURE.

The structure of the rocks in the Pocket coal district is comparatively simple. Throughout the greater part of the area the beds lie nearly horizontal, dipping gently northwestward. Along the base of Stone Mountain, however, they are sharply upturned, and this mountain is composed of vertical strata which produce sharp, knife-blade ridges. It is possible that the beds are more or less faulted along the northern side of Stone Mountain, where their dips change from a low angle to vertical within less than one-fourth of a mile. No definite evidence of a fault along this line, however, was observed in the field. Throughout the central part of the district, where the rocks are nearly horizontal, no faults were observed or reported.

GEOLOGIC OCCURRENCE OF COAL.

The rocks of the Pocket coal district all belong to the Pottsville group, of Pennsylvanian age. They have an estimated thickness of about 4,000 feet. The beds constituting the lower half of the section have not been subdivided into formations in this district. They consist mainly of sandstone and shale with many beds of coal distributed throughout. The beds of workable thickness, however, are confined largely to the upper half of the section.

During the present investigation information was obtained from representatives of the Black Mountain Coal Land Company, the principal owner of this part of the Little Black Mountain coal field, concerning the relative position of all the important workable coal beds with respect to a gray, coarse-grained sandstone occurring near the summit of Little Black Mountain, which is said to be the Harlan sandstone. This information, together with observations on the quality of the coal of the different beds, is here set forth.

There are twelve known workable coal beds in this district and two which may possibly be workable. They have a combined thickness of about 54 feet, and occur within a stratigraphic interval of about 2,090 feet. These beds are designated by numbers ranging from 1 to 12. Bed 1, the lowest in the series, occurs about 2,090 feet below the so-called Harlan sandstone, and bed 12, the highest, immediately beneath it. A generalized section, omitting all details and showing the relative positions of the various workable coal beds of this district, is given below:

Generalized section showing positions of coal beds in the Pocket district, Virginia.

	Feet.
Harlan sandstone (?), exposed	40
Coal bed 12	4½
Interval	60
Coal bed 11	3
Interval	300
Coal bed 10	6
Interval	40
Coal bed 9	4½
Interval	100
Coal bed 8	4
Interval	100
Coal, impure	4
Interval	100
Coal bed 7	3½
Interval	325
Coal bed 6	4½
Interval	275
Coal bed 5	3½
Interval	180
Coal bed 4	2½
Interval	180
Coal bed 3	3½
Interval	40
Coal bed 2 A	3
Interval	40
Coal bed 2	3
Interval	300
Coal bed 1	4½
	2, 134

DETAILED DESCRIPTION OF COAL BEDS.

General statement.—Only the coal beds of commercial importance occurring in the upper half of the Pottsville group were studied. A number of coal beds lower in the Pottsville, and also in the basal formation of that group, the Lee conglomerate, have been mined at country banks for years, but these are thin and they were not examined. According to reports, there are five or six of these beds, ranging in thickness from 2 to 3 feet.

The following notes give in ascending order a brief description of the stratigraphic position, thickness, and general characteristics of each of the more important workable coal beds in the Pocket coal district.

Bed 1.—About 2,090 feet below the base of what is believed to be the Harlan sandstone occurs a coal bed which is known locally as bed 1. This bed is said to range in thickness from 3½ to 6 feet, with an average of 4½ feet, and it is generally free from partings. It usually has a sandstone roof and floor, although in some localities a "draw slate" is present between the coal and overlying sandstone, which attains a maximum thickness of 7 feet. As this is the lowest workable bed in the series, it has a wider distribution than any other coal bed in the district. It outcrops in the bluffs on either side of Straight Creek, a short distance above its mouth, and is carried by the dips beneath the level of that stream some distance below Black Mountain station.

Bed 2.—About 300 feet above bed 1 is bed 2, which averages 3 feet in thickness. It is overlain by sandstone and underlain by shale and contains no partings of appreciable thickness. This coal bed outcrops on the west bank of Straight Creek, about one-fourth mile below Black Mountain station, where it passes beneath the level of the creek.

Bed 2 A.—Forty feet higher stratigraphically than bed 2 is another somewhat thicker coal bed, which has been designated bed 2 A. In some localities this coal bed is said to reach a thickness of 6 feet, but its normal thickness is about 3 feet. The bed generally consists of clean coal without partings, and has a sandstone roof and shale floor. It has been mined slightly at a country bank on the west side of Straight Creek, at Black Mountain station, where it occurs about 10 feet above the level of the valley.

Bed 3.—This coal bed occurs about 40 feet above coal bed 2 A, and nas a thickness of 3 feet 2 inches at the Virginia Lee Company's mine, one-fourth mile above Black Mountain station, on the west side of Baley Trace, where the bed is now worked. This thickness is slightly below the average. A 2-inch parting occurs about 1 foot above the base, and the coal is overlain by drab shale, which is said to afford an exceptionally strong roof. The floor is of clay. Bed 3 passes beneath the level of Baley Trace near the mouth of Fawn Branch.

Bed 4.—At about 180 feet above bed 3 is bed 4, which has a thickness of about 2½ feet. This attains workable thickness at a few places in this field. It is exposed on the west side of Baley Trace, above the mouth of Fawn Branch.

Bed 5.—This coal bed occurs about 180 feet above No. 4. It ranges in thickness from 3 to 4 feet and is clean and free from partings. It is overlain by sandstone and underlain by clay. At the head of Fawn Branch, where this bed is being opened at many places, a measurement of one of the beds opened by the Virginia Lee Company gives a thickness of 3 feet 7 inches, with no appreciable parting. Bed 5 is opened and mined at many places along Fawn Branch, Baley

Trace, Straight Creek, and Gin Creek, and is regarded by operators as one of the most valuable coal beds in the district. It is mined at Darbyville and consequently is known to some extent as the Darby bed. It is said to be the stratigraphic equivalent of the Taggart coal of the Big Stone Gap region.

Bed 6.—About 275 feet above bed 5 is bed 6, which at the head of Straight Creek, at the Virginia Iron, Coal and Coke Company's mine, has a thickness of 4 feet 4 inches, with a ½-inch parting 14 inches above the base. It is overlain by shale and underlain by clay. This coal was examined at the head of Straight Creek, where it outcrops at an elevation between 1,600 and 1,700 feet.

Bed 7.—Between beds 6 and 7 there is a stratigraphic interval of 325 feet. Coal bed 7 has an average thickness of 3½ feet, and is separated near the middle by a clay parting. It has a shale roof and floor. This coal outcrops relatively high in the slope of Little Black Mountain, and consequently has a smaller areal distribution than any of the beds described above. A section of this coal bed, measured in an opening on the left fork of Gin Creek, is as follows:

Section of coal bed 7 on left fork of Gin Creek.

	Ft.	in.
Shale, exposed	5	
Coal	2	5
Clay, light gray		7
Coal	1	9
Shale.		
Total coal	4	2

Bed 8.—About 200 feet above No. 7 occurs bed 8, which has a thickness of 4 feet. This bed was not examined. It occurs some distance up the slopes of Little Black Mountain, and consequently has a relatively limited distribution in the district, underlying only the higher portions of the mountain. At a horizon halfway between Nos. 7 and 8 there is a coal bed which attains workable dimensions in some places, but the bed as a whole contains so large a percentage of shale that it can not be worked.

Bed 9.—This bed occupies a position about 100 feet above No. 8. It has a thickness of nearly 5 feet and in some localities it contains a thin parting in the lower half. It has been opened at many places along the southern slope of Little Black Mountain, but is reported not to have been mined anywhere within the district. It was examined by the writer at the heads of Baley Trace and Gin Creek. The sections of the bed at these two openings, which are about 1½ miles apart, are very similar. The coal is overlain and underlain by shale. A section of the bed at the opening on Baley Trace is given on the next page.

Section of coal bed 9 at Wax opening, at the head of Baley Trace.

	Ft.	in.
Shale, sandy.		
Coal	3	6
Shale, carbonaceous		1½
Coal	1	1
Coal, impure		4
Total coal	4	11

Bed 10.—About 40 feet above bed 9 occurs bed 10, which is one of the thickest coal beds in the district. It has an average thickness of 6 feet, and contains a clay parting in the upper part, also a thin coaly shale layer about 2 feet above the base. The bed is usually overlain by sandstone and underlain by shale. It outcrops high in the slopes of Little Black Mountain, and covers but a small area within the district. Three sections of bed 10 were measured, two at the head of Baley Trace and one on the left fork of Gin Creek. The following sections are representative of the bed:

Section of coal bed 10 at the head of Baley Trace.

	Ft.	in.
Sandstone, gray	8	
Coal	1	7
Shale, coaly		1½
Coal		3½
Clay, light gray		8
Coal	2	6
Shale, coaly		1½
Coal	2	6
Total coal	6	10½

Section of coal bed 10 at the head of Gin Creek.

	Ft.	in.
Coal	1	
Clay		4
Coal	2	8
Shale, coaly		1
Coal	2	1
Total coal	5	9

Bed 11.—About 300 feet above bed 10 occurs bed 11. This coal bed was not examined, but it is reported to be 3 feet thick. It outcrops high on the mountain slope, being only 70 feet below the base of the Harlan sandstone, and underlies only the upper portion of Little Black Mountain.

Bed 12.—This is the highest workable bed known in the district. It occurs 60 feet above bed 11, immediately beneath a massive gray coarse-grained sandstone believed to be the Harlan sandstone. The bed has a thickness of 4 to 5 feet and consists of firm, massive coal. As it is the highest coal bed on the slopes of Little Black Mountain, it has the smallest distribution of all the beds within the district. It has been opened at a number of places, but, like all beds above No. 6, it has not been mined in the Pocket district. A section of this bed is given below:

Section of bed 12 at the head of the left fork of Gin Creek.

	Ft.	in.
Sandstone (Harlan?).		
Coal		6
Shale, carbonaceous		$4\frac{1}{2}$
Coal	4	
Clay.		
Total coal	4	6

CHARACTER OF COAL.

PHYSICAL PROPERTIES.

During the examination of the coal of this district special attention was given to a study of the physical properties, and a number of samples were collected for comparative study. The result of a systematic study shows that the coals of the different horizons, 14 in number, do not differ widely in physical properties, but, on the other hand, bear a regional resemblance to each other. Certain exceptions were noted, however, which will be described.

The coals of this district are usually of a pitch-black color, with a dark-brown streak and brown to black powder. They have a subdued vitreous luster, owing to the fact that they are composed of indistinct bands of bright and dull coal. The coal has a distinctly bedded structure, which on close examination is found to be laminated. It has cubic jointing or cleavage, the major joints occurring at intervals of about 4 inches and the minor at one-half inch. The coal breaks with an irregular fracture and is moderately brittle, although in some beds in the district it is tough. In no place was the coal observed to be crumbly. It has a metallic impact and is moderately heavy. The coal burns with a long, yellow flame, emitting a bituminous odor. In burning it leaves a relatively small amount of ash, which is reddish-yellow in color and moderately fine. There is very little sulphur or resin in the coal, but mineral charcoal is fairly abundant. These general statements concerning the physical properties of the coals of this district do not wholly apply to beds 7 and 12. The former contains coal which, although bedded, is decidedly more massive than the average coal of the district. It is also firmer and more resistant to breakage. On the whole, the coal of bed 7, from a physical point of view, is regarded by the writer as a superior variety. The coal of bed 12 is also a very firm, finely laminated coal, and in some respects resembles a splint coal. It breaks in large blocks and appears to resist weathering more successfully than some of the other coals.

CHEMICAL PROPERTIES.

In addition to the samples of coal obtained for a comparative study of physical properties, a number were collected in the uniform manner prescribed by the United States Geological Survey for chemical analysis. The result of these analyses is given in the following table:

Analyses of coal samples from the Pocket district, Virginia.[a]

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

No. of coal bed	5	9	10	12
Location	Baley Trace.	Gin Creek.	Left fork of Gin Creek.	
Laboratory No.	6236	6238	6237	6239
Sample as received:				
Prox. Moisture	3.42	4.44	5.31	5.49
Prox. Volatile matter	34.36	35.99	32.66	36.03
Prox. Fixed carbon	58.83	53.59	53.23	51.87
Prox. Ash	3.39	5.98	8.80	6.61
Ult. Sulphur	.58	.76	.75	1.24
Ult. Hydrogen	5.25	5.19	5.13	5.19
Ult. Carbon	77.98	71.95	70.39	71.47
Ult. Nitrogen	1.29	1.25	1.36	1.12
Ult. Oxygen	11.51	14.87	13.57	14.37
Calories	7,852	7,424	7,099	7,283
British thermal units	14,134	13,363	12,778	13,109
Loss of moisture on air-drying	1.40	2.10	3.10	3.10
Air-dried sample:				
Prox. Moisture	2.05	2.39	2.28	2.47
Prox. Volatile matter	34.85	36.76	33.71	37.18
Prox. Fixed carbon	59.66	54.74	54.93	53.53
Prox. Ash	3.44	6.11	9.08	6.82
Ult. Sulphur	.59	.77	.78	1.28
Ult. Hydrogen	5.16	5.07	4.94	5.00
Ult. Carbon	79.09	73.49	72.64	73.76
Ult. Nitrogen	1.31	1.28	1.40	1.16
Ult. Oxygen	10.41	13.28	11.16	11.98
Calories	7,964	7,582	7,326	7,516
British thermal units	14,334	13,650	13,187	13,528
Thickness of coal bed		*Ft. in.* 4 10	*Ft. in.* 5 10	*Ft. in.* 4 6

[a] As soon as taken these samples were placed in tightly fitting screw-top cans which were hermetically sealed six hours later.

COKING QUALITIES.

Although practical coking tests have not been made of all the coal beds in the Pocket coal district, it is believed by the writer that coke of average quality could be made from most of the workable beds. Samples of coke, apparently of excellent quality, that were seen in the field, were said to have been made of run-of-mine coal from beds 5 and 6, and also of mixed coal from these two beds. So far as could be ascertained no practical coking tests have been made of coals from other beds in the district, but the adhesion test described by Pishel[b] was applied to samples of coal from beds 3, 5, 6, 7, 9, 10, and 12 with fairly satisfactory results. This process, given briefly, is as follows:

Pulverize in an agate mortar a small quantity of the coal to be tested until it will pass through a 100-mesh sieve. Pour out the pulverized coal and observe the condition of the mortar and pestle. With some coals the mortar and pestle will be deeply

[b] Pishel, M. A., A practical test for coking coals: Econ. Geology, vol. 3, No. 4, June-July, 1908.

covered with a coating of coal dust, which adheres so strongly to the agate surface that it is removed with difficulty. With other coals there will be only a thin film of coal dust adhering to the mortar and pestle, while with still others both mortar and pestle will be nearly as clean after the coal is pulverized as they were before the operation began. * * * The degree of adhesion seems to coincide with the coking qualities of the coal. If it adheres strongly the coal will probably make excellent coke; if it adheres only slightly the coal possesses the coking qualities to only a slight extent, if at all; and if the mortar shows no coating of dust the coal is to be regarded as noncoking.

DEVELOPMENT.

Coal has been mined from small banks in this district for many years to supply a small local demand. The heavily forested condition of the region makes wood so cheap and easy to obtain that there was little incentive on the part of the native population to develop coal for domestic fuel. With the building of the Louisville and Nashville Railroad and other lines into this district increased interest was shown in the coal beds and considerable prospecting was done.

The following companies are operating or are preparing to operate in the near future: Virginia Lee Company, Dominion Coal Company, Black Mountain Mining Company, Lee Coal Company, Darby Coal and Coke Company, Bondurant Coal Company, Monarch Coal and Coke Company, Black Mountain Collieries Company, and Virginia Iron, Coal, and Coke Company.

CLASSIFIED LIST OF PAPERS DEALING WITH COAL, COKE, LIGNITE, AND PEAT CONTAINED IN PUBLICATIONS OF U. S. GEOLOGICAL SURVEY, EXCEPT THOSE ON ALASKA.[a]

Compiled by WILLIS T. LEE and JOHN M. NICKLES.

This list contains the more important papers published by the United States Geological Survey dealing with coal, coke, lignite, and peat, from an economic standpoint. The page references indicate whether a paper is devoted wholly or in part to these subjects.

Papers general in scope are given first; then those dealing with restricted areas are listed in chronologic order under the States arranged alphabetically.

STATISTICAL.

The reports on coal in the volumes of Mineral Resources of the United States contain, in addition to statistical matter, various other information. The statistics are given for the United States as a whole and for the States severally in alphabetic arrangement.

Mineral Resources of the United States. Albert Williams, jr. [For 1882–3], 1883: Coal, pp. 1–107. Calendar years 1883 and 1884, 1885: Coal, pp. 11–143; The manufacture of coke, by J. D. Weeks, pp. 144–213. Calendar year 1885, 1886: Coal, pp. 10–73; The manufacture of coke, by J. D. Weeks, pp. 74–129.

Mineral Resources of the United States. David T. Day. Calendar year 1886, 1887; Coal, by C. A. Ashburner, pp. 224–377; The manufacture of coke, by J. D. Weeks, pp. 378–438. Calendar year 1887, 1888: Coal, by C. A. Ashburner, pp. 168–382; The manufacture of coke, by J. D. Weeks, pp. 383–435. Calendar year 1888, 1890: Coal, by C. A. Ashburner, pp. 168–394; The manufacture of coke, by J. D. Weeks, pp. 395–441. Calendar years 1889 and 1890, 1892: Coal, by E. W. Parker, pp. 145–286. Calendar year 1891, 1893: Coal, by E. W. Parker, pp. 177–356; The manufacture of coke, by J. D. Weeks, pp. 357–402. Calendar year 1892, 1893: Coal, by E. W. Parker, pp. 263–550; The manufacture of coke, by J. D. Weeks, pp. 551–602. Calendar year 1893, 1894: Coal, by E. W. Parker, pp. 187–414; Manufacture of coke, by J. D. Weeks, pp. 415–460.

Mineral Resources of the United States, 1894, nonmetallic products. Sixteenth Ann. Rept., pt. 4, 1895: Coal, by E. W. Parker, pp. 1–217; Manufacture of coke, by J. D. Weeks, pp. 218–304; Origin, distribution, and commercial value of peat deposits, by N. S. Shaler, pp. 305–314.

Mineral Resources of the United States, 1895. Seventeenth Ann. Rept., pt. 3, 1896: Coal, by E. W. Parker, pp. 285–542; Coke, by J. D. Weeks, pp. 543–620.

[a] For publications on coal in Alaska, see Bulletin No. 335, 1908, pp. 130–133.

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