GEOLOGY AND COAL RESOURCES OF THE SIERRA BLANCA COAL FIELD, LINCOLN AND OTERO COUNTIES, NEW MEXICO.

By Carroll H. Wegemann.

INTRODUCTION.

OBJECT OF THE INVESTIGATION.

Coal in the vicinity of the Sierra Blanca, N. Mex., has for the last 20 years attracted the attention of mining men. The coal is of good quality and has been mined in considerable quantity, but the broken character of the beds and the great number of igneous dikes and sills which have been intruded into them are serious drawbacks to mining. The work here reported was undertaken as a detailed study of the White Oaks district and a rapid reconnaissance of the coal basin as a whole, with special reference to the relations of the beds mined and prospected at several localities, the quality of the coal, and the extent to which it has been injured by faulting, squeezing, and the intrusion of igneous material. The problem proved to be very complex, and the time which could be spared for the work was all too short. Much still remains to be done, but it is hoped that the results embodied in this brief report may be of value to the general reader and may form the basis of future more extended studies when these are undertaken.

LOCATION AND EXTENT OF THE SIERRA BLANCA COAL FIELD.

The Sierra Blanca coal field occupies an area 32 miles in length and 24 miles in width, extending from White Oaks on the north to Ruidoso and Three Rivers on the south, and from Capitan on the east to the line of the El Paso & Southwestern Railroad on the west. (See Pl. XXVII, p. 446.) Broadly, the area is a structural basin surrounded by older sedimentary rocks and intruded along its axis by a mass of igneous material which forms the Sierra Blanca, the culminating point of which is the peak known as Sierra Blanca.

The coal beds on the west side of the Sierra Blanca have thus far not proved equal in economic importance to those on the east side. Coal has been mined in large quantity at Capitan and at White Oaks, on the east side of the range, and the output of these mines in 1901 made Lincoln County the third in the State in the production of coal. Mining has now ceased, however, except to supply local demand.

The districts of Capitan and of White Oaks, although parts of the one large coal field, are practically cut off one from the other by the igneous masses of Patos Mountain and Carrizo Peak, so that in the pass between these mountains the coal-bearing rocks form a strip

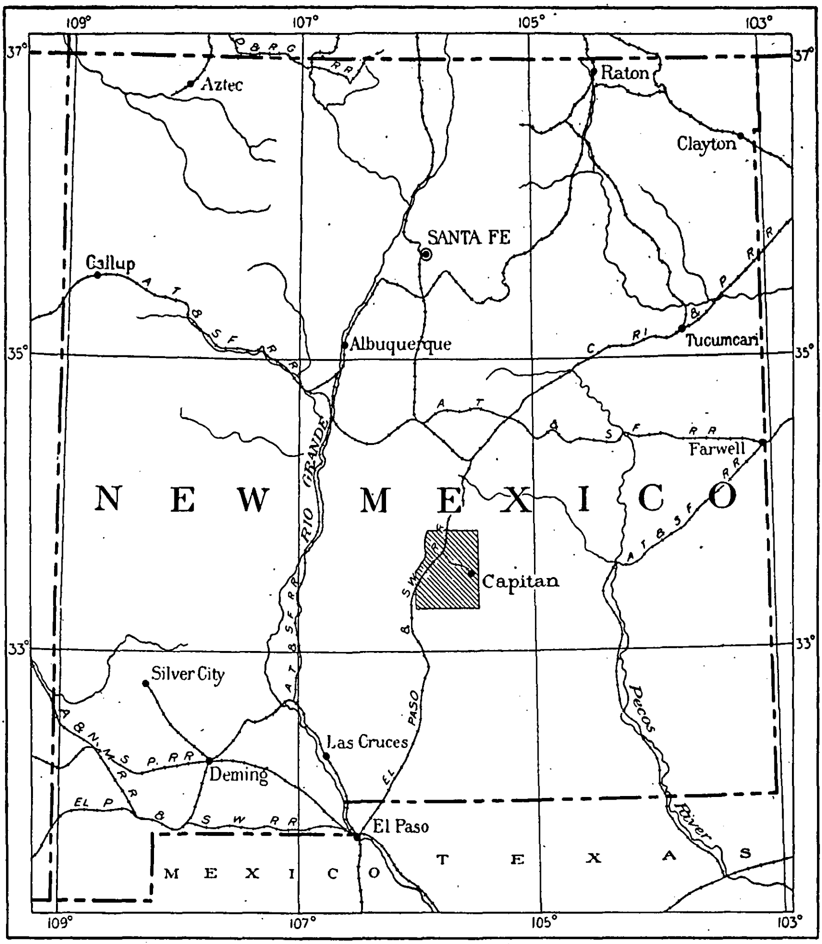

FIGURE 16.—Map of New Mexico, showing location of the Sierra Blanca coal field.

but a few rods in width. Of the two districts that of Capitan, as here considered, is many times the larger, extending from the Tucson Mountains on the north to the valley of the Ruidoso on the south. Future work may show that this part of the field should be regarded rather as three districts—the Tucson, the Capitan, and the Ruidoso—but in the present discussion it may be considered as a unit. The White Oaks district comprises an area of about 3 square miles southeast of the little gold-mining town of White Oaks. It lies in a valley hemmed in on the east, south, and west by mountains of igneous rock, and is at the extreme northeast side of the Sierra Blanca coal basin.

FIELD WORK AND LAND SURVEYS.

In carrying out the field work for the present report a detailed examination of the White Oaks district was first made, this being followed by a rapid reconnaissance of the entire Sierra Blanca coal field. The time spent on the work was one month, from the middle of October to the middle of November, 1912. The treatment of the subject matter in the report is twofold; the broader studies in general geology apply to the region as a whole, whereas the detailed observations on the coal beds are confined for the most part to the White Oaks field.

The general map of the Sierra Blanca field is based on a map of the Lincoln National Forest, published in 1908 by the Forest Service. Locations on it were made for the most part with reference to the land surveys.[1] In the White Oaks district the mapping was detailed and was done with a telescopic alidade on a 15-inch plane table. Locations were made by a system of triangulation expanded from a measured base line.[2] Section corners were located when found, the land net being afterward drawn from them. The east tier of sections in T. 6 S., R. 11 E., is represented on the map as unusually wide, the lines being drawn on the basis of the location of a supposed township-line corner a little less than a mile south of Baxter Mountain. This tier of sections is recorded on the township plat of the General Land Office as 1 mile in width, and it is possible that in the present work the identity of the corner mentioned was mistaken. T. 6 S., R. 12 E., and T. 7 S., R. 13 E., were originally surveyed in 1882 by Hall and Brown and T. 6 S., Rs. 11 and 13 E., the following year by John Shaw.

ACCESSIBILITY.

The El Paso & Southwestern Railroad traverses the western border of the Sierra Blanca coal field, and from the town of Carrizozo a branch line extends to Capitan. Stage lines run from Carrizozo to both Capitan and White Oaks. The field may also be reached from Roswell on the Atchison, Topeka & Santa Fe Railway by way of Lincoln, but the distance from Roswell is much greater than that from Carrizozo.

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[1] The author is indebted to Mr. O. E. Meinzer, of the U. S. Geological Survey, for free use of his unpublished notes and maps of the region west of the Sierra Blanca. This material was gathered in the preparation of a report on the water resources of the Tularosa Basin, N. Mex. (Water-Supply Paper 343), soon to be published.

[2] For a detailed discussion of the method see Wegemann, C. H., Plane-table methods as adapted to geologic mapping: Econ. Geology, vol. 7, pp. 621-637, 1912.

HISTORY OF DEVELOPMENT.

Coal was mined in the vicinity of Capitan in the middle eighties to supply Fort Stanton, but it was not until 1899 that the large mines of the New Mexico Fuel Co. were opened. The development of the coal mines at White Oaks was dependent on the growth of the gold-mining industry in that field, as the coal was used chiefly to supply power for the mines and mills. The history of the White Oaks district therefore begins with the discovery of gold at the North Homestake property on Baxter Mountain in 1879.[1] The location of the South Homestake and other gold properties soon followed, the town of White Oaks being settled by the miners. In 1890 development was begun on the Old Abe gold mine on Baxter Mountain. The mine is well known for the value of its ores, the unusual association of its minerals, and the depth (1,300 feet) of its practically dry workings. The value of the output to January 1, 1904, is given by Jones[2] as $875,000. Since that date the production has been small.[3] A company known as the Wild Cat Leasing Co. is at present operating the North and South Homestake properties, and both the Old Abe and Wild Cat companies operate coal mines.

Many of the details of the development of coal mining in the Sierra Blanca coal field are not on record, but the following notes,[4] given in chronologic order, present the main facts of the history:

1882-83. White Oaks district: The official reports of the Territory of New Mexico for the years 1882 and 1883 state that "In the region of White Oaks there are large bodies of coal," and J. V. Hewett, president of the Old Abe Co.,[5] referred in 1896 to the increase in coal mining as the White Oaks gold camp developed during the 15 years previous.

1885.[6] Capitan district: Coal mined about 3 miles west of Capitan for use at Fort Stanton.

1895. White Oaks district: Wells & Parker mine, 3 miles southeast of White Oaks; slope 425 feet in length; bed 4 feet thick; production, 3,506 tons, valued at $16,000. Apparently other mines were in operation at this time, for J. V. Hewett, writing in this year, makes the following statement:[7] "The total output of coal at White Oaks has resulted in 6,000 tons for the past year, this production being limited by local consumption only for milling and mining service and custom service."

1896. White Oaks district: Wells & Parker mine, production 4,910 tons, valued at $19,640.

1897. No information obtained.

1898. White Oaks district: Old Abe coal mine opened December 19, 1898.

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[1] For the quaint story of this discovery see Jones, F. A., New Mexico mines and minerals, 1904.

[2] Op. cit.

[3] For a full description of this and other mines in the White Oaks district see Graton, L. C., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 179-182, 1910.

[4] Much of the information here presented is taken from the reports of the U. S. coal-mine inspector for the Territory of New Mexico.

[5] Hewett, J. V., Mines of New Mexico, Bureau of Immigration, Santa Fe, pp. 71-72, 1896.

[6] Date uncertain; approximate.

[7] Hewett, J. V., op. cit.

1899. White Oaks district: Old Abe coal mine up to June 30 produced 1,469 tons, valued at $2,672.

Capitan district: Akers & Ayers mines, 1 mile north of Capitan, were opened by the New Mexico Fuel Co., W. P. Thompson, general manager, operating for the New Mexico Railway & Coal Co., of New York City. Two beds of coal were worked, the Akers 3½ to 6 feet in thickness and the Ayers 2½ to 3½ feet.

1900. Capitan district: Akers No. 1 mine (afterward known as Capitan No. 1), production 41,260 tons, valued at $82,520. Akers No. 4 mine (afterward known as Capitan No. 2), production 29,327 tons, valued at $58,654. These mines were on the same bed and about 1 mile apart. Ayers Nos. 2, 7, and 8 were about 3,000 feet from Akers No. 1 and on a different bed. Production of these mines, 13,227 tons, valued at $26,454.

White Oaks district: Old Abe coal mine, production 4,246 tons, valued at $9,649.58.

1901. Lincoln County ranked third in the territory in the production of coal.

Capitan district: Production 169,440 tons, valued at the mines at $2 a ton. Ayers bed no longer worked. Akers No. 1, slope 800 feet long. Akers No. 4, slope 1,250 feet long. Linderman mine, 3 miles west of Capitan, J. J. Blow, general manager. The slope, 450 feet in length, was put down near the site of the old mine worked in 1885 to supply Fort Stanton. Many faults were encountered and the coal differed greatly in thickness. No production.

White Oaks district: Old Abe coal mine, production 3,342 tons.

1902. Capitan district: Capitan No. 1 (Akers No. 1), production 54,417 tons; slope 1,200 feet. Capitan No. 4 (Akers No. 4), production 60,978 tons; slope 1,500 feet. Capitan Nos. 6, 7½, 8, and 10 mines were suspended, the coal being worked out.[1] The beds were much broken by intrusive igneous rock. No. 7 produced 4,116 tons, but was closed down because a dike was encountered. The output of the Capitan district was less than that of the preceding years.

White Oaks district: Old Abe, production 2,391 tons.

1903. Capitan district: Production 96,000 tons, the marked decrease in comparison to the previous year's production being due to the difficulty of mining because of the disturbed character of the beds.

White Oaks district: Old Abe, production 2,096 tons.

1904. Capitan district: Production 90,995 tons.

White Oaks district: Old Abe mine, production 1,500 tons.

1905. Capitan district: Production, 42,250 tons. The last shipment of coal from mine No. 2 was made April 27 and the mine abandoned. The last shipment from mine No. 1 was made June 3, but a small amount of coal was afterward mined to supply Fort Stanton.

White Oaks district: Old Abe mine, production 890 tons.

1906. Capitan district: Mine No. 1, produced 1,895 tons and was abandoned.

White Oaks district: Old Abe mine, production 650 tons.

1907. Capitan district: Mine No. 1, production 796 tons.

White Oaks district: Old Abe mine, production 1,160 tons.

1908. Capitan district: Production 842 tons.

White Oaks district: Old Abe mine, production 1,530 tons.

District west of the Sierra Blanca: Willow Springs mine, in sec. 3, T. 9 S., R. 10 E.; coal bed 2½ to 5 feet thick, dip 16° SE.; depth of slope 320 feet; production 150 tons, sold in Carrizozo; closed down December 14 and not reopened.

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[1] The exact locations of these mines and the years in which they were opened are not given in the inspector's reports and were not ascertained.

1910. Capitan district: Gray mine (near the old Linderman mine, unsuccessfully opened in 1901), a slope 250 feet long sunk by S. T. Gray, of Capitan. Coal bed 3 feet 6 inches thick; dip 8°; output 250 tons.
White Oaks district: Old Abe mine, production 2,065 tons.
District west of the Sierra Blanca: Conner & Smith mine, 6 miles south of Carrizozo, coal bed 4 feet 10½ inches thick, including four shale partings.

1911. White Oaks district: Old Abe mine, production 1,658 tons.

1912. White Oaks district: Old Abe mine, production 538 tons. Wild Cat mine, opened about March 1; production to December 31, 2,012½ tons.

1913. White Oaks district: Old Abe mine, production 124 tons. Wild Cat mine, production 2,656 tons; 8 men employed; length of slope, 250 feet.

TOPOGRAPHY.

The trend of the Sierra Blanca, which occupies the middle of the Sierra Blanca coal field, is approximately north and south. Its highest point, Sierra Blanca Peak, attains an altitude of 11,882 feet. Nogal Peak, 9 miles north of Sierra Blanca, is over 9,000 feet above sea level, and Church Mountain, 3 miles farther north, over 8,000 feet. Church Mountain forms the end of the unbroken range. North of it rise, through the surrounding sedimentary strata, great masses of igneous material which form more or less isolated mountains. These were probably contemporaneous in origin with the main range and are the virtual continuation of it. Such are Vera Cruz and Tucson mountains, Carrizo Peak south of White Oaks, Patos Mountain east of the town, and, in part, Baxter Mountain, which lies west of White Oaks. Vera Cruz and Tucson mountains lie somewhat east of the line of the main range and are in alignment with the Capitan Mountains, which extend from a point 7 miles northeast of Capitan eastward for 20 miles at right angles to the Sierra Blanca. The position of Vera Cruz and Tucson mountains suggests their possible relation to both ranges.

The crest of the Sierra Blanca is comparatively narrow. Only 10 miles west of it lies a great undrained arid plain known as the Tularosa Basin, down the center of which in comparatively recent times a mass of basaltic lava has been poured. This has formed what is known to the Mexicans as the "malpais," or badland, an area of jagged lava destitute of soil and so broken by crevices and pits that it is extremely difficult to cross even on foot. Along the eastern edge of the plain, near the foot of the range and at an altitude of about 5,000 feet, the coal-bearing rocks, which dip eastward, appear at the surface. In this vicinity the country is treeless and semiarid, but the land supports abundant native grasses which cure on the stem at the close of the rainy season and furnish excellent feed for stock.

On the east of the Sierra Blanca the coal beds outcrop at elevations of 6,000 to 7,000 feet above the sea. The land is for the most part timbered and is much better watered than the country to the west of the mountains, particularly in the southern part of the coal area, where perennial streams head in the main range. As is to be expected, the temperature decreases very noticeably with increase in altitude, so that within comparatively short distances marked differences in climate are encountered.

One of the largest streams in the area is the Rio Ruidoso, a beautiful mountain torrent which flows eastward from Sierra Blanca Peak and is joined on the north by Eagle Creek, which also heads in the highest part of the range. The Rio Bonito, a stream equal in size to the Rio Ruidoso, heads between Sierra Blanca and Nogal peaks, draining the slopes of both, and flows eastward to join the Rio Ruidoso, the two streams forming the Rio Hondo, a branch of the Pecos. Salado Creek joins the Rio Bonito from the north, but does not flow from so high land nor have so good water as that stream.

Over the rest of the coal basin the streams are intermittent and water is obtained from scattered springs, wells, or cisterns.

The principal railroad town in the area is Carrizozo, which lies in the wind-swept semiarid plain at some distance from the mountains. White Oaks has a much more pleasing situation, lying in a valley shut in on all sides by timbered hills. In the nineties it was one of the famous gold camps of the Territory, but it is now half deserted, most of its business having gone to its more prosperous rival on the railroad. Capitan, to which on certain days a train runs over the branch line from Carrizozo, was once a thriving coal town. With the closing of the mines its business activity was lessened, but it still supplies a considerable area of country and is the headquarters of the supervisor of the Lincoln National Forest. The former gold camp of Bonito on the Rio Bonito is deserted and the post office has been discontinued. However, post offices are located at the gold properties at Parsons and at Angus, and on the Rio Ruidoso there is a store and post office called Ruidoso. Fort Stanton is now used as a United States marine hospital.

GEOLOGY.

SEDIMENTARY ROCKS.

GENERAL CHARACTER.

The geology of the Sierra Blanca field has not hitherto been studied in detail, and the correlation of its strata with those of other fields in the State in which geologic work has been done is not an easy task, inasmuch as many of the fossils found in the beds are representatives of undescribed species concerning the stratigraphic range, of which but little is known.

The strata of the Sierra Blanca field may be divided on lithologic grounds into seven formations, as follows:

Stratigraphic section, Sierra Blanca coal field, N. Mex.

	Feet.
1. Coal-bearing formation; shale, sandstone, and thin beds of limestone containing two to eight beds of bituminous coal that differ greatly in thickness; a few leaf impressions; fresh water	630
2. Shale, sandstone, and limestone; the upper third of this division consists of shale interbedded with impure limestone, weathering buff and containing numerous fossils; below are interbedded sandstone and shale beds; and at the base lies a heavy stratum of sandstone, which usually forms an escarpment	440
3. Shale, dark gray and bluish, having near its base two or more thin beds of bentonite and a bed of blue limestone; fossils collected near the base identified as Benton; estimated thickness	500
4. Dakota (?) sandstone; buff, coarse sandstone, interstratified at its top with thin beds of shale resembling that of the Benton; contains plant impressions but nothing sufficiently well preserved for identification; possible representative of the Dakota sandstone (Upper Cretaceous) and Comanche series (Lower Cretaceous)	175
5. Morrison (?) formation, shale, variegated pink and green, containing thin beds of limestone, shale, conglomerate, and beds of white sandstone; possible representative of the Morrison formation; estimated thickness	590
6. Limestone (Carboniferous), gray; estimated thickness	700
7. Red beds (Carboniferous).	

Coal-bearing formation (No. 1 of general section).—The following section, measured in the vicinity of the Wild Cat mine, White Oaks district, is given as typical of the coal-bearing formation:

Section of coal-bearing rocks near the Wild Cat mine, White Oaks district.

	Ft.	in.
Shale.		
Coal		9¾
Shale	1	
Coal	2	4
Shale	23	
Coal		8
Covered (shale?)	115	
Coal		5
Shale and sandstone	107	
Bone		3½
Coal (Wild Cat mine)	1	10½
Coal, bony		1
Shale	2	6
Coal		8
Shale	4	
Limestone		6

	Ft.	in.
Covered (shale?)	24	
Coal	1	6
Shale		6
Coal		4
Covered (shale?)	9	8
Limestone, blue	5	
Sandstone, white	15	
Shale	4	
Coal		10
Shale and sandstone	15	
Coal	1	3
Shale	11	
Sandstone, white	26	
Shale	36	
Sandstone, iron stained	2	
Shale	18	
Sandstone	4	
Shale	4	
Coal		6
Covered	150	
Sandstone	15	
Coal	1	10
Shale, iron stained	25	
Limestone bed at top of formation 2, p. 10.		
	630	6¾

All the strata of this formation, including the coal beds, are exceedingly variable in character and thickness and the measurements here given would not hold for any other locality.

The formation has yielded but few fossils. These represent a land flora and the formation containing them was doubtless deposited in fresh water. At the old Williams mine, about 3 miles southeast of White Oaks, some specimens of fossil fruit were obtained from a hard shale stratum about 5 feet above the coal bed. These specimens are discussed by F. H. Knowlton as follows:

This locality was visited by Mr. Stanton in 1889 and the only specimens he obtained were fruits like the present specimens and probably from the identical place. I identified the first specimens as *Nyssa lanceolata* Heer, as determined by Lesquereux, and I can see no reason to change the identification. Lesquereux's material was from the Denver formation of the Denver Basin, and I should presume these to be of the same approximate age; but obviously a single species, and that a fruit, is an insecure basis for an age determination.

Two leaf impressions were obtained from the sandstone immediately overlying the coal at the abandoned opening of the Old Abe mine, 2½ miles southeast of White Oaks, which were not sufficiently well preserved for identification. Leaves collected by M. R. Campbell[1] in 1906 "from a sandstone bed closely underlying the coal at an

[1] Campbell, M. R., Coal in the vicinity of Fort Stanton Reservation, Lincoln County, N. Mex.: U. S. Geol. Survey Bull. 316, pp. 431–434, 1907.

abandoned mine about a mile west of the village of Capitan" (Capitan No. 2) were determined by F. H. Knowlton as probably of Laramie age:

From this small but interesting collection I have been able to identify the following forms with a considerable degree of certainty: *Cinnamomum affine* Lesquereux, *Platanus raynoldsii?* Newberry, Populus sp.? cf. *P. melanarioides* Lesquereux. The most abundant form in the collection is the Cinnamomum, which appears to be the *C. affine* of Lesquereux, but the leaves are rather smaller than the normal leaves of that species and not all of them quite agree with the types. It may be that it is a new but closely related species, though if correctly determined—and I believe it is—it would indicate a Laramie age for the beds. The specimen identified with *Platanus raynoldsii* is a mere fragment from the base of the leaf, but it can hardly be another species. The Populus is a smaller leaf than the type specimen of *P. melanarioides*, but is otherwise indistinguishable. My opinion is that the beds in question are Laramie in age.

Since this determination was made much new information has been gained concerning Tertiary floras. Mr. Knowlton stated recently in conversation with the writer that he now considers the collection here described to belong in all probability to the flora of the post-Laramie rather than to the Laramie, the species being similar to those from the Denver formation of the Denver Basin,[1] or its probable equivalent, the Raton formation of northern New Mexico.[2]

There is no lithologic indication that the coal-bearing strata in the White Oaks field belong to more than one formation. The lowest coal bed which is found in the field outcrops in the NE. ¼ NW. ¼ sec. 5, T. 7. S., R. 13 E., 318 feet stratigraphically below the coal bed at the Wild Cat mine. Fossil collection 8073 was obtained 25 feet below this lowest coal. (See p. 430.) The stratigraphic position of this collection with reference to other collections indicates that it is probably to be considered as of Montana age, although Mr. Stanton states that the Inoceramus is suggestive of the Colorado. The 25 feet of strata between the coal bed (which, with the overlying formation is believed to be of post-Laramie age) and the bed carrying Montana ? fossils consists of dark ferruginous shale apparently conformable with the strata above and below. Its age is indeterminate, although on lithologic grounds it would be classed with the overlying beds. There is thus no physical indication of a great time break, such as is represented by the post-Laramie unconformity in the Denver Basin.

Shale and sandstone formation (No. 2 of general section).—A detailed section of the strata of the formation underlying the coal-bearing rocks was measured northwest of the Wild Cat mine and is a continuation downward of the measured section on page 427.

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[1] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, 1896.

[2] Knowlton, F. H., Results of a paleobotanical study of the coal-bearing rocks of the Raton Mesa region of Colorado and New Mexico: Am. Jour. Sci., 4th ser., vol. 35, pp. 526–530, 1913.

Section of the rocks underlying the coal-bearing rocks northwest of the Wild Cat mine, White Oaks district.

	Feet.
Shale of coal-bearing formation.	
Limestone, impure, bluish gray, weathers buff (fossil collection 8073; see p. 14)	2
Shale, gray	55
Sandstone, yellow	4
Limestone, thin-bedded, bluish gray; weathers buff; fossiliferous.	5
Shale and sandstone	30
Limestone, impure, bluish gray; weathers buff; fossiliferous	4
Shale, gray	35
Limestone, impure, bluish gray; weathers buff; fossiliferous	5
Shale, gray	28
Sandstone	10
Shale, gray	25
Sandstone, coarse, cream-colored	27
Covered (shale and limestone?)	15
Oyster bed, small shells	1
Covered (shale?)	48
Sandstone, gray, calcareous; many oysters at top	5
Covered (shale?); oysters near top	40
Sandstone, cream-colored and pink, coarse	18
Covered (shale?)	21
Shale, weathers brown, contains near top great numbers of Turritella and Ostrea	16
Sandstone, white, cream-colored, and pink, large Inoceramus found on surface	50±
	444±

Some of these strata, especially the limestone beds, are very fossiliferous, the fossils being of marine or brackish-water types. The determinations in the following list of collections were made by T. W. Stanton:

8069. Blanchard Gulch in Tucson Mountains, 6 miles northeast of Nogal, N. Mex.:
    Ostrea sp. Young shells.
    Cardium sp. related to C. curtum M. and H.
    Tellina sp.
    Mactra sp.
    Pugnellus sp. related to P. fusiformis (Meek).
    It is possible that this lot may be of Colorado age; but in my judgment it represents a horizon of early Montana age. There is a lack of distinctive types and the species are probably undescribed.

8070. One-half mile north of White Oaks, N. Mex., from brown sandy limestone near top of formation 2:
    Ostrea sp. Young shell.
    Inoceramus sp. Fragment.
    Cardium sp.
    Turritella sp.
    Gyrodes sp.
    Pugnellus sp.
    Same fauna as 8069.

8071. Two miles east of White Oaks, N. Mex., and 65 feet above the base of formation 2:
Ostrea sp.
Corbula sp.
Turritella sp.
Apparently same fauna as 8069 and 8070.

8072. Same locality as 8071, near top of formation 2, in calcareous bed below the highest sandstone:
Ostrea sp.
Cardium sp.
Same fauna as 8069–8071.

8073. Two miles south of White Oaks, N. Mex., and 1,000 feet southeast of Wild Cat mine; 24 feet below lowest coal:
Ostrea sp.
Inoceramus sp. Fragment of a thick-shelled species.
Cardium.
Shark's tooth.
The Inoceramus in this lot is suggestive of upper Colorado.

8074. At Well's ranch, 2 miles southeast of White Oaks, N. Mex., from limestone layers between sandstone series and coal group:
Ostrea soleniscus Meek.
Modiola sp.
Cardium sp.
Veniella sp.
Tellina? sp.
Turritella? sp.
Shark's teeth.
Probably belongs to same fauna as 8069–8072.

The Pugnellus in the fauna from White Oaks resembles but is not identical with *P. fusiformis* (Meek), and the same may be said of the Cardium as compared with *Cardium curtum* M. and H. These forms suggest possible correlation with the Colorado group, but there are other elements in the fauna that indicate a higher horizon. Previous collections from the region obtained by me in 1889 and by Mr. O. E. Meinzer in 1911 have been tentatively referred to the Montana group, and I still think that this reference is correct, though it must be admitted that in the collections examined there is lack of ammonoids and other definitely characteristic forms such as are most depended upon in stratigraphic determinations.

The cliff-forming sandstone beds in the lower part of this formation and their associated shales, although fossil bearing, do not preserve the shells as perfectly as the overlying limestone beds. The small collection No. 8071 was obtained 65 feet above the base of the formation, but unfortunately the species have a wide range and are thus of little value in age determination. A large Inoceramus was collected a little below the horizon of No. 8071, and of this specimen Mr. Stanton states that it suggests the thick-shelled forms characteristic of the upper part of the Colorado group.

Shale formation (No. 3 of general section).—A complete section of the strata of this formation was not measured by the writer. The beds are for the most part gray shale, resembling that of the Benton of Wyoming. A 10-foot bed of fine-grained bluish-gray limestone, which when struck with a hammer gives off an odor of brimstone, lies

25 feet above the base. Above the limestone occurs a 10-inch bed of bentonite (hydrous silicate of alumina) and 20 feet higher a second bed of bentonite 2 inches thick. No analysis was made of the bentonite, but it is so similar to the bentonite characteristic of the Benton formation in the north that there seems little question of its identity. The shale below the limestone just described is interbedded with sandstone similar to that of the underlying formation, so that there is no sharp line of division between the sandstone below (supposed Dakota) and the overlying shale. The preceding observations were made at exposures along Salado Creek, 2 miles south of Capitan.

M. R. Campbell,[1] in his study of the Fort Stanton Reservation, estimated the total thickness of the shale (No. 3 of general section) to be about 500 feet. He obtained a small fossil collection on which T. W. Stanton in 1906 reported as follows:

> The lot from near the upper gate of the Fort Stanton Reservation consists of dark calcareous shale, with many specimens of *Inoceramus labiatus* Schlotheim and some imperfect imprints of two species of ammonites, probably belonging to the genus Prionotropis. The horizon is in the Benton group.

Dakota (?) sandstone (No. 4 of general section).—The cliff-forming sandstone, here designated as Dakota (?), is well exposed 4 or 5 miles northeast of White Oaks, where its thickness, as measured by the writer, is 175 feet. It also forms an escarpment east of Capitan and at many other localities surrounding the coal area. No recognizable fossils have been obtained from it, although it carries fragmentary plant impressions and is therefore apparently of fresh-water origin. It may be the equivalent of the Dakota sandstone (Upper Cretaceous) or it may be in part Comanche (Lower Cretaceous). The 3-foot bed of carbonaceous shale at its base is suggestive of the Lower Cretaceous coal farther to the north, although there is no indication here of the coarse conglomeratic bed below, which underlies the coal in that locality.

Morrison (?) formation (No. 5 of general section).—The shaly strata here tentatively correlated with the Morrison formation generally outcrop in this area in a valley outside the ridge formed by the sandstone bed of formation 4. They consist principally of shale but contain also thin sandstone and limestone beds and beds of shale conglomerate in a calcareous matrix. The colors are soft in tone and vary from white to yellow, green, gray, blue-gray, and purple, being well described as variegated. The beds were classed by Campbell[1] tentatively as Morrison and there is no reason to change this tentative classification. So far as known they are unfossiliferous in this locality and except for their stratigraphic position and lithologic character there is little evidence bearing on the subject of their age.

[1] Campbell, M. R., Coal in the vicinity of Fort Stanton Reservation, Lincoln County, N. Mex.: U. S. Geol. Survey Bull. 316, p. 434, 1907.

Carboniferous limestone and red beds (Nos. 6 and 7 of general section).—The Carboniferous limestone and red beds which outcrop as a rule some distance beyond the coal area were given but little study in the present investigation. No. 6 is probably to be correlated with the San Andreas limestone, the uppermost formation of the Pennsylvanian as described by Lee.[1]

COMPARISON OF THE WHITE OAKS SECTION WITH THE CARTHAGE SECTION.

The division of the section at White Oaks into formations (see columnar section, Pl. XXVII) is to be regarded as tentative only, as the paleontologic evidence is by no means conclusive. In a report on the Carthage coal field, which lies 60 miles west-northwest of White Oaks, James H. Gardner[2] gives the following stratigraphic section, which appears to be very similar lithologically to the section at White Oaks:

Part of general section of rocks in the Carthage region.

* * * * * * *

	Feet.
Montana:	
Sandstone, tan-colored and drab shale with traces of coal	600
Shale and thin beds of sandstone. Top contains Ostrea sp., *Anomia micronema* Meek?, Modiola related to *M. regularis* (White), Corbicula? sp., Corbula sp., Melania sp., and Admetopsis? sp	40
Coal, Carthage	5
Shale, drab	20
Sandstone, brown, massive	20
	685
Colorado:	
Shale, drab, with yellowish lime concretions	120
Shale, yellowish, with brown sandstone	45
Sandstone, brown, massive, soft, fossiliferous, containing Ostrea sp., *Ostrea lugubris* var. *belliplicata* Shumard, Pinna sp., Pholadomya sp., Fasciolaria? sp., *Prionotropis woolgari* (Mantell)? and *Coilopoceros colleti* Hyatt	15
Shale, drab	40
Shale, drab, with thin brown sandstone	135
Sandstone, gray, massive	10
Sandstone and shale; in center fossiliferous sandstone containing *Inoceramus labiatus*, Cardium sp., Cyprimeria sp., Psilomya sp., Gyrodes sp., Fasciolaria? sp., and Volutoderma? sp	30
Shale, drab	500
	895

[1] Lee, W. T., and Girty, G. H., The Manzano group of the Rio Grande valley, N. Mex.: U. S. Geol. Survey Bull. 389, 1909.

[2] U. S. Geol. Survey Bull. 381, p. 455.

	Feet.
Dakota (?):	
Sandstone, gray, hard, in bold hogback, some thin shale	200
Triassic (?):	
Sandstone, dark red, with red and drab shales	1,300
Shale, gray, with pinkish chert inclusions, minute bone fragments	20
Shale, red, and some sandstone	260
Sandstone, red, and red shale	100
Conglomerate, with coarse quartz pebbles, dark, white, and yellow	15
Shale, variegated, and red sandstone	300
	1,995
Carboniferous:	
Limestone, bluish gray, weathers yellowish; could possibly be used with higher shale for manufacture of Portland cement	200
[Total thickness of this part of section	3,975]

The coal-bearing rocks of the Carthage section were provisionally referred by Gardner to the Montana, although they appear to occupy the same stratigraphic position as the coal-bearing rocks in the White Oaks field. At Carthage fossils of undoubted Colorado age were collected 205 feet below the coal, whereas at White Oaks the distinctive collections, on the evidence of which the beds below the coal-bearing rocks are regarded as of Montana age, come from horizons less than 200 feet below the lowest coal bed. The fossils from White Oaks are less characteristic than are those from the Carthage field. It is not impossible that the strata which carry the doubtful Montana fauna in the White Oaks field represent the 205 feet of strata below the coal at Carthage from which no fossils were collected, and that the sandstone beds of Colorado age at Carthage are the equivalent of those in the lower part of formation 2 in the White Oaks section.

TERRACES.

The Sierra Blanca, like most of the ranges of this general region, is flanked by terraces, the gravel cover of which constitutes one of the more recent deposits of the area. The terraces are a serious hindrance to the tracing of the coal beds, as the soil and gravel which usually cover them effectually conceal all underlying strata. A description of the terraces in the vicinity of White Oaks will serve to illustrate their character throughout the area.

The town of White Oaks is situated at the junction of the three forks of an intermittent stream. The valley of this stream is comparatively narrow and is cut in bedrock. Its bluffs rise steeply a hundred feet or more to the level of a broad terrace whose slopes rise toward the mountains. The soil cover of this terrace is but a few feet thick, and the bedrock outcrops at many places in the small valleys which trench it. Some 200 or 300 feet above this terrace a second terrace slopes upward to the base of the mountains and is covered with gravel, some of the bowlders being a foot or more in diameter. The thickness of the gravel was not measured, but it is probably not great, for this terrace, like the first, has been cut by stream action from the underlying rocks rather than built up by outwash from the mountains. Similar terraces are developed 25 miles southeast of White Oaks, near Fort Stanton, on the east side of the Sierra Blanca. They are the result of erosion by streams heading in the mountains, but the conditions which produced them are not well understood. Regional uplift, after a period of erosion in which the streams had time to reach grade and to widen their valleys into broad flats, would rejuvenate the streams, causing them to intrench their courses and leave the flats as terraces. As suggested by A. C. Spencer[1] a similar result might follow marked climatic change with decrease in rainfall, which by decreasing the load furnished the streams at their heads, would increase their down-cutting power, enabling them to intrench themselves in flats which they had previously formed. In the White Oaks region this hypothesis is perhaps the more probable one.

IGNEOUS ROCKS.

In any consideration of the Sierra Blanca coal field the igneous rocks play a most important part. Not only do they compose the main range of the Sierra Blanca and the isolated peaks which extend that range northward, thus cutting out the coal beds from fully one-third of the area, but as dikes and sills they intrude the coal-bearing rocks which surround the mountains, interrupting the coal beds at unexpected places and rendering mining difficult. The precise relation of the dikes and sills to the main intrusion is not easily determined because of the gravel-covered terraces which surround the igneous mass of the main range and effectually conceal the underlying rocks. Some portions of the rock of the dikes are closely related in composition to the rock of the mountain mass, but other portions of it are distinct. The igneous rock of the main range is not homogeneous in composition, but differs considerably from place to place and appears to be the result of several epochs of intrusion, the later rocks cutting the earlier.

In the present work no attempt was made to study the igneous rocks except as they affect the coal beds, and because of the lack of good exposures even such study was far from satisfactory. The following list of specimens collected at different places throughout the

[1] Spencer, A. C., U. S. Geol. Survey Geol. Atlas, La Plata folio (No. 60), p. 10, 1899.

area and their determinations will give a general idea of the character of the igneous rocks:[1]

1. Diorite (?), much altered, gray, with a large amount of magnetite, from the Hopeful gold mine 1 mile southeast of Nogal Peak. The country rock at this locality is classed by Graton[2] as monzonite porphyry, to which this diorite is probably closely related. He considers it as one of the oldest igneous rocks exposed in the range and states that it is probably related to the main intrusive of the White Oaks district, namely, that at the gold mines on the east side of Baxter Mountain.

2. Soda rhyolite, light gray-brown, from the north side of Carrizo Peak about 300 feet above the base of the mountain. This rock, which appears to be representative of the mass composing the north flank of Carrizo Peak, is probably intrusive like the diorite, but has many of the characteristics of a rapidly cooled surface flow.

3. Soda rhyolite[3] from the SE. ¼ sec. 21, T. 7 S., R. 11 E. This rock forms several buttes in this locality, the largest of which is several hundred feet in height.

4. Trachyte, yellowish brown, stained and banded, one-half mile north of White Oaks, from a sill intruded into the coal-bearing formation.

5. Granodiorite porphyry, light-colored to yellowish brown, porphyritic with dense fine groundmass, 1 mile north of White Oaks, from a dike 50 feet in width which cuts the Cretaceous sediments. This rock, although but one-half mile from the trachyte sill represented by specimen No. 4, is very different from it.

6. Rhyolite, light to purplish in color. About 1 mile northwest of old Three Rivers post office on west side of the Sierra Blanca. Rock probably from a dike cutting sedimentary rocks beneath an igneous flow or sill which caps the high "palisades" in this locality.

7. Basalt, reddish, iron stained, porphyritic, vesicular. Same locality as No. 5. This rock was collected from a bowlder which had apparently fallen from the top of the cliff. It is probably from a surface flow.

8. Basalt porphyry, dark porphyritic rock from a sill in sec. 21, T. 11 S., R. 9½ E., northeast of headquarters of Fall's ranch.

9. Lamprophyre, probably a monchiquite, dark, fine-grained porphyritic. Wells & Parker coal mine, White Oaks field, from a thin sill 6 feet above the coal bed.

10. Monchiquite type of lamprophyre, dark, dense, porphyritic rock, resembling No. 8, 1½ miles north of White Oaks, from a thin dike cutting beds which are probably those of formation 6 of the section given on page 10.

11. Basalt, dark, vesicular, amygdaloidal, porphyritic, 10 miles north of Carrizozo from the recent lava flow of the "malpais."

12. Augite kersantite,[3] dark gray, from a sill several hundred feet in thickness which caps Milagro Hill 1 mile northeast of Oscuro. The sill is underlain by the coal-bearing beds of formation 1.

From the diversity of the rocks contained in the foregoing list it is reasonable to suppose that they represent several epochs of intrusion, and the field relations bear out such a supposition. As shown under the discussion of structure, the oldest igneous rocks in the region were probably intruded during the Tertiary after the deposition of the coal-bearing rocks. From that time on almost to the present there have been successive epochs of intrusion and volcanic

[1] The writer is indebted to E. S. Larsen and J. F. Hunter, both of the U. S. Geological Survey, for determinations of rock specimens.

[2] Graton, L. C., Ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 178, 1910.

[3] Collected by O. E. Meinzer. (See note, p. 421.)

activity. In some places the molten rock cooled before reaching the surface, forming dikes and sills which have been in part uncovered by subsequent erosion; in others it welled out on the surface in flows. The most recent of these flows is the great lava flow known as the "malpais," west of Carrizozo, which was formed in all likelihood but a few hundred years ago. The surrounding topography has not changed since the rock cooled, and near the cinder cones at the north end of the flow, which apparently mark the site of the last volcanic activity, may be seen the fissures in the lava from which the cinders and pumice were ejected, their walls reddened by oxidation due to the intense heat.

STRUCTURE.

The Sierra Blanca coal field, as outlined by the coal beds which outcrop around its margin, is a broad syncline 32 miles from north to south by 24 miles from east to west. Along the axis of this syncline has been intruded a great mass of igneous rock, which forms the Sierra Blanca and its outliers to the north. The timber that clothes most of the surface, and the gravel-covered terraces, which practically cover all bedrock for many miles in a zone bordering the igneous mass, present serious obstacles to the study of the structure of the region. However, excellent key rocks are present. The Dakota (?) sandstone with the variegated shale below it, the fossiliferous limestone and sandstone strata below the coal-bearing rocks, and the coal beds themselves are easily recognized at different places throughout the field and form the basis for the determination of the structure. In the following discussion of the structure many data that would ordinarily be given under the head of coal are included, as the determination of the structure is often dependent on the tracing of the coal beds.

The town of White Oaks, on the northeastern edge of the coal basin, lies in a much-faulted area. Less than half a mile north of the town the coal-bearing rocks, which dip to the west, are cut off one-fourth of a mile from their outcrop by a fault with downthrow on the east, which brings the shale of Benton age almost on a level with them. A little farther west a second fault throws the shale below the Dakota (?), which here dips to the west and is cut off by the igneous mass which forms the east flank of Baxter Mountain. The fault zone can be traced north and northeast across sec. 24, T. 6 S., R. 12 E., where there has been considerable intrusion of igneous rock along the fault planes. The Dakota (?) sandstone is cut out by the fault in the SE. ¼ sec. 24, T. 6 S., R. 11 E., and the underlying Morrison (?) formation appears west of the stream valley which apparently follows the fault zone. These beds also dip to the west toward the mountain. East of the creek in the SW. ¼ sec. 24, T. 6 S., R. 12 E., the fossiliferous shale and limestone underlying the coal-bearing formation outcrop, the dip being to the southeast at an angle of 12°. The same beds, duplicated by faulting, outcrop on the east side of the same section and dip southeast at an angle of 6°.

Baxter Mountain is formed only in part by igneous rock. The crest appears to be composed of sandstone belonging to formation 2 of the section on page 426, which is underlain by shale. The strata dip to the southwest and were probably brought to this position by the upthrust of the intrusion which forms the east flank of the mountain.[1]

The mountain in the NE. ¼ sec. 13, T. 6 S., R. 12 E., and the NW. ¼ sec. 18, T. 6 S., R. 13 E., was not examined in detail but appears to be synclinal and coal is reported on its crest. There is a coal mine in the valley east of the mountain in the NE. ¼ sec. 18, and a little west of the mine mouth a rather large fault trends approximately north and south with downthrow on the east. If the report of coal near the mountain crest is correct it is probably the same bed or one near it, the difference in elevation being due to the displacement along the fault plane. It is not unlikely that this fault may be connected with the zone of displacement in sec. 24 mentioned above.

The escarpment facing the northwest in the SE. ¼ sec. 24 is formed by the beds of the formation underlying the coal, which here dip 6° SE. This dip would carry the beds below the escarpment formed by them in the central part of sec. 30, T. 6 S., R. 13 E., were it not for a fault with downthrow on the northwest which apparently corresponds with the valley in this locality.

The escarpment in sec. 30 outlines a gentle syncline which opens to the southwest as shown on the map, the strike of the beds changing from N. 58° E. near the southwest corner of sec. 30 to N. 46° W. in the NE. ¼ sec. 31. Part of this change in strike takes place along the line of the igneous dike which runs northeast from the center of sec. 31, cutting at right angles across the beds. For almost 1 mile southeast of this dike the strike of the beds (N. 46° W.) is constant, but it changes abruptly in the SW. ¼ sec. 32, T. 6 S., R. 13 E., where a fault with downthrow on the southeast cuts across the beds at right angles to the strike. The line of this fault, like that of many others in the region, is occupied by a stream valley. Southeast of the fault the strike of the coal beds is north-south and the beds are apparently unbroken as far as Old Abe mine No. 1, now abandoned. Just south of the opening of this mine the coal bed is cut by a fault trending N. 53° E., with downthrow on the southeast, which shifts the coal outcrop 400 feet to the east. The bed can be traced for

[1] See cross section by Jones, F. A., New Mexico mines and minerals, fig. 31, p. 174, 1904.

one-fourth of a mile south of this place, but in the center of sec. 5 is concealed by gravel. A group of coal beds is exposed in the SE. ¼ of the same section, one of which probably corresponds to the Old Abe bed. If such correlation is correct the outcrop of the bed has been thrown some distance to the east, presumably by faulting in the area covered by the gravel. In the vicinity of the old Wells & Parker mine, which is situated in the SE. ¼ sec. 5, occur several igneous dikes and sills, and a short distance south of the mine the outcrop of the coal-bearing rocks is narrowed to a strip but a few rods in width in the pass between the igneous masses of Carrizo Peak and Patos Mountain. Southeast of the pass the outcrop of the sandstone and limestone beds of the formation between the coal-bearing rocks and the Dakota (?) sandstone appears to bear to the east. Farther south they are either faulted or bent back to the west again, as the coal group that occurs a short distance stratigraphically above these rocks outcrops in sec. 26, T. 7 S., R. 13 E., on the east side of the Tucson Mountains. The strike of the beds is here N. 25° E., and the dip 19° NW., toward the igneous mass of the mountains.

Between the Tucson Mountains and the Capitan field the structure was not studied. In the latter area, as described by Campbell,[1] the coal-bearing rocks which dip to the northwest are broken by a considerable fault which passes just west of Capitan and follows for some distance the valley of Magado Creek, trending west of south. The downthrow is on the west, the coal being brought to a level with the strata of the underlying formation. A second fault was observed by the writer which parallels the first and lies northwest of it but has its downthrow on the east, thus duplicating the outcrop of the coal beds about 2 miles west of Capitan, where the beds are opened in the Gray mines. The fault just west of Capitan was traced by Campbell[2] southwest to the west side of sec. 29, T. 9 S., R. 14 E., and was also observed by him where it crosses Bonito Creek, 2 miles east of Angus. It may possibly be connected with the great fault on Carrizo Creek, described below. The outcrops of the coal beds, which southwest of Capitan are cut out by the fault, are apparently brought to the surface again farther west by faulting, as coal is reported in sec. 36, T. 9 S., R. 13 E. This second displacement may be a continuation of that which duplicates the coal outcrop 2 miles west of Capitan.

There is a fault or upturn of the strata against the igneous mass of the mountains about one-half mile northwest of Angus, on the road from Parsons to Capitan, for coaly shale, which apparently belongs to the coal-bearing formation, is exposed at this locality close to the contact of the sedimentary and igneous rocks, and red shale, which

[1] Campbell, M. R., Coal in the vicinity of Fort Stanton Reservation, Lincoln County, N. Mex.: U. S. Geol. Survey Bull. 316, p. 433, 1907.

[2] Op. cit.

lies some distance stratigraphically below the coal-bearing formation, is exposed just north of Angus. It is to be regretted that time would not permit more detailed examinations in this locality. On Eagle Creek, 4 miles south of Angus, coal-bearing rocks are exposed, the dip being in general toward the mountains.

On Carrizo Creek, in secs. 33 and 34, T. 11 S., R. 13 E., occur the most southerly exposures of the coal-bearing rocks. These are broken in many places by igneous dikes. Along the valley of Carrizo Creek in sec. 34 a great north-south fault throws the Dakota (?) sandstone on the west far below the top of the Carboniferous limestone that stands in a bold cliff on the east bank of the stream. It is worthy of note that the downthrow here is on the west side of the fault like that of the east fault at Capitan, with which this fault may possibly be connected. This condition is in accord with the fact that the dip of the strata along the east side of the range is in general toward the mountains. It is the reverse of the movement in the second fault west of Capitan and in that noted 3 miles northeast of White Oaks, where east of the synclinal mountain the downthrow along the fault line is to the east.

South of Carrizo Creek there are no exposures oi the coal-bearing formation, the beds belonging for the most part to the Carboniferous.

Across the Sierra Blanca to the west the coal-bearing rocks outcrop in the neighborhod of Three Rivers. In the NW. ¼ sec. 28, T. 11 S., R. 9½ E., the strike is N. 9° W., and the dip 14° E. Farther southeast the strike changes rather abruptly until it is almost east and west and the dip is to the north. Coal is reported in sec. 20, T. 11 S., R. 10 E., and in sec. 12, T. 11 S., R. 9½ E., which probably represents the same bed or one at about the same horizon. Northwest of old Three Rivers post office two flows or sills of igneous rock which cap a prominent mesa show the effect of folding, which has bent them into a shallow syncline, pitching to the north. The position of this syncline, together with the change in strike of the beds in sec. 28, T. 11 S., R. 9½ E., as noted above, suggests that the coal beds are involved in the structure, and that the beds reported to outcrop near the mountains may be the same as those in sec. 28 and may have been brought to the surface on the east limb of the narrow syncline. Their position may, however, be due entirely to faulting.

North of Three Rivers the exposures were not examined by the writer. It appears, however, from Meinzer's work[1] that fossiliferous beds which belong to the formation underlying the coal outcrop along the railroad 4 miles south of Oscuro, the strike being approximately north-south and the dip 30° E. If the strike of N. 9° W., observed on the beds in sec. 28, T. 11 S., R. 9½ E., northeast of the Fall ranch, remained unchanged to the north, it would carry them 1½ miles east

[1] See note on p. 421.

of this outcrop near the railroad. Whether the strike changes or whether the outcrop is shifted to the west by faulting is uncertain.

From the above-mentioned outcrop on the railroad the structure appears to be regular to a place about 1 mile northeast of Oscuro, where a thin coal bed is exposed, the strike at this locality being approximately north-south and the dip 20° E. Soft yellow sandstone, probably underlying the coal, is exposed along the railroad one-half mile northwest of the coal outcrop, and a sandstone bed, probably the Dakota (?), occurs 2 miles farther west near the "malpais." This sandstone ledge can apparently be traced for about 6 miles and beds of red and yellow sandstone, supposedly of Morrison age, are exposed stratigraphically below it on the west. One reading taken on the Dakota (?) sandstone 6 miles north of Oscuro gave a dip of 10° SE.

The same succession of rocks may be recognized west of Carrizozo, the dip being to the southeast. Between Carrizozo and Oscuro, however, the strata appear to have been considerably disturbed by faulting and intrusion. Several sills of igneous rock, which appear to have been originally intruded along bedding planes, have been tilted from the horizontal by subsequent earth movement and now form hills with escarpments facing to the northwest. As an example may be cited Willow Hill, 6 miles south and 1 mile west of Carrizozo. Halfway down the steep westward-facing escarpment of this hill is an outcrop of coal which is doubtless the same bed as that exposed north of Oscuro or one very nearly at the same horizon. To judge, however, from the outcrops of the Dakota (?) and higher beds of sandstone which appear west of the railroad, the coal outcrop should lie about 5 or 6 miles due west of Willow Hill. It seems almost certain that the bed at Willow Hill is brought into its present position by a fault with downthrow to the west which lies just west of the coal outcrop and trends a little east of north. Willow Hill is therefore a block mountain, its steep western escarpment being marked by a fault, whereas the more gentle eastern slope corresponds to the surface of the igneous sill which was bent by earth movement subsequent to its intrusion. The two mountains south of Willow Hill appear to be of the same type. How many more faults traverse the region it is impossible to say from the meager data at hand.

Four miles west and 1 mile north of Carrizozo a sandstone ridge rises in a series of three islands above the black surface of the recent lava flow and is continued to the south beyond the lava area. This sandstone is probably Dakota (?) and the ridge midway between its outcrop and Carrizozo is probably composed of the formation that underlies the coal, as limestone is here recorded by Meinzer. This outcrop can be traced northeast to the south side of sec. 6, T. 7 S., R. 11 E. It seems likely that north of this place the beds are broken by a fault, which throws the outcrop 3 miles to the west, near the edge of the lava flow, where the stratum dips 4° SE. Meinzer collected fossils at both localities and the beds are believed to be identical. The Dakota (?) is exposed 1½ miles farther northwest. The Dakota (?) and the fossiliferous beds of the formation below the coal are also exposed on the north and south sides respectively of sec. 5, T. 6 S., R. 11 E., but the strike has here changed to northwest-southeast, the dip being 25° SW. These outcrops appear to be close to the point of a syncline the axis of which pitches to the south. From sec. 5 the outcrop of the Dakota (?) swings more and more to the south past Lone and Baxter mountains. One mile south of the Baxter Mountain the beds examined by the writer strike N. 15° W. and dip 10° SW. It is worthy of note that the dip is here away from Baxter Mountain rather than toward it, the reverse of the condition north of White Oaks on the east side of the mountain.

The structure of the Sierra Blanca coal field as a whole, as stated at the outset, is evidently synclinal; the beds on either side of the mountain mass dip toward it and are succeeded by older and older formations as distance from the mountains increases. Whether the syncline existed prior to the formation of the mountains, which were intruded along the line of weakness of its axis, or whether it had its origin in the earth movements which produced the mountains, or whether it is due to subsequent folding of the sedimentary strata by pressure against the rigid igneous mass is impossible to determine from the data at hand. The presence of the end of a syncline opening to the south in the area northwest of Baxter Mountain, and a possibly similar structure opening to the north near Three Rivers, together with the slight synclinal structure exhibited southeast of White Oaks on the east side of the range, are suggestive of an upturn of the beds adjacent to the intrusion. This is more apparent on Baxter Mountain, where the crest and western flank of the mountain are formed of sedimentary strata tilted to the west apparently by the intrusion of the igneous rock which forms the east flank of the mountain.

The time of the mountain uplift is suggested by the intrusion by dikes and sills of the coal-bearing rocks, which are believed by Knowlton to be of post-Laramie age. This fixes the time of the part of the earth movement from which the intrusions doubtless resulted as later than the deposition of the coal-bearing sediments. The absence of any unconformity, so far as observed, in the recognized Cretaceous formations, or between them and the coal-bearing formation, would seem to preclude the possibility of mountain-building movements during the deposition of these formations. We may therefore assume that the formation of the Sierra Blanca took place after the deposition of the coal-bearing formation. This conclusion is somewhat at variance with that of Graton,[1] who considered

[1] Graton, L. C., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 168 et seq., 1910.

the monzonite porphyry of Nogal Peak to have been intruded in late Cretaceous time. It is probable, however, that in making this statement he regarded the coal-bearing rocks as undoubtedly Cretaceous in age.

THE COAL.

WHITE OAKS DISTRICT.

The coal-bearing area at White Oaks is very small. It is cut off from all other areas of the coal-bearing rocks by igneous intrusions on the northwest, southwest, and southeast and is bounded on the northeast by areas of barren rock below the coal. It is impossible to trace the coal beds for any considerable distance across the field because of the deep cover of gravel which overlies most of the area. The coal has been prospected in many places and the beds can be seen only at these prospects and at a few natural outcrops in the beds of dry gulches. As the coal beds themselves differ greatly in thickness from place to place, correlation can be made only by means of the associated rocks and by comparison of the stratigraphic distances between the beds. Such correlation is necessarily unsatisfactory.

So far as known the highest bed exposed in the field is near the township line in the SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 32. (See Pl. XXVI.) The coal lies in two benches that are separated by 12 inches of shale, the upper bench measuring $9\frac{3}{4}$ inches and the lower 25 inches, including a 3-inch bone parting $2\frac{1}{2}$ inches from the top. At a distance of 249 feet stratigraphically below this bed lies the coal worked at the Wild Cat mine, the section of which is as follows:

Section of coal bed at the Wild Cat mine.[1]

		Ft.	in.
Shale.			
Coal			6
Bone			2
Shale, dark		1	6
Bone			$3\frac{1}{2}$
Coal	Mined		$8\frac{1}{4}$
Bone	Mined		$1\frac{1}{4}$
Coal	Mined		11
Coal, impure	Mined		1
Shale, black		2	6
Coal			8
		7	5

The bed mined is indicated by the brace in the section, and this part was sampled at the place where the section was measured. The analysis is given as No. 15054 on page 451. In the north entries of the mine the bed is only 12 or 14 inches thick. The mine is a slope run

[1] This section was measured in the west entry near the main slope. The section given on Pl. XXVI was measured at the top of the slope.

on the dip of the bed and side entries driven from it, the rooms being driven up the rise from the entries. The coal cars are brought to the surface by a hoisting engine and the coal is used in the production of electric power for the Homestake gold properties west of White Oaks, which are operated by the Wild Cat Co. A few rods north of the Wild Cat mine is a second opening made by the same company on a bed which appears to be the same as that just described, though it is only 12 inches thick. There has been considerable slipping along the bedding planes of the strata in this locality and it may be that the difference in the thickness of the coal is due entirely to this cause. At a point 300 feet northwest of the north opening the company drilled a test hole in 1912 to the depth of 134½ feet. A record of this test has been furnished through the courtesy of the company and is given below. Coal was found at the following depths:

At 61 feet: 14 inches of coal, doubtless representing the bed opened at the Wild Cat mine.[1]
At 67½ feet: 6 inches of coal.
At 75 feet: 2 inches of coal.
At 92 feet: 18 inches of coal.
At 94 feet: 4 inches of coal.
At 128 feet: 10 inches of coal.

At a distance of 375 feet stratigraphically below the coal bed of the Wild Cat mine lies a bed 22 inches thick which is exposed in the NE. ¼ NW. ¼ sec. 5, T. 7 S., R. 13 E. Twenty-four feet below it fossil collection 8073, comprising marine Cretaceous invertebrates, was obtained. The coal bed appears to occupy the same position with reference to the underlying Cretaceous sandstones as the bed 20 inches thick exposed in the SW. ¼ NE. ¼ sec. 31, and is probably to be correlated with it. The thin beds about one-fourth mile northeast of the Wild Cat mine are probably to be correlated as shown on Plate XXVI.

Near the middle of the NW. ¼ sec. 5, T. 7 S., R. 13 E., is the opening of the abandoned mine, Old Abe No. 1. The coal here measures 46 inches in thickness and has a thin streak of bone 2 inches from its top. The bed is overlain by sandstone and 32 feet above the coal lies a second bed 12½ inches in thickness and 15 feet above that a third bed 9 inches thick. The strike of the bed in the Old Abe mine is approximately north-south, and corresponds with the strike at the Wild Cat mine. If there is no fault between the two mines the Old Abe bed lies considerably below the Wild Cat bed, and it seems not improbable from a comparison of the sections that the 9-inch bed 47 feet above the Old Abe bed is to be correlated with the

[1] This record makes note of several small beds which were not observed in surface outcrops and is probably more accurate than sections 6, 7, and 8 on Pl. XXVI, which were compiled from surface observations.

10-inch bed 65 feet below the Wild Cat bed. It seems strange, however, if these beds are really the same, that the thick bed exposed at the Old Abe mine does not appear in some of the gulches which cut the strata northeast of the Wild Cat mine. Whether the bed is thinner in this locality or is merely concealed by the overlying gravel, or whether a fault actually exists between the two mines, it is impossible to say. Just south of the Old Abe No. 1 mine a fault trending in a northeast direction with downthrow to the southeast shifts the coal outcrop 400 feet to the east. Five hundred feet south of the fault the bed is opened in the present workings of the company, Old Abe No. 2. A slope is run on the dip of the bed, which is here about 20°, and side entries driven from it, the rooms being driven up the rise from the entries and the coal cars hoisted to the surface by a whim. The coal is used in White Oaks and vicinity. A section of the coal bed in this mine is as follows:

Section of coal bed at the Old Abe No. 2 mine.

	Ft.	in.
Sandstone.		
Coal		2
Bone		1
Coal	1	½
Bone		¼
Coal		10¾
Bone		¾
Coal		4
Coal, tough		1
Coal	1	4
Shale.		
	4	¼

A sample of the entire bed was here taken and the analysis is given as No. 15053 on page 451. The Old Abe bed may be traced one-fourth mile south of the mine, but farther south for one-third mile there are no exposures.

Coal is exposed on the road in the NW. ¼ SE. ¼ sec. 5, where a bed 32 inches thick is overlain by a 30-foot bed of sandstone. The strike of this coal bed would carry it above the bed exposed at the abandoned Williams mine 600 feet farther southeast, and the Williams bed is above another bed 26 inches thick, which is exposed on the road 375 feet east of the Williams mine. There are, therefore, three beds, measuring 32, 30, and 26 inches, exposed at this locality, which may represent the three principal beds that appear to be present farther north, in the vicinity of the Old Abe and Wild Cat mines. The stratigraphic distance, however, between the two upper beds appears to be only about 70 feet, whereas that between the Wild Cat and the principal bed above it is almost 250 feet. There is a possibility that the structure may be complicated by faults which are not apparent at the surface and that the stratigraphic distances, as computed from surface measurements, may not represent the true distances between the beds. The coal at the abandoned Wells & Parker mine is separated from the exposures near the Williams mine by an intrusive sill or dike and its correlation with the coal at the Williams mine is therefore uncertain. No thick beds are exposed south of this point and north of the divide, though some thin streaks of coal appear in the pass which lies between the two mountains to the south.

Half a mile north of the Wild Cat mine the strike of the country rock changes from north-south to N. 62° W., and the sandstone bed which forms a prominent escarpment in the NE. ¼ NW. ¼ sec. 32 outcrops in the NW. ¼ NE. ¼ of the same section with a marked change in strike. As stated previously it is evident that a fault exists somewhere along the bottom of a valley which enters the main valley from the northeast. The downthrow of this fault is on the southeast side. Northwest of this fault coal is exposed at only three localities. The first locality is in the SW. ¼ NE. ¼ sec. 31, where a bed 20 inches thick appears in the bottom of a dry gulch. About one-third mile south of this locality a shaft 30 feet deep has been sunk by Mr. Price in the same gulch. A coal bed was penetrated which measures 14 inches in thickness at the shaft but which differs greatly from place to place along the short entries run from the base of the shaft. It is doubtful whether this bed is workable. A third prospect, which is separated by an intrusive dike from the bed just described, was formerly opened in the NE. ¼ SW. ¼ sec. 31 but is now so concealed by the caving of the overlying rocks that a measurement of the coal can not be obtained. It is reported that in one of the wells on the south side of the creek in the town of White Oaks a bed of coal 5 or 6 inches thick was encountered. One-half mile north of the town, on the west side of an intrusive dike, a bed of carbonaceous shale has been prospected and a third of a mile farther to the north several beds of the same material outcrop on the north side of the creek. No coal as much as 14 inches thick was found. The area of the coal-bearing rocks in this locality is very small, for in the NE. ¼ NE. ¼ sec. 25, T. 6 S., R. 11 E., dark-blue limestone, believed to be that near the base of the shale of Benton age, is exposed. There is evidently a fault between this exposure and the coal-bearing rocks east of it, the downthrow being to the east. A sandstone bed bearing plant impressions, which probably is the Dakota (?) sandstone, outcrops a little southwest of the exposure of the dark-blue limestone. This exposure must be separated by a fault from the exposure of the limestone just mentioned, as normally the Dakota (?) sandstone occurs below the limestone of Benton age. All sedimentary rocks are cut off a little west of the Dakota (?) outcrop by the intrusive mass that forms the east flank of Baxter Mountain, but the Dakota (?) sandstone again appears at the surface in sec. 35, T. 6 S., R. 11 E., where its strike is N. 15° W. and its dip 10° W. From this place the Dakota (?) sandstone swings to the northwest, west, and south, outlining a synclinal basin situated east of the great lava flow that lies west of Carrizozo. This syncline may contain near its middle a small area of coal land.

On the east flank of a synclinal mountain, 3½ miles northeast of White Oaks, two beds of coal have been mined in a small way. The lower is 16½ inches and the upper 17½ inches thick, and the two beds are 115 feet apart stratigraphically. A few rods west of the opening of the mine there appears to be a north-south fault having an upthrow on the west which brings the rocks underlying the coal to the surface. It is reported also that at the top of the synclinal mountain which lies west of the fault there are outcrops of coal, but this area was not examined in detail. No coal is reported in the general region north of this locality.

COAL BEDS OF THE REMAINDER OF THE SIERRA BLANCA FIELD.

The following notes were made during a rapid reconnaissance of the entire coal field, no attempt being made to trace coal beds from one locality to another. It is practically certain, however, that the beds described are all members of the coal group in the coal-bearing formation described on pages 10–12.

In the Tucson Mountains, 4 miles southeast of the pass between Patos Mountain and Carrizo Peak, two beds of coal are exposed in the SE. ¼ SW. ¼ sec. 26, T. 7 S., R. 13 E. They dip 19° to the northwest and strike N. 25° E. The section of the beds is as follows:

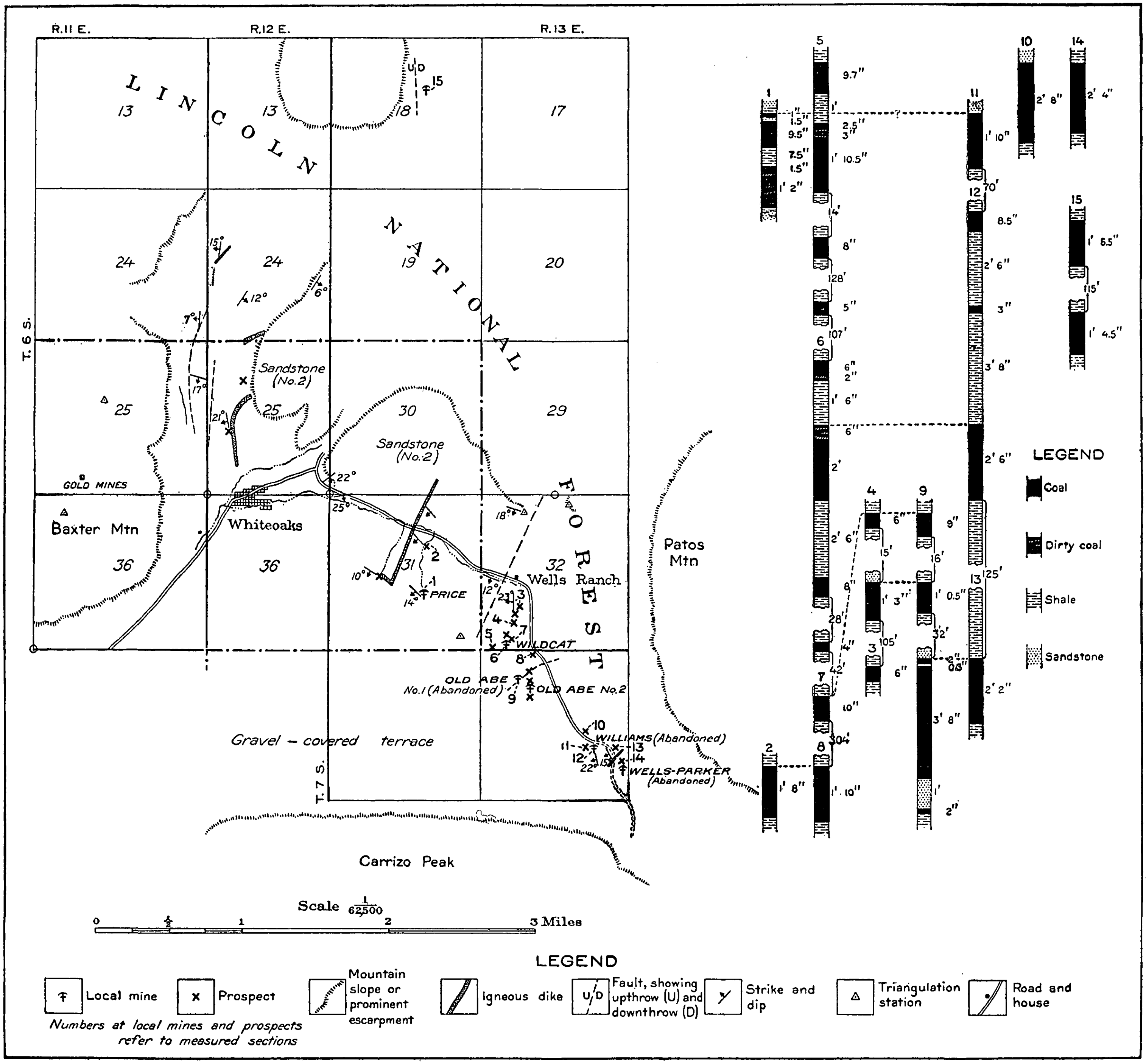
Section of coal beds in the SE. ¼ SW. ¼ sec. 26, T. 7 S., R. 13 E.

	Ft.	in.
Shale.		
Coal	3	6
Shale, covered	42	
Coal	2	
Bone		5
Coal, reported		11
Sandstone, shaly.		
	48	10

These two coal beds outcrop well up on the side of the Tucson Mountains. As the core of the mountains is apparently igneous rock, the coal area is cut off by it on the northwest.

The mines at Capitan lie about 8 miles southeast of the Tucson Mountains. The fact that two coal beds are exposed at each place suggests that they are probably to be correlated with each other, although the beds were not traced through the intervening area.

The mines known as Capitan Nos. 1 and 2 were opened on the thicker of the two beds. Both mines are now abandoned, but a section of the coal bed was measured near the mouth of mine No. 2.



MAP OF THE WHITE OAKS DISTRICT, SIERRA BLANCA COAL FIELD, N. MEX., AND SECTIONS OF THE COAL.

By Carroll H. Wegemann.

Section of coal bed at the Capitan No. 1 mine.

	Ft.	in.
Sandstone, white.		
Shale, carbonaceous		2
Coal		10
Sandstone, white		3
Coal		9
Sandstone		$\frac{3}{8}$
Coal	1	9
	3	$9\frac{3}{8}$

In the report of the coal-mine inspector for 1899 the thickness of this bed, called the Akers, is given as $3\frac{1}{2}$ to 6 feet and that of the bed known as the Ayers as $2\frac{1}{2}$ to $3\frac{1}{2}$ feet. (See p. 421.) Campbell[1] also gives the thickness of the bed at mine No. 2 as greater than that recorded in the section here given. The two beds have been opened in mines and prospects for about 3 miles along their outcrop, which lies on the west side of a considerable fault. This fault[1] passes about half a mile west of the village of Capitan in a nearly north-south direction, turns a little to the west up the valley of Magado Creek, and then south, crossing the west side of sec. 29, T. 9 S., R. 14 E. The downthrow is to the west, the coal beds being brought down to a level with the underlying formation, which forms an escarpment southeast of them, about one-half mile southwest of Capitan.

A second fault, parallel to the first and about 1 mile northwest of it, brings the coal outcrop to the surface about 3 miles west of Capitan, where it was opened in 1885 in one of the first mines of the region to supply coal for Fort Stanton. The activity of the mine was apparently of short duration. In 1901 a slope known as the Linderman mine was opened near the site of the former mine, but was soon abandoned because of the faults and the irregularity of the coal bed. From the arrangement of the old openings which may still be seen it is probable that both beds of coal exposed near Capitan are here present and were prospected.

S. T. Gray, of Capitan, is now operating a mine northeast of the old openings.

In 1899 the large mines at Capitan were opened by the New Mexico Fuel Co. They reached their greatest production, 169,440 tons, in 1901, after which year the output steadily decreased until 1905, when the mines were practically abandoned. It is reported that many intrusive dikes were encountered in the mines and that because of the difficulty of mining the coal could not compete with that from the mines at Dawson in Colfax County.[1]

[1] Campbell, M. R., Coal in the vicinity of Fort Stanton Reservation, Lincoln County, N. Mex.: U. S. Geol. Survey Bull. 316, pp. 431–434, 1907.

On Eagle Creek, in the SW. ¼ sec. 35, T. 10 S., R. 13 E., a thin bed of coal is said to outcrop, but it was not seen by the writer.

Above Charles Wingfield's ranch on the Rio Ruidoso, in the NE. ¼ NW. ¼ sec. 28, T. 11 S., R. 13 E., 8 feet of carbonaceous shale containing a thin seam of coal outcrops and has been prospected. The shale is overlain by a bed of sandstone which ranges from 4 to 8 feet in thickness. In the SW. ¼ NE. ¼ of the same section 3 feet 10 inches of coal was reported in a well at a depth of 180 feet.

On a branch of Carrizo Creek in the NW. ¼ NW. ¼ sec. 34, T. 11 S., R. 13 E., a bed of coal outcrops on a claim belonging to Paul Herman and has been prospected in a slope. The bed dips 13° NW. and strikes N. 65° E. A section measured at this locality is as follows:

Section on Paul Herman's coal claim in the NW. ¼ NW. ¼ sec. 34, T. 11 S., R. 13 E.

	Ft.	in.
Sandstone, white	15	
Shale	20	
Coal		3
Sandstone, partly covered, green and white	20±	
Shale	3±	
Coal		1½
Bone		¾
Coal; opened in slope	2	7
Shale, black, carbonaceous		2
Shale, gray	3±	
Sandstone	6	
Shale, gray	3	
Shale, black	1	
Shale, gray	2	
Coal		3
Shale, black.		

Near the base of this section is a peculiar shale conglomerate in sandstone matrix similar to that observed above one of the coal beds prospected near Capitan.

The coal bed given in the above section as 2 feet 7 inches thick is decidedly irregular. Another measurement, taken only 10 feet from the first, gives a thickness of 3 feet 3 inches. At the mouth of the prospect slope the coal bed is overlain by a basic intrusive rock, which sends a "stringer" 6 to 10 inches in width down into the coal. The strata in the vicinity seem to be much broken by intrusive dikes. In the next canyon south of the Herman prospect the Dakota (?) sandstone, the overlying shale of Benton age, and the fossiliferous beds between the Dakota (?) and the coal-bearing formation are exposed. On the west these beds are cut off by an igneous dike intruded along a fault plane; the downthrow in this locality is on the east, for the same beds outcrop at a higher elevation on the west of the dike.

Coal is exposed and has been prospected on the S. M. Johnson coal claim in the SE. ¼ sec. 33, T. 11 S., R. 13 E., but an exact measurement of the bed at this place was not obtained.

No coal is known south of Carrizo Creek, that region being occupied for the most part by rocks of Carboniferous age.

On the west side of the range, east of the Fall ranch, in the NW. ¼ sec. 28, T. 11 S., R. 9½ E., several thin coal beds are exposed, the section being as follows:

Section showing coal beds near the Fall ranch, in the NW. ¼ sec. 28, T. 11 S., R. 9½ E.

	Ft.	in.
Coal		5
Sandstone	15±	
Covered	35	
Sandstone	10±	
Coal	1	2
Shale	1	
Coal		9
Shale	1	4
Coal		4
Shale.		

The dip of the beds at the locality of this section is 14° E. and the strike S. 11° E. This strike changes abruptly, for in the SW. ¼ sec. 22, one-half mile northeast of this locality, the dip is 24° N. and the strike S. 80° E.

Whether the coal beds reported in sec. 12, T. 11 S., R. 9½ E., and in sec. 20, T. 11 S., R. 10 E., were brought to their present position by folding or faulting it is impossible to say without more detailed study.

The coal reported in sec. 16, T. 11 S., R. 9½ E., is probably the same bed as that which outcrops in sec. 28 of the same township. Coal is reported by Meinzer and also by Jones[1] 1½ miles north of Oscuro, on the west slope of Milagro Hill. Jones gives the thickness as 14 inches. The bed has been prospected by a slope.

Coal is reported in a drill record at Carrizozo at depths of 115, 220, and 300 feet. From the outcrop of the fossiliferous beds west of Carrizozo the coal outcrop of the overlying formation should lie about 1 mile west of the town. A mile west of Carrizozo and 6 miles to the south a bed has been prospected on the west side of Willow Hill and in the valley southeast of it. This bed dips eastward toward the intrusive core of the hill and as it probably represents one of the beds found at Carrizozo it is probable that a fault exists a little west of the coal outcrop. This fault, like that noted on the east side of the Sierra Blanca, would have its downthrow on the west. North-

[1] Jones, F. A., New Mexico mines and minerals, p. 105, 1904.

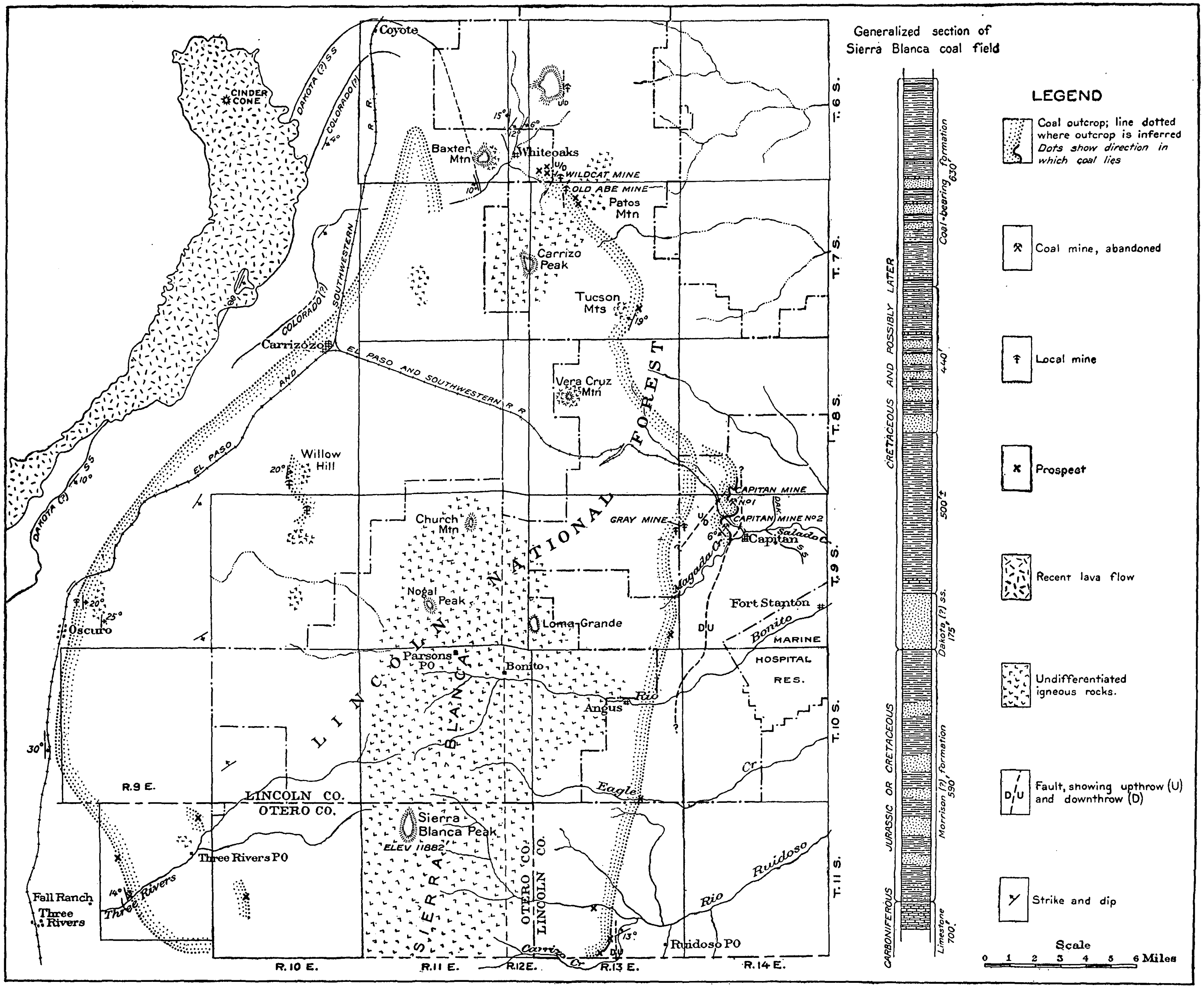
east of Carrizozo a narrow synclinal basin, which probably contains coal, lies between the outcrop of the Dakota (?) sandstone, which dips to the west on the west side of Baxter Mountain, and the outcrop of the formation underlying the coal, which dips to the east on the east side of the "malpais." The probable extent of the coal in this basin is indicated on the map, its outcrop being drawn by inference from that of the underlying beds. The coal beds are broken by intrusions in sec. 21, T. 7 S., R. 11 E., and doubtless at other places, and it seems probable that the fault mentioned on page 440 also affects them. The quality and thickness of the coal beds in this area can only be ascertained by drilling, as there are no surface outcrops.

COAL ANALYSES.

The following table gives analyses of two samples of coal from the White Oaks field. Sections of the beds from which these samples were taken are given on pages 442, 444, under the description of the coal beds from which the samples were obtained.

In the tables the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form is not well suited for comparison, because the amount of moisture in the sample as it comes from the mine is largely a matter of accident and consequently analyses of the same coal expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted for general comparison. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated. Analysis D represents the coal after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance, free from the most significant impurities. Forms C and D, which are obtained from the others by recalculation, represent theoretical conditions that do not exist.

In the analytical work it is not possible to determine the proximate constituents of coal or lignite with the same degree of accuracy as the ultimate constituents. Therefore the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only, whereas the ash (in the ultimate analysis), sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. The determination of the calorific value to individual units is not reliable, hence in the column headed "Calories" the heat values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest tens, as the value of a British thermal unit is about one-half that of a calorie.



MAP AND SECTION OF THE SIERRA BLANCA COAL FIELD, LINCOLN AND OTERO COUNTIES, N. MEX.

By Carroll H. Wegemann.

Analyses of coal samples from the White Oaks district of the Sierra Blanca coal field.

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

Laboratory No.	Name of mine.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
15053	Old Abe No. 2..	0.9	A	2.5	37.9	44.9	14.70	0.83	5.15	68.06	1.23	10.03	6,815	12,260
			B	1.6	38.2	45.4	14.83	.84	5.10	68.68	1.24	9.31	6,875	12,380
			C	....	38.8	46.1	15.07	.85	4.99	69.80	1.26	8.03	6,985	12,580
			D	....	45.7	54.3	......	1.00	5.88	82.18	1.48	9.46	8,225	14,810
15054	Wild Cat.......	1.3	A	2.5	34.6	46.0	16.86	.76	4.97	66.65	1.32	9.44	6,640	11,960
			B	1.2	35.1	46.6	17.08	.77	4.89	67.53	1.34	8.39	6,730	12,110
			C	....	35.5	47.2	17.30	.78	4.81	68.38	1.35	7.38	6,815	12,270
			D	....	43.0	57.0	......	.94	5.82	82.69	1.63	8.92	8,240	14,830

Proximate analyses of bituminous and semibituminous coal in the air-dried form (B) for comparison with that of coal from the White Oaks district.

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

Mine and field.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	British thermal units.
Mine No. 2, Dawson, N. Mex	1.5	38.2	45.4	14.9	12,670
Sugarite No. 1, Raton, N. Mex	1.7	39.0	50.2	9.1	13,350
Buck mine, Buck, Okla	1.2	34.9	56.2	7.7	13,920
Cainesville mine, Cainesville, Mo	5.6	43.1	38.4	12.9	11,450
Baby mine, Pocahontas, Va	1.0	18.2	77.1	3.7	15,350

The White Oaks coal does not "slack" or crumble on exposure and hence is above subbituminous in grade, and its calorific value of a little over 12,000 British thermal units on an air-dried sample places it in the class of bituminous coal. As will be seen from the table of comparisons given above, it compares well with the Dawson coal but is inferior in heating value to the coal from Raton. It is better coal than that from Cainesville, Mo., but is inferior to some of the Oklahoma coal. It is low in sulphur but high in ash and in oxygen, both of which reduce its heating value.[1] A general idea of its heating value in comparison with that of the semibituminous coal of the East may be obtained from the analysis of the Pocahontas coal given in the above table.

DIFFICULTIES OF MINING.

The principal drawbacks to mining in the Sierra Blanca coal basin are the interruption of the coal beds by intrusive dikes of igneous rock, the presence of numerous faults, and the thinning of the beds in many places owing to movement along bedding planes.

[1] White, David, The effect of oxygen in coal: U. S. Geol. Survey Bull. 382, 1909.

Intrusive dikes encountered in mining are difficult to penetrate; they may be many feet in thickness and the coal bed which they interrupt may have undergone movement along the plane of the intrusion, so that the coal on one side of the dike may not be directly opposite that on the other.

Some intrusions are said to have injured the coal adjacent to them. C. A. Fisher mentions an example in the Capitan mines of the alteration of the coal adjacent to an igneous intrusive to "a so-called coke or slag, which is noncombustible."[1]

In the present examination the writer did not observe this phenomenon. At one of the prospects near Carrizo Creek a bed of coal is cut by a small intrusive dike about 12 inches wide, but no alteration of the coal adjacent to the dike seemed to have occurred. At the Wells & Parker coal mine, southeast of White Oaks, the presence of the igneous sill does not appear to have materially affected the coal 4 feet below it.

The location of intrusive dikes may often be detected, even on a soil or gravel covered surface, by the presence of igneous bowlders and pebbles which weather out of the underlying rock. The occurrence of a few igneous pebbles has little significance, but their presence in great numbers in certain well-defined bands can usually be relied on as an evidence of an underlying igneous rock.

The larger faults can as a rule be recognized at the surface, but many of the smaller ones are concealed. They make mining difficult not only by displacing one part of the bed with reference to the other, and ending the coal abruptly against a face of rock, but also, where the displacement is slight, by fracturing the coal, and thus increasing greatly the percentage of slack in the product of the mine.

In many places the coal beds are locally thinned by earth movements which have caused the sedimentary strata to slide one over the other. As the coal beds are relatively soft and easily crushed they have furnished planes of easy movement along which much of this readjustment of the strata has taken place. As a result the coal is in many places so crushed as to increase greatly the amount of "slack" and the thickness of the bed is rendered inconstant, the coal being "bunched" in some places and in others practically obliterated.

[1] Fisher, C. A., Coal fields of the White Mountain region, N. Mex.: U. S. Geol. Survey Bull. 225, p. 294, 1904.

COAL NEAR THOMPSON, GRAND COUNTY, UTAH.

By Frank R. Clark.

INTRODUCTION.

The area here described lies about 5 miles north of Thompson, Utah, and comprises about 4 square miles of the Book Cliffs coal field, which lies north of the Denver & Rio Grande Railroad. Owing to the recent commercial development of the coal this examination was made in the early part of July, 1913,[1] for the purpose of collecting data for an intelligent, well-founded classification and valuation of the land. Most of the coal lies in three beds, which range in thickness from 1 foot to 6 feet. The lower and middle beds are very irregular in thickness and character, being badly split by shale and bone partings, but the upper bed is comparatively free from these impurities. The distance between the three principal coal beds that are present in this area differs greatly from place to place, showing no definite increase or decrease in any particular direction.

The Book Cliffs coal field extends in a general northwestward direction from Grand River, Colo., to Castlegate, Utah, a distance of about 175 miles. Thompson, Utah, a station on the Denver & Rio Grande Railroad (see fig. 17), lies about midway between Sunnyside, Utah, and the Colorado State line. The area here described consists of secs. 27, 28, 33, and 34, in T. 20 S., R. 20 E., Salt Lake base and meridian. The coal, which is bituminous, is mined under the trade name of Bear coal by the American Fuel Co. of Utah, which began its operations in March, 1912. The post office, established at the mine, is Neslen.

The writer was assisted in the field examination by H. Clark, of Thompson, Utah. Mr. Thomas, the superintendent, and other mine officials were very courteous and gave many interesting facts connected with their mining operations and the difficulties they have had to overcome in the development of their properties.

[1] Although this work was done in 1913, the unavoidable delay in the publication of the Survey's annual volume including short reports on work done during that year has made it desirable to include this report in the volume for 1912.

PREVIOUS WORK.

The previous geologic reports [1] on the Book Cliffs coal field, or portions of it, dating as far back as 1878, deal with the geology and

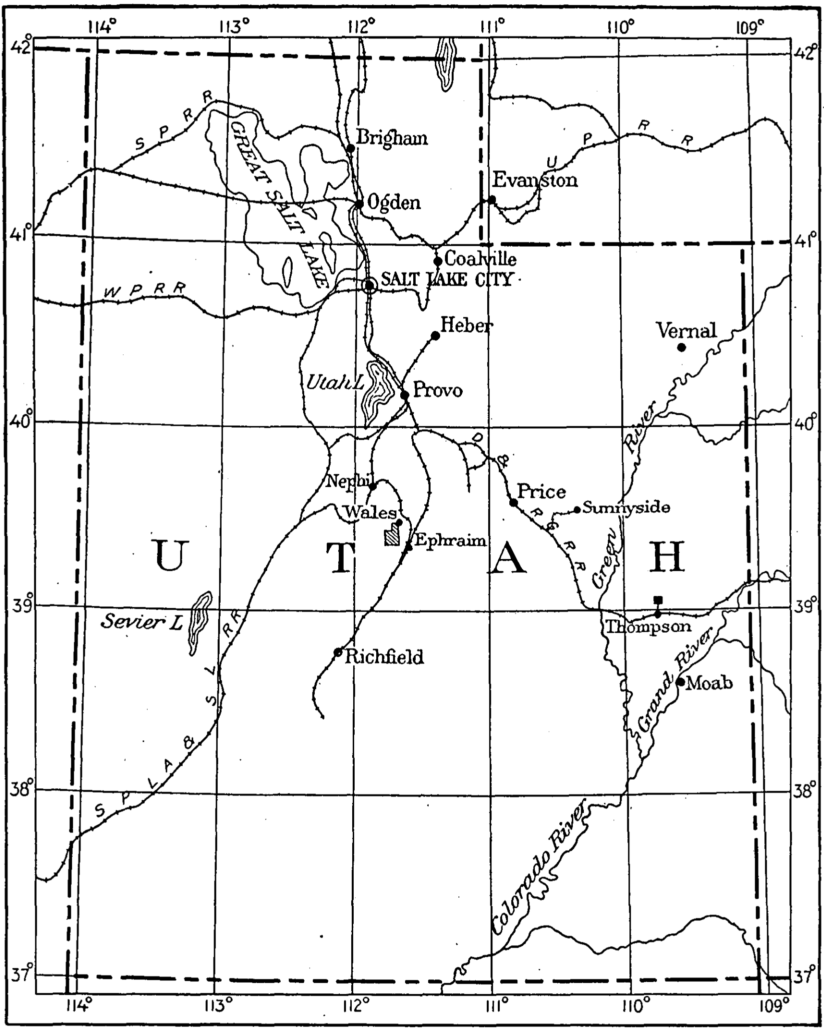


FIGURE 17.—Map of Utah, showing location of Thompson and Wales coal fields.

coal resources in a broad way and contain no mention of this small area. G. B. Richardson [2] in 1909, however, published a report of a

[1] Peale, A. C., Geological report on the Grand River district: U. S. Geol. and Geog. Survey Terr. Tenth Ann. Rept., pp. 170–185, 1878. Hillis, R. C., Coal fields of Colorado: U. S. Geol. Survey Mineral Resources, 1892, p. 353, 1893. Eldridge, G. H., Asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 1, p. 332, 1901. Storrs, L. S., The Rocky Mountain coal field: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, p. 436, 1901. Lakes, Arthur, The Book Cliffs coal mine: Mines and minerals, vol. 24, pp. 289–291, 1904; The Grand River coal field: Min. Reporter, vol. 51, pp. 379–381, 1905. Taff, J. A., The Book Cliffs coal field west of Green River, Utah: U. S. Geol. Survey Bull. 285, pp. 289–302, 1906.

[2] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, p. 37, 1909.

very rapid reconnaissance survey of the Book Cliffs coal field from Grand River, Colo., to Sunnsyide, Utah, which deals with the broader features of the geology and coal resources of this area. He states that more development had been done in this area than in any other part of the Book Cliffs in Utah considered in his paper, but this early development amounted to little more than propsecting.

FIELD WORK.

The field examination was made by the writer in great detail and with considerable care. The coal-bearing strata were very thoroughly prospected with pick and shovel and the beds were opened at many points, at each of which the character of the coal was noted and careful measurements of the thickness of the bed and the various partings were made. The coal outcrops were meandered with plane table, telescopic alidade, and stadia rod, and all points at which the coal was examined, as well as many intervening points on the outcrop, were carefully located. The horizontal control was furnished by corners established by the General Land Office. The altitude of all points located was also determined by vertical angles. The initial altitude, 5,730 feet, was taken from a bench mark on the railroad just south of the coal jigs or washers, so that the elevations are all referred to the sea-level datum plane.

LAND SURVEYS.

The four sections (27, 28, 33, and 34) included in this area are the only subdivisions that have been made in T. 20 S., R. 20 E. The survey was made in October, 1907; the corner stones are plainly marked, and the writer's traverses indicate that they were accurately located. No discrepancies were found between the actual position of the corners and the position shown by the Land Office plat.

The American Fuel Co. of Utah, whose coal mine is located in sec. 27, have recently completed a very careful transit and chain survey of their lands in this vicinity and have set posts at all of the "forty" corners embraced within their property. A number of these private posts were located during the investigations covered by this report and are shown on the map (Pl. XXVIII, p. 468).

TOPOGRAPHY.

RELIEF.

The topography of the Book Cliffs is characterized by a series of nearly perpendicular sandstone ledges alternating with sloping shale benches. Here and there the bold southward-facing escarpment has been deeply trenched by streams, forming more or less narrow steep-sided canyons that range from one to several miles in length. The area herein described lies in the drainage of Thompson Creek, a typical canyon stream, which with its branching short steep-sided gulches has very thoroughly dissected the Book Cliffs.

The Book Cliffs north of Thompson are divided topographically into two parts, a lower and an upper escarpment, separated by a broad shale bench. Near the railroad on the north is the lower perpendicular sandstone escarpment, about 75 feet high, which forms an impassable barrier except where erosion has worn it away. Above and back of this ledge extends a nearly flat surface which is sparsely covered by "scrub" cedars, sagebrush, and some grass. North of this bench rises very abruptly the upper escarpment of the Book Cliffs in which the coal beds are found. At the base of this escarpment throughout this area occurs a nearly perpendicular ledge about 100 to 150 feet high, above which alternate relatively thick, nearly perpendicular sandstone ledges and thin sloping shale benches.

The elevations above sea level in the area under discussion range from about 5,300 feet in the bed of Thompson Creek to about 8,000 feet on the divides. The total relief is thus about 2,700 feet.

DRAINAGE.

This area is drained primarily by two main southward-flowing streams, Thompson Creek and the Right Fork, together with numerous short gulches which contain running water only during heavy rains or the season of melting snows. The two main streams are, however, perennial, though the water seldom flows, except in time of floods, beyond a point just below the south line of sec. 33.

The Denver & Rio Grande Railroad owns the water of Thompson Creek, and has a 7-mile pipe line which carries the water from its source in the canyon to storage tanks on the railroad at Thompson. The water from the Right Fork of Thompson Creek is owned and used by the American Fuel Co. of Utah for their coal-mining camp at Neslen, in sec. 27.

STRATIGRAPHY.

The beds exposed in this region are considered from the best evidence now available to be of Upper Cretaceous age, and to belong to the Mesaverde formation and the Mancos shale. The coal is found in the lower part of the Mesaverde formation.

The columnar section shown on Plate XXVIII (p. 468) gives the general character of the beds exposed in this area. The section, except that part containing the coal beds, which is drawn from measurements made between locations 14 and 61 in the center of sec. 27, is reproduced from Richardson's report on the Book Cliffs coal field, Utah. The section as a whole is more or less generalized, but that part which includes the coal-bearing strata was measured in this area. The amount of coal shown in this section is doubtless too great, as all these beds are probably not present in all parts of the Neslen district.

The Mesaverde formation, which overlies the Mancos shale, is essentially of brackish or fresh water origin and consists of a series of alternating beds of buff sandstone and gray shale with the amount of sandstone greatly in excess of the shale except in the coal-bearing portion. The sandstone is composed of quartz grains with some mica. The shales are more or less sandy, but in the vicinity of the coals contain some carbonaceous material.

The Mancos shale, which possesses certain well-defined characteristics, lies beneath, and in this area outcrops to the south of the coal-bearing strata. It is a marine clay shale, bluish gray to drab in color, and differs but little either in color or character except in its upper part, where it is more sandy and in places contains lenses of impure limestone.

Richardson, in his report on the Book Cliffs coal field, draws the contact between the Mesaverde formation and the Mancos shale at the base of the lower sandstone cliff shown on the map.

STRUCTURE.

The structure of that part of the Book Cliffs field discussed in this paper is very simple and regular. The beds dip gently (2°–3°) north or slightly northeast. The dips and strikes recorded on the map are based on actual measured differences in elevation of points along the outcrop of the same coal bed and not on mere generalized observations.

The area is practically free from faults, only one having been observed, a block fault, which extends across the SW. ¼ sec. 28 in a northwest-southeast direction. The fault planes inclose a small lenticular block, one edge of which is broken off and the other edge appears at location 5 in the SE. ¼ SE. ¼ SW. ¼ sec. 25. The maximum width of the block as shown 300 feet west of location 29, in the NE. ¼ SW. ¼ sec. 28, is 200 feet. Northward from this locality the width of the block decreases until at location 2, in the NE. ¼ NW. ¼ SW. ¼ sec. 28, it is but 40 feet. This block has dropped with reference to the adjoining strata, and the vertical throw was measured at a number of points as follows: At location 5 the throw is but a few feet, and the fault disappears not far south of this point. The throw on the west side of the block at location 4, in the N. ½ SE. ¼ SW. ¼ sec. 28, is 10 feet, whereas at location 31 it is 20 feet on the west side and only 5 feet on the east side of the block. The maximum throw is not far north of these points and probably does not exceed 30 feet. At location 2, in the NW. ¼ SE. ¼ SW. ¼ sec. 28, there is practically no vertical throw, the fault planes being marked simply by broken or crushed sandstone, and beyond this point northward there is no evidence whatever of any displacement. The presence of this fault can have little effect on the future development of the coal, as practically all the coal that is under sufficient cover to be of economic value lies east of the fault.

THE COAL.

GENERAL FEATURES.

The coal beds lie nearly flat and hence they have sinuous outcrops which retreat far into the plateau where they cross the stream valleys and which project on every spur out to the extreme front of the cliffs. Three continuous coal beds are exposed throughout the area, and the outcrop of each is represented on the map (Pl. XXVIII, p. 468) by a full line. These outcrops were meandered with a plane table, Gale telescopic alidade, and stadia rod. Altitudes of most of the coal sections measured were obtained by vertical angles. A list of these altitudes is given below:

Altitudes of bottom of coal bed at localities where sections were measured in area near Thompson, Utah.

Bed A.		Bed B.		Bed C.	
No. of locality:[1]	Feet.	No. of locality:[1]	Feet.	No. of locality:[1]	Feet.
1	5,743	26	5,784	51	5,786
2	5,772	27	5,835	52	5,857
3	5,797	28	5,856	53	5,883
4	5,834	29	5,890	54	5,913
5	5,845	30	5,880	55	5,914
6	5,848	31	5,923	56	5,938
7	5,878	32	5,917	58	5,964
8	5,903	33	6,005	59	5,955
10	5,852	34	5,911	60	5,894
11	5,832	35	5,919	61	5,854
12	5,838	36	5,881	62	5,908
13	5,810	37	5,876	63	5,947
14	5,779	39	5,823	64	5,975
15	5,853	40	5,889	65	5,974
16	5,848	41	5,915	66	5,967
17	5,917	42	5,943	67	6,071
18	5,961	43	6,012	68	6,064
19	5,977	44	6,010	69	6,083
20	5,973	45	6,033	70	6,118
21	5,999	46	6,070	71	6,123
22	6,047	47	6,102	72	6,142
23	6,069	48	6,087	73	6,155
24	6,025	49	6,115	74	6,207
25	6,143	50	6,167		

The three beds are here designated by the letters A, B, and C, A being the lowest and C the highest bed. Measurements of the coal in these beds were made at many places on the outcrop and the results are shown graphically on Plate XXVIII. The locations of the coal sections on the map are numbered consecutively from left to right along the outcrop, beginning with No. 1 on bed A at the extreme northwest corner of the area. The numbers used to mark the location of the coal sections on the map are also used to designate the corresponding graphic section.

[1] See map, Pl. XXVIII, p. 468.

At a number of places local thin, seemingly isolated lenses of coal occur above and below each of the three principal beds, but the available information regarding these lenses does not justify an attempt to correlate one exposure with another or to assume the bed to be continuous between any two.

The presence of rocks more or less altered by the burning of the coal is very common in many localities in the Book Cliffs field, but in the area under discussion only three places were found where the coal has been burned. Beds B and C are burned for a short distance north of locations 27 and 52 in sec. 28. Another burnt area lies south of location 57, in sec. 28, and in the NE. ¼ sec. 33. Evidence of local burning was also found in the E. ½ SE. ¼ sec. 34.

COAL BED A.

Bed A is stratigraphically the lowest bed whose outcrop is shown on the map (Pl. XXVIII), and it is believed from the evidence at hand to be a continuous bed throughout the area. The exposures are good and a casual examination creates the impression that the bed maintains a fairly constant thickness over the entire area. A detailed study of the graphic sections, however, demonstrates great irregularity in the thickness of the coal and the character of the bed.

Twenty-five detailed sections of coal bed A were measured and are designated on the map by numbers 1 to 25, inclusive, arranged consecutively along the outcrop from north to south. They show a range in thickness from 2 feet 7 inches at location 1 to 6 feet 2 inches at location 14, including partings at both places. The coal bed is generally overlain by shale or sandy shale, which in turn is overlain by a buff sandstone, but in places this sandstone rests directly on the coal. This sandstone contains many joint planes, is indurated and thinly bedded, but is extremely irregular in thickness and character as well as occurrence. Where the sandstone is thinnest it weathers into rectangular blocks, ranging from 3 to 6 feet long by 2 to 8 inches on the side; in the thicker parts of the sandstone these blocks weigh several tons. The floor of bed A is almost universally shale or sandy shale, but in some places the coal rests on a few inches of bone or carbonaceous shale. The variations in the character of the roof and floor of bed A are very well shown in the sections on Plate XXVIII.

Bed A is generally separated into two or more benches. In many places the upper bench, containing from 5 to 10 inches of coal, is separated from the rest of the bed by 3 to 10 inches of yellow clay. South and east along the outcrop from location 1 to location 9 the bed shows a wide range in the number and arrangement of partings and in the total thickness of coal, even between adjacent sections. There is no apparent regularity in this change in any direction. The difference shown in three sections measured in a single continuous exposure at location 9 affords a good example of what may be expected to occur in any of these coal beds. The coal bed in this exposure, which is about 60 feet in length, contains a shale parting that increases toward the south from 4 inches to 4 feet, but the two benches of coal remain approximately of the same thickness. Sections 10 and 11 both show bed A to be split into two benches by 6 inches of shale. The total thickness of coal in sections 9, 10, and 11 ranges from 3 feet 6 inches to 3 feet 11 inches. Southeast of location 12 the coal bed consists of two benches. The lower bench ranges in thickness from 3 feet 10 inches to 4 feet 11 inches and as far southeast as a point in the vicinity of location 23 is only locally split by partings. The upper bench of bed A, between locations 12 and 22, is separated from the lower by 6 to 10 inches of clay or shale. This part of the bed is variable in character and thickness, being represented in many places by only a thin bed of carbonaceous shale. The coal in this bench at no place exceeds 10 inches in thickness. South of location 23 the sections measured at locations 24 and 25 show bed A to be very badly split by partings. (See Pl. XXVIII.) The chemical composition of this coal is shown in the table of analyses on page 470 (No. 17578).

LOCAL THIN LENSES ABOVE AND BELOW COAL BED A.

At several localities thin beds of coal (6 inches to 1 foot 8 inches in thickness) are exposed at distances ranging from 3 feet 6 inches to 16 feet below bed A. At location 9 coal 6 inches in thickness is exposed, representing, it is believed, the same bed as the 20-inch bed below bed A at location 11. The exposures at location 15 do not show any coals below bed A, but several streaks of carbonaceous shale are exposed below it at location 17. One or more of these shale beds may be the equivalent of the 10-inch bed of coal at location 16, or of the 17-inch coal at location 18, both of which lie below bed A. At location 24 the 15-inch bench of coal at the top of the section is overlain by 2 inches of ash, showing that part of this bench has been locally burned. At a distance of 1 foot 2 inches above this 2-inch ash bed another bed of ash one-half inch thick outcrops and is overlain by shale and clay. The following list of sections gives the character and thickness of the thin beds below bed A and also the distance between bed A and certain other local lenses not mentioned in the above discussion:

Sections of coal beds or lenses below bed A in secs. 27, 28, and 34, T. 20 S., R. 20 E.

Location 3.

	Ft.	in.
Coal bed A.		
Interval	8	
Shale.		
Coal, impure	1	4
Shale.		
Total coal	1	4

Location 11.

	Ft.	in.
Coal bed A.		
Interval	6	8
Clay.		
Coal, bright	1	8
Total coal	1	8

Location 12.

	Ft.	in.
Coal bed A.		
Interval	15	6
Clay.		
Coal	1	8
Bone		3
Shale	2	
Total coal	1	8

Location 14.

	Ft.	in.
Coal bed A.		
Shale, carbonaceous	1	2
Shale, sandy	2	
Coal, bright		8
Shale, sandy	4	6
Shale, clay	5	
Coal, bright	1	3
Bone		9
Shale	3+	
Total coal	1	11

Location 16.

	Ft.	in.
Coal bed A.		
Shale, sandy	4	
Coal		10
Shale, slightly carbonaceous	5	
Clay	4	
Shale, carbonaceous	1	8
Coal		6
Shale.		
Total coal	1	4

Location 18.

	Ft.	in.
Coal bed A.		
Shale, sandy	4	
Coal	1	5
Shale.		
Total coal	1	5

Location 20.

	Ft.	in.
Coal bed A.		
Shale, sandy	3	
Clay	3	
Coal, bright	1	1
Shale, sandy	2	
Interval	12	
Coal		11
Shale, sandy	3	
Total coal	2	

Location 21.

	Ft.	in.
Coal bed A.		
Shale	1	6
Clay	6	
Sandstone, buff	4	
Coal		6
Shale	3	
Shale, sandy	14	
Clay	3	
Shale, carbonaceous		5
Coal		4
Shale	3	
Total coal		10

Location 23.

	Ft.	in.
Coal bed A.		
Clay	3	6
Coal		10
Shale.		
Total coal		10

From the available data it is impossible to say with certainty whether or not the beds given in this list represent "splits" from bed A or whether they are merely local thin lenses which have no direct connection with bed A or with one another. It is believed, however, that some of the sections of coal below bed A represent the same bed, which is probably local and of very little economic importance.

There are only two places (locations 14 and 20) where coal was found in outcrops between beds A and B. At location 14 coal 1 foot 8 inches in thickness is exposed 16 feet 9 inches stratigraphically above bed A, and at location 20 the following section was measured 15 feet stratigraphically above bed A:

Section of coal measured at location 20, 15 feet above bed A, in the NW. ¼ SE. ¼ NE. ¼ sec. 34, T. 20 S., R. 20 E.

	Ft.	in.
Clay	3	
Coal		7
Bone		3
Coal		4
Shale.		
	4	2

These sections may or may not belong to the same bed, but no other exposures were observed in this area at this horizon, and it seems probable that they represent only local lenses. They have no immediate commercial value.

COAL BED B.

Coal bed B is the first continuous coal bed above bed A. The distance between beds A and B ranges from 45 to 100 feet, with the maximum at locations 27, 33, and 43, and the minimum at locations 36, 39, and 44. There is no apparent constant change in this interval in any given direction but merely an irregular variation from place to place. Bed B is overlain by a massive sandstone, but most of the coal sections show an intervening layer of softer material which ranges in thickness from a few inches to 1 or 2 feet. This roof material is in some places bone, in others a mass of alternating thin lenses of shale and coal, and in others carbonaceous shale, clay, shale, or sandy shale. The sandstone is massive or heavy bedded, buff to gray in color, and from 5 to 20 feet in thickness. It does not everywhere lie in a perfect plane but locally shows slight undulations or rolls. It rests directly on the coal at a few places and in others it may cut out parts of the coal.

The floor material of bed B is universally a shale or sandy shale, but the coal in a few of the sections examined is separated from the shale floor by a few inches of bone.

The coal of bed B is black in mass and in places shows an apparent banding, which is due to the alternating beds of vitreous and dull coal. It is characterized by the more or less regular right-angled joint planes, which show very distinctly wherever the coal is freshly exposed. Bed B is sometimes known as the Ballard coal, receiving this name from the fact that several years ago a man named Ballard opened a local mine in sec. 27 which produced some coal.

Twenty-three detailed sections (Nos. 26 to 50, inclusive, on Pl. XXVIII) were measured on this bed at points along the outcrop from north to south at distances ranging from 500 feet to one-half mile apart. They are all, except sections 31 and 33, given on Plate XXVIII, and show that the bed is very badly split by partings of bone and shale. As the exposures are very good the true character of the bed is probably indicated by these sections. Out of all the measurements made no two are identical, and the thickness of the coal ranges from 1 foot 8 inches at location 46 to 6 feet 6 inches at location 40, with many different thicknesses between these limits. The bed is so irregular in thickness and character, and the thickness and extent of the partings so changeable, that mining it becomes a very uncertain and expensive operation.

Bed B at location 28 consists of two benches. The upper bench, containing 2 feet 8 inches of coal, is separated from the heavy-bedded sandstone above by 8 inches of coal and shale occurring in interbedded "knife-blade" lenses. The lower bench, consisting of 4 inches of coal underlain by 3 inches of bone, is separated from the upper bench by 2 feet 4 inches of brown shale. At location 29 the brown shale separating the two benches is 4 feet 6 inches thick, and the lower coal bench is here represented by only 9 inches of bone underlain by brown shale. For those reasons only the upper bench at locations 28 and 29 is shown graphically in the sections on Plate XXVIII, but it is believed that the lower bench at these localities is the same as the lower 9-inch bench of coal at locations 30 (in the W. ½ NW. ¼ SE. ¼ sec. 28) and 32 (in the NW. ¼ SW. ¼ SE. ¼ sec. 28). Section 32 (Pl. XXVIII) is a characteristic section of bed B. The top 6 inches of impure coal is made up of many "knife-blade" lenses of coal and shale interbedded, a material associated with bed B at many places throughout this area, in some places forming the roof of the coal and in others occurring as partings between benches. The upper bench, which constitutes the main part of bed B, has been burned out at location 33, leaving only the lower bench of 10 inches of coal exposed, which is probably the same as the 16-inch bench at the base of the section at location 34.

The extremely variable character of bed B is well illustrated by the exposures in the vicinity of locations 48 and 49, where the bed is split into two main benches, the upper of which is again divided by thin partings into three benches. This latter splitting, however, may be entirely local. Section 48 is shown on Plate XXVIII.

The upper bench diminishes in thickness toward the east from location 48 until it wholly disappears some 700 feet from that point, the position of the coal being occupied by a heavy bedded sandstone. The upper bench reappears at location 49 but is only 4 inches thick. The outcrop of bed B between locations 49 and 50 does not show a continuous exposure, but at location 50 the bed contains two benches, the upper 14 inches thick and the lower 2 feet 1 inch thick, the two being separated by 1 foot 9 inches of brown shale.

The developments of the American Fuel Co. of Utah prove the bed to possess the same irregular character under cover that it is shown to have along the outcrop by the sections on Plate XXVIII. The chemical properties of this coal are shown in the table of analyses on page 470 (No. 17577F). The sample from bed B was taken from mine No. 1–A on the east side of the creek in the NE. ¼ SW. ¼ NW. ¼ sec. 27, at a point 1,200 feet east and slightly south from the mouth of the mine. The point in the mine from which the sample was taken is designated on the map by location 38.

COAL BED C.

Bed C is the next bed stratigraphically above bed B. The distance between beds B and C ranges in extreme cases from 15 to 50 feet, but at most places it is between 30 and 50 feet. This irregularity may be explained in part by the change in thickness from place to place of the heavy bedded sandstone overlying bed B. Where this sandstone attains its greatest thickness it makes up fully half of this interval (the other half being shale and sandy shale), whereas at other points it is not more than 4 or 5 feet thick. Bed C, at most places where sections were measured, is overlain by a shale or sandy shale, but at a few places sandstone rests immediately on the coal or within 2 or 3 feet of the top of the coal. The coal is black, massive, jointed, and stands up under weathering for a considerable length of time. Although there was no opportunity to obtain an unweathered sample for chemical analysis, the physical properties suggest that it is as good a grade of fuel as the coal from either bed A or bed B. Twenty-four detailed sections (Nos. 51 to 74, inclusive) of this bed were measured along its outcrop and 23 of these are shown on Plate XXVIII.

Bed C differs decidedly from beds A and B in the absence of shale and bone partings and in the more nearly constant thickness of the coal, which averages about 4 feet. At location 64 it is only 1 foot 11 inches thick, but the bed at every other point measured contains not less than 3 feet 6 inches, and at several localities as much as 5 feet or more of good clean coal. The character and thickness of this bed are so well shown on Plate XXVIII that little need be said here. The only section omitted from the plate is section 62, which is practically identical with section 63. The one condition likely to hinder the development of this coal is the generally shaly character of the roof, which is less stable than the sandstone roof of beds A and B. The floor material of bed C is everywhere shale or sandy shale. It is believed, however, that bed C holds out more favorable inducements for extensive future development than either bed A or bed B.

LOCAL COALS ABOVE BED C.

At many places exposures show a number of coal beds lying above bed C at distances ranging from 1 foot 5 inches to 16 feet. The coal in these lenses ranges in thickness from 7 inches to 3 feet 11 inches. At location 51 a thickness of 1 foot 3 inches of bone is exposed above bed C, which is believed to be the equivalent of the 15-inch bed of coal outcropping 10 feet 8 inches stratigraphically above bed C at location 52. At a distance of 20 feet stratigraphically above bed C, at location 55, bony coal 1 foot 2 inches in thickness is exposed. The interval between bed C and the bony coal is occupied by shale and clay except for a 6-foot bed of friable sandstone separated from bed C by 2 inches of clay. About 300 feet west along the outcrop from location 56 coal 1 foot 2 inches in thickness is exposed about 8 feet stratigraphically above bed C. The intervening material here is composed of gray clay. At location 61 the following section, containing two thin lenses of coal, was measured 50 feet stratigraphically above bed C:

Section of coal beds measured 50 feet stratigraphically above bed C at location 61.

	Ft.	in.
Shale, gray	3	
Coal		3
Clay, gray	8	
Coal		10
Shale, brown	1	6
	13	7

Several beds of carbonaceous shale are exposed at location 63 above the 14-inch bed in the list given below. These shale bands probably represent some of the topmost coals exposed above bed C at location 61. The following list gives the thickness of these beds at each locality and the distance between bed C and the coal above it.

Sections of coal beds stratigraphically above bed C in secs. 27, 28, and 34, T. 20 S., R. 20 E.

Location 52.

	Ft.	in.
Sandstone, buff, massive	10	
Shale and coal interbedded		3
Coal, bright		6
Shale and coal lenses interbedded		3
Shale		3
Clay	3	
Sandstone, massive	7	
Shale, sandy	1	
Shale, carbonaceous		8
Coal	1	3
Shale, sandy	4	
Bone	1	
Interval, clay	5	8
Coal bed C.		
Total coal	1	9

Location 54.

	Ft.	in.
Clay.		
Coal		4
Bone		6
Shale, brown	1	
Clay, gray	5	
Shale	2	
Coal		7
Shale.		
Interval	5	
Coal bed C.		
Total coal		11

Location 58.

	Ft.	in.
Shale.		
Shale, carbonaceous		7
Coal		9
Bone		8
Shale	1	5
Coal bed C.		
Total coal		9

Location 59.

	Ft.	in.
Shale.		
Bone		5
Coal		7
Shale.		
Interval	6	4
Coal bed C.		
Total coal		7

Location 60.

	Ft.	in.
Shale	2	
Shale, carbonaceous		6
Bone		2
Coal	2	3
Shale.		
Interval	7	4
Coal bed C.		
Total coal	2	3

Location 61.

	Ft.	in.
Shale.		
Bone		6
Shale, sandy		1
Coal	1	6
Shale, sandy	5	6
Coal	1	9
Shale, sandy	2	7
Coal bed C.		
Total coal	3	3

Location 62.

	Ft.	in.
Sandstone	5	
Clay	12	
Sandstone	1	6
Clay	1	3
Shale, carbonaceous	1	6
Clay, gray	24	
Coal	1	2
Clay, gray	2	2
Bone		10
Shale, gray	1	8
Coal bed C	3	6
Total coal	4	8

Location 63.

	Ft.	in.
Clay, gray	8+	
Shale, carbonaceous	1	3
Coal	1	2
Clay, gray	8	
Coal bed C.		
Total coal	1	2

Location 67.

	Ft.	in.
Clay, gray.		
Bone		6
Coal	3	
Shale.		
Interval	12	2
Coal bed C.		
Total coal	3	

Location 68.

	Ft.	in.
Sandstone, thinly bedded	2	
Clay	3	
Shale, carbonaceous	2	
Clay	5	
Coal, impure	2	
Bone	1	
Clay.		
Interval	16	
Coal bed C.		
Total coal	2	

Location 69.

	Ft.	in.
No coal exposed above this shale.		
Shale, slightly carbonaceous	2	
Clay	3	
Coal	1	4
Bone		10
Shale.		
Interval	7	2
Coal bed C.		
Total coal	1	4

Location 70.

	Ft.	in.
Shale.		
Coal	1	6
Shale.		
Interval	5	
Coal bed C.		
Total coal	1	6

Location 71.

	Ft.	in.
Sandstone	6	
Shale, sandy		4
Coal, impure		4
Shale, gray		2
Coal		11
Shale, carbonaceous		4
Coal		6
Interval	4	
Coal bed C.		
Total coal	1	9

Location 72.

	Ft.	in.
Sandstone	15	
Coal		7
Shale, sandy		2
Coal		4
Shale, carbonaceous		8
Interval	6	11
Coal bed C.		
Total coal		11

The available data are not sufficient to warrant a definite correlation of these local beds, but it is suggested that the coals exposed above bed C at locations 58 to 63, inclusive, may really belong to one bed, although there is no definite rock stratum traceable at the surface which assures such a correlation. Between locations 63 and 67 none of these beds are exposed, but from locations 67 to 72, inclusive, there is another series of coal exposures above bed C which may also all belong to the same lens or bed, though they may or may not belong to the beds above bed C at locations 58 to 63. All this, however, is mere speculation and is made merely as a tentative suggestion.

PHYSICAL CHARACTER AND CHEMICAL COMPOSITION.

The coal of this area is bituminous in grade and black in color. Much of it exhibits a banded appearance, due to the presence of alternating dull and vitreous layers. In many exposures the coal is a hard massive bed with no evidence of bedding or cleavage planes within the coal itself. In general, however, it is cut by a system of prominently developed right-angled joints, which aid much in producing a high percentage of "lump" when the coal is mined, many of these "lumps" being too large to be easily handled by one man. The coal contains hard and soft layers in places, but as a rule it is dense and hard to pick. The common feature of beds A and B is the bone and shale partings, which split the coal bed so as to materially reduce its value. Bed C is characterized by the absence of partings. The marked jointing present in the coal is best developed along its outcrop, and on weathering it breaks into small cubical blocks and finally into a dark-brown to black powder.

The coal is relatively low in moisture, ranging from 6 to 7 per cent as mined. The low moisture content is responsible for the slow weathering or disintegration of the coal on exposure to the atmosphere. Coal which had been lying in heaps exposed to the weather for a year or more was practically unaltered in appearance. It is therefore of very good stocking quality.

The coal of bed A in the ground is black and massive but breaks into large blocks when mined; its powder is brown, and it showed coking qualities when the Pishel[1] coking test was applied.

The following analyses give the composition of samples from beds A and B. Sample No. 17577F from bed B was taken in a mine in active operation, No. 1–A (in the NE. ¼ SW. ¼ NW. ¼ sec. 27) of the American Fuel Co. of Utah. Sample No. 17578 from bed A was taken in a prospect which had just been opened at location 14, at a point 85 feet from its mouth. This place is probably beyond the zone of appreciable weathering and therefore these two samples represent the freshest coal available. The samples were obtained by cutting a channel across the bed and excluding those portions so indicated in the following sections:

Sections of coal bed sampled in mine No. 1–A and in prospect at location 14.

Mine No. 1–A, 1,200 feet east of opening.

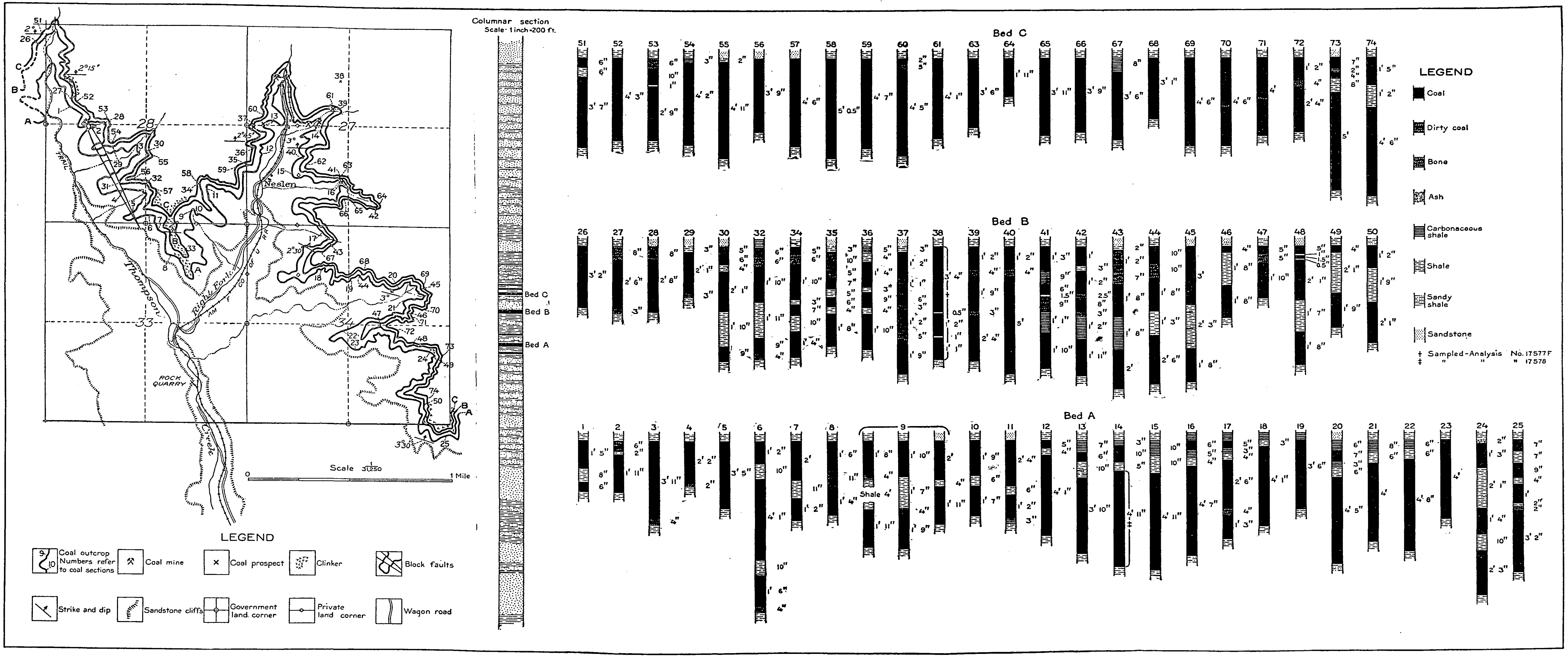
	Ft.	in.
Sandstone, massive.		
Shale [2]		6
Coal, bright, blocky	1	3
Coal, dull, probably high in ash	1	1
Coal, bright, massive	1	
Shale		½
Coal, bright, massive, hard	1	2
Bone, low in ash		1
Coal, bright, massive, hard	1	1
Shale, sandy [2]		4
Shale.[2]		
	6	6½

Location 14.

	Ft.	in.
Sandstone.[2]		
Shale [2]		10
Coal [2]		8
Shale [2]		4
Clay [2]		3
Coal, bright, massive	4	3½
Shale.[2]		
	6	4½

After cutting the sample, collecting it on a waterproof cloth, and breaking it into pieces small enough to pass through a half-inch mesh screen, it was mixed and quartered down to about 4 pounds, sealed in a can, and mailed to the laboratory of the Bureau of Mines, at Pittsburgh, Pa., where the analysis was made by standard methods. The analysis of each sample is given in four forms, marked A, B, C, and D. Analysis A represents the condition of the coal at the point in the mine from which the sample was cut, where the amount of moisture is largely an accident. This form is therefore not well suited for comparison, as analyses of the same coal made in this way may differ greatly. Analysis B shows the condition of the sample

[1] Pishel, M. A., The Pishel coking test: Colliery Engineer, pp. 674–679, July, 1913.
[2] Excluded from sample.



MAP OF THE THOMPSON COAL FIELD, GRAND COUNTY, UTAH, AND SECTIONS OF THE COAL.

By F. R. Clark.

after drying at a temperature slightly above the normal until its weight remains constant. This form is the one best adapted for comparison. Analysis C gives the theoretical condition of the coal after all the moisture has been expelled. Analysis D represents the coal free from both moisture and ash. This is supposed to represent the true coal substance free from the most important impurities. Forms C and D are obtained from the others by recalculation. They should not be used for ordinary comparison, as they represent theoretical conditions that never exist.

In analytical work it is not possible to determine the proximate constituents of coal with the same degree of accuracy as the ultimate constituents. Therefore the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only, whereas the ash (in an ultimate analysis), sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. It should also be understood that the calorific determination to individual units is not reliable; therefore, in the column headed "Calories" the heat values are given to the nearest five units and in the column headed "British thermal units" they are given to the nearest tens (the value of the British thermal unit being about one-half that of the calorie).

It will be found, on comparing the analyses of the Bear coal of the area under discussion with analyses of other bituminous coals from some of the active mines in the Book Cliffs field, that the Bear coal is comparatively high in ash but low in sulphur, and that it is slightly higher in moisture but lower in heating value. The volatile matter and fixed carbon are accordingly lower in the Bear coal.

Analyses of coal samples from the district north of Thompson and from other parts of the Book Cliffs coal field in Utah and Colorado.

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

Coals from the vicinity of Thompson, Utah.

Laboratory No.	Mine and bed.	Location.				Number on Pl. XXVIII.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
		Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17577F	American Fuel Co.'s mine 1-A (middle bed)	NW.	27	20 S.	20 E.	38	2.0	A	7.1	37.1	45.4	10.4	0.66	5.59	65.98	1.45	15.88	6,510	11,720
								B	5.3	37.8	46.3	10.6	.67	5.48	67.29	1.48	14.43	6,640	11,950
								C	......	39.9	48.9	11.2	.71	5.17	71.05	1.56	10.27	7,010	12,620
								D	......	44.9	55.1	......	.80	5.82	80.04	1.76	11.58	7,895	14,210
17578	Prospect (lower bed)	NW.	27	20 S.	20 E.	14	1.3	A	6.4	37.8	45.2	10.6	.61	......	......	......	......	6,590	11,860
								B	5.1	38.3	45.9	10.7	.62	......	......	......	......	6,680	12,020
								C	......	40.4	48.3	11.3	.65	......	......	......	......	7,040	12,670
								D	......	45.5	54.5	......	.73	......	......	......	......	7,935	14,280

Coals from the Sunnyside district, Utah.[a]

Laboratory No.	Mine and bed.	Quarter.	Section.	Township.	Range.	Number on Pl. XXVIII.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
12630	Utah Fuel Co.'s mine No. 3 (upper bed)	SW.	4	15 S.	14 E.	......	1.5	A	5.1	38.4	48.7	7.8	0.51	5.54	70.72	1.58	13.84	7,010	12,620
								B	3.6	39.1	49.4	7.9	.52	5.45	71.80	1.60	12.70	7,120	12,810
								C	......	40.5	51.3	8.2	.54	5.25	74.49	1.66	9.83	7,385	13,290
								D	......	44.1	55.9	......	.59	5.72	81.17	1.81	10.71	8,045	14,490
12631	Utah Fuel Co.'s mine No. 3 (lower bed)	SW.	4	15 S.	14 E.	......	2.1	A	5.1	39.9	47.7	7.3	1.37	......	......	......	......	7,095	12,770
								B	3.0	40.8	48.7	7.5	1.40	......	......	......	......	7,245	13,040
								C	......	42.1	50.2	7.7	1.44	......	......	......	......	7,475	13,450
								D	......	45.6	54.4	......	1.56	......	......	......	......	8,095	14,570
12632	Utah Fuel Co.'s mine No. 1 (lower bed)	SE.	32	14 S.	14 E.	......	3.4	A	5.9	38.7	48.8	6.6	1.73	5.43	71.28	1.52	13.45	7,135	12,840
								B	2.7	40.0	50.5	6.8	1.79	5.23	73.79	1.57	10.80	7,385	13,290
								C	......	41.1	51.9	7.0	1.84	5.07	75.80	1.62	8.66	7,585	13,660
								D	......	44.2	55.8	......	1.98	5.45	81.52	1.74	9.31	8,160	14,680

Coal from Castlegate, Utah. [b]

2097	Castlegate (Castlegate bed)	....	2	13 S.	9 E.	......	3.5	A	6.1	40.1	45.5	8.3	0.56	......	......	......	......	6,785	12,220
								B	2.7	41.5	47.1	8.7	.58	......	......	......	......	7,035	12,660
								C	......	42.7	48.4	8.9	.60	......	......	......	......	7,230	13,010
								D	......	46.9	53.1	......	.66	......	......	......	......	7,935	14,290

Coals from the vicinity of Palisades, Colo. [c]

3550	Cameo (Cameo bed)	NW.	34	10 S.	98 W.	......	4.3	A	8.4	33.3	47.6	10.7	0.60	5.45	65.52	1.20	16.50	6,470	11,640
								B	4.3	34.8	49.7	11.2	.63	5.19	68.46	1.26	13.25	6,755	12,160
								C	......	36.4	51.9	11.7	.66	4.92	71.54	1.31	9.85	7,060	12,710
								D	......	41.2	58.8	......	.74	5.58	81.04	1.48	11.16	8,000	14,400
3541	Palisades (Palisades bed)	SW.	3	11 S.	98 W.	......	2.0	A	7.5	36.0	50.5	6.0	.85	5.26	68.43	1.55	17.92	6,840	12,310
								B	5.6	36.8	51.5	6.1	.87	5.14	69.83	1.58	16.47	6,980	12,560
								C	......	39.0	54.5	6.5	.92	4.78	73.99	1.68	12.15	7,395	13,310
								D	......	41.7	58.3	......	.98	5.11	79.12	1.79	13.00	7,905	14,230
3490	Book Cliffs (Cameo? bed)	SW.	8	10 S.	99 W.	......	......	A	11.4	34.3	44.5	9.8	.84	5.46	61.84	1.07	20.95	6,165	11,100
								B	6.2	36.3	47.1	10.4	.89	5.13	65.51	1.13	16.92	6,530	11,760
								C	......	38.7	50.2	11.1	.95	4.73	69.81	1.21	12.19	6,960	12,530
								D	......	43.5	56.5	......	1.07	5.32	78.54	1.36	13.71	7,830	14,100

[a] U. S. Geol. Survey Bull. 471, pp. 648–649, 1912. [b] Bur. Mines Bull. 22, pt. 1, p. 190, 1913. [c] U. S. Geol. Survey Bull. 371, pp. 44–45, 1909.

No. 17577F: Sample from mine No. 1–A of American Fuel Co., of Utah, taken by F. R. Clark from bed B (middle seam Bear coal) at point 1,200 feet east of mine opening. Coal unweathered. The entire bed, containing 5 feet 8½ inches of coal from floor to roof, was sampled.

No. 17578: Sample from prospect at location 14, taken by F. R. Clark at point 85 feet east of opening on bed A (lower seam Bear coal). The sample was cut from fresh face, but coal may be slightly weathered. The entire lower bench of 4 feet 3½ inches of coal was sampled.

Nos. 12630 and 12631: Samples from mine No. 3, at Sunnyside, Utah. No. 12630 was taken by F. R. Clark from upper "vein" at a point 1¾ miles southwest of mouth of mine, being cut from face of second crosscut off first right entry of No. 1 rise. The entire bed, 4 feet 8 inches in thickness from roof to floor, was sampled. No. 12631 was taken by F. R. Clark from lower "vein" at a point 1¾ miles from mouth of mine, from "the dips" (entries going down the dip from the main haulage way). The upper 6 feet 10 inches of the 8-foot bed of coal was sampled.

No. 12632: Sample from mine No. 1, at Sunnyside, Utah, taken by F. R. Clark from lower "vein" across face of the Fowler slope. The lower 5 feet 5 inches of the 7-foot bed was sampled. These analyses of the Sunnyside coals are here included as a basis for comparison with the coals north of Thompson.

No. 2097: Sample of coal from Castlegate mine, Castlegate, Utah, taken by J. A. Taff in 1905 from the east part of mine, 10-foot cut.

No. 3550: Sample from Cameo mine of the Grand Junction Mining & Fuel Co., taken by G. B. Richardson in August, 1906, from the Cameo bed in room No. 5 off main entry. The entire bed, 8 feet 7 inches in thickness from roof to floor, was sampled, except a 1-inch parting about 2 feet from roof.

No. 3541: Sample from the Palisades mine, Palisades, Colo., taken by G. B. Richardson, in August, 1906, from the Palisades bed in room No. 1, west entry. The entire bed, 3 feet 10 inches in thickness from roof to floor, was sampled.

No. 3490: Sample from the Book Cliffs mine of the Book Cliffs Coal Co., taken by G. B. Richardson in July, 1906, from the Cameo (?) bed in the west entry. The whole bed, 8 feet 6 inches in thickness from roof to floor, was sampled, except an 8-inch parting near the middle.

Nos. 3550, 3541, and 3490 were taken from mines in active operation and therefore they probably represent unweathered coal. These analyses are here given for the purpose of comparison with the coals mined at Thompson, Utah.

The moisture and ash are important factors in reducing the commercial value of coals. They not only displace their own weights of combustible matter, but actually use up part of the heat available during the combustion of the coal. The rapidity with which coal slacks on exposure to the weather depends chiefly on its percentage of moisture. The higher the percentage of moisture the sooner the coal disintegrates and is reduced to slack, so that the lower the moisture in a coal the better is its stocking quality. The high percentage of ash not only increases the cost of handling coal in a power plant, but also decreases the efficiency of the furnace. The composition of the ash as well as its percentage in the coal has an effect on the furnace. Ash is composed largely of silica, alumina, iron, and lime, and an ash high in iron and lime is easily fusible and is likely to clinker badly.

The ratio of volatile matter to the fixed carbon indicates in a general way the type of furnace best adapted for burning any coal. The common type of furnace will burn a coal low in volatile matter without throwing off much smoke (unburned carbon), whereas the smokeless burning of a highly volatile coal requires a specially constructed furnace.

The theoretical heating value of the coal is the total amount of heat developed by the complete combustion of a unit weight of fuel. The calorie is the quantity of heat required to raise the temperature of 1 gram of water 1° C. at its maximum density. The British thermal unit is the amount of heat required to raise the temperature of 1 pound of water 1° F. at its maximum density, 39.1° F. With these suggestions in mind, a close study of the analyses (p. 470) will give the relative commercial value of the coals represented in this table, so far as their chemical composition affects this value.

ESTIMATED TONNAGE.

All coal beds in this area measuring 14 inches and upward were mapped and a few thin beds were also examined. From the data thus collected the tonnage of each bed and of each of the smaller lenses was estimated, and the results added to give the total tonnage for the area. The tonnage of the local thin lenses of coal adds comparatively little (less than 7 per cent) to the total tonnage of coal, most of the coal within this area being contained in the three principal beds (A, B, and C).

The data available for making this estimate relates only to the condition and the character of the coal at the surface, as shown by sections measured along the outcrops. The difficulty of making such an estimate is further increased by the fact that the beds are badly "split" by partings, which materially affect the thickness of the clean coal from place to place, even between near-by sections.

For the basis of this estimate of tonnage any two or more benches of a coal bed are considered as two or more individual beds if the parting between benches exceeds in thickness the thinner of the two benches which it separates. The minimum workable thickness for a bed of coal of this grade is 14 inches, and therefore any bench of coal less than 14 inches in thickness, which by the above rule is reduced to an individual bed, is not considered in computing this tonnage.

The figures herein given were computed by obtaining the general average of all the coal in each of the beds over 14 inches thick and considering this general average to be the equivalent of the solid coal in any bed throughout the area if the beds were not split by partings. These figures give approximately the total coal underlying this area without considering how much of this quantity may in practice be mined.

Bed A, by the above method of computation, contains approximately 8,020,080 short tons of coal, on the assumption that bed A is the equivalent of a uniform bed of solid coal 47 inches thick throughout this area; bed B contains approximately 5,644,800 short tons, on the assumption that this bed is the equivalent of a bed of solid coal 40 inches thick underlying the entire area; bed C, by the same computation, is assumed to be the equivalent of a bed of solid coal 49 inches thick over the whole area, which gives 6,307,480 short tons of coal.

The total tonnage of all the local lenses over 14 inches thick and not included in beds A, B, and C is approximately 1,368,800 short tons, less than 7 per cent of the quantity contained in the three principal beds.

Estimated tonnage by beds in area north of Thompson, Utah.

	Short tons.
Bed A	8, 020, 080
Bed B	5, 644, 800
Bed C	6, 307, 480
Local thin lenses	1, 368, 800
	21, 341, 160

In general a bed of coal of this grade 1 foot thick contains approximately 1,800 tons to the acre, 1,500 tons of which may be mined under favorable conditions and a minimum of 1,000 tons under very poor conditions.

HISTORY AND DEVELOPMENT OF MINING.

Coal has been reported in the Book Cliffs since the time of the earliest explorers of this region, but there are only a few localities along the great length of coal outcrop where any development on a commercial basis has been carried on. At a number of places, however, the beds have been prospected and worked to supply ranchers and small towns.

The coal in the area under discussion attracted little attention or economic interest until some time in 1900, when Mr. Ballard and others opened a mine on bed B at location 39 and sold coal under the name of the Ballard Coal Co. This mine had no railroad connection, and in order to place the coal on the market it had to be hauled by wagon a distance of about 5 miles to Thompson, on the Denver & Rio Grande Railroad. This company, however, did practically nothing in the way of real development, their mine never advancing beyond what would ordinarily be called a prospect.

Early in March, 1912, the American Fuel Co. of Utah began operations on the property on which the Ballard Co. had its workings. They shortly afterward built good substantial buildings to house their employees, and they now have a company store, post-office and office building, a clubhouse, a hotel, shops, and buildings for the workmen, as well as barns for the mine stock. They also built a branch railroad from Thompson to the mines in sec. 27, T. 20 S., R. 20 E., which gives them an easy outlet for the coal mined.

This company gave the name of "Bear coal" to the coal which they contemplated mining in this region, and named the beds lower, middle, and upper, which correspond respectively to beds A, B, and C of this report. They first started development on bed B (the middle bed) on both the east (mine No. 1–A) and west (mine No. 1–B) sides of the Right Fork of Thompson Creek, in the NE. ¼ SE. ¼ NW. ¼ sec. 27. The company shipped their first coal to the market in October, 1912, but did not reach their average daily output of 150 tons until the beginning of January, 1913. From the time the mines were opened in October, 1912, to November, 1913, they mined approximately 47,500 tons of coal.

The development has probably been greatly retarded and the expense of mining the coal increased by reason of the impurities in the coal in the form of bone and shale partings. The measurements along the outcrop of bed B show the coal to be badly "split" by bone and shale, the occurrence of which is both irregular and uncertain, and the underground development has proved the existence of the same conditions away from the outcrop. The workings toward the west in mine No. 1–B proved the bed to be of less value in that direction than toward the east, a fact which is very well shown by the measurements along the outcrop. The development in the west workings was continued for several months, but the company finally abandoned this mine on account of the occurrence of a thick parting of shale, which separated the coal into two benches, neither of which was thick enough to be profitably mined by itself.

The occurrence of these bone and shale partings in considerable quantities in bed B throughout the mine, together with the fact that the coal is generally "frozen" to the bone or shale, make three individual operations necessary for the removal of enough of the impurities to place the coal on the market in competition with other Utah and Colorado coals. First, after the coal is shot from the face the miner's pick is used to cleave the coal loose from the bone or shale; second, the heap must be hand picked to remove the large pieces of waste; and third, the coal is washed by the Standard Stewart jigs to remove the fine particles of bone and shale.

It is estimated that by these operations about 12 to 15 per cent of the total mine production is removed and discarded as waste material, and that the average reduction in the ash content is about 25 per cent. As the removal of these impurities is an expensive operation the company abandoned their west workings when their advancing developments showed an increasing deterioration in the coal bed.

There is a wide difference in the amount of the impurities, even over local areas. At the point from which the sample for analysis 17577F was cut, the whole bed from floor to roof was being mined and the ash content is only 10.6 per cent; this, however, is probably an exceptional condition, and possibly within a very short distance more than half of the same total thickness would have to be excluded in mining.

At the time of the writer's visit the company were just beginning the development of bed A (lower bed), which they considered could be mined much more economically than bed B. It appears from the development since July, 1913, up to December, 1913, that bed A is thicker and freer from bone and shale partings than is bed B. The workings were run to the north and east from the point of entry (just west of location 14, Pl. XXVIII). Toward the east the showing was very good; to the north it was rather poor for a considerable distance, beyond which 6 feet of good coal appeared. It may be noted that the measurements on the outcrop show this bed to be more constant in thickness and to contain fewer partings toward the east than toward the north and west.

So far as the surface exposures reveal the true character of a coal, bed C holds out more inducements for extensive profitable development than either of the two lower beds. It everywhere maintains a fair workable thickness and is characterized by the absence of partings.

The "Bear" coal makes a very good steam fuel and finds a ready market for locomotive use on the main line of the Denver & Rio Grande Railroad. It is of good stocking quality, and wherever it has been tried has proved to be a good domestic fuel. There is little doubt that if it can be profitably mined the coal from the Neslen district will find a place in the markets of Utah, Idaho, Nevada, and California.

STONE AVAILABLE FOR RAILROAD CONSTRUCTION AND OUTSIDE MINE BUILDINGS.

The sandstone beds of this region have been extensively used in the construction of the railroad to the coal mines and for mine and other buildings at Neslen. They have also attracted some attention and interest outside of the local use as a source of building material. These beds occur in the upper part of the Mancos shale and in the Mesaverde formation and form vertical cliffs from 5 to 75 feet in height. They are massive, more or less friable, quartzose sandstones with some mica, and are generally free from serious jointing except locally. The rock is predominantly gray in color, though some of it weathers to buff.

Besides the stone quarried for local construction, one shipping quarry had been in operation previous to the writer's visit, but at that time work was suspended. The quarry is located in the NE. ¼ SW. ¼ SE. ¼ sec. 33, T. 20 S., R. 20 E., and the claim is owned by Walker Bros. and others. It is reported that some of the product from this quarry has been shipped to Salt Lake City for building stone. The total thickness of the sandstone at the quarry is over 75 feet. The upper 10 to 15 feet is bedded, the individual beds ranging from 2 to 6 feet in thickness. Approximately the next 60 feet of the ledge is massive and contains only one bedding plane near the middle. Below this massive portion occurs another bedded deposit, ranging in thickness from 10 to 20 feet or more, in which the beds differ from a few inches to a few feet. This grades into the underlying typical Mancos shale. The massive character of the 60-foot bed changes from place to place, being locally cut by bedding and joint planes.

The stone when quarried breaks into blocks weighing several tons. In the yard at the time of the writer's visit were blocks ranging from 7 feet by 1 foot by 3 feet, through many shapes and dimensions, to cubes 4 feet on the side. The blocks break with clean-cut edges and the fresh surfaces have a pleasing gray color.

The outcrop of this bed extends for many miles in both directions, and an inexhaustible supply of the stone is available. There are also many other sandstone ledges, accessible for local use, higher in the geologic section, which probably contain just as good building material but are not so accessible to the railroad.

COAL NEAR WALES, SANPETE COUNTY, UTAH.

By Frank R. Clark.

INTRODUCTION.

The field here described was examined to determine whether or not coal occurs in a small area lying west and southwest of Wales, near the base of the east face of the Gunnison Plateau. Coal was found in two zones. The lower coal zone outcrops near the base of the east face of the plateau and the upper near the top. The lower zone contains bituminous coal of some economic value, but the coal is probably irregular in thickness, ranging from 1 foot to 5 feet, and also n character, being badly split by bone and shale partings. The upper zone contains only very thin lenses of coal interstratified with carbonaceous shale and clay and is of no economic value.

Sanpete Valley trends northeast to southwest across Sanpete County, in central Utah. (See fig. 17, p. 454.) It lies between two great upland masses, Wasatch Plateau on the east and Gunnison Plateau on the west, and is drained by San Pitch River, the principal northern tributary of Sevier River.

Wales, one of the smallest of several thriving towns in Sanpete Valley, is in the western part of the valley at the base of Gunnison Plateau. The area here described includes the eastern parts of Tps. 15 and 16 S., R. 2 E., Salt Lake base and meridian, and lies west and southwest of Wales. (See Pl. XXIX, p. 484.)

The field examination, made by the writer in the early part of September, 1913,[1] was of a reconnaissance nature and was made for the purpose of obtaining general information regarding the quality and quantity of the coal and of determining the probable limits of the land containing coal of economic importance. The writer was assisted in the field examination by G. W. Clark. The citizens of Ephraim, Utah, courteously gave much information regarding the roads and trails as well as the coal and coal prospects. The writer wishes also to acknowledge the assistance rendered by H. R. Thomas, of Wales, who gave some interesting facts relating to the coal and made possible the notes herein given on the history of its early development.

[1]Although this work was done in 1913, the unavoidable delay in publishing the Survey's annual volume including short reports on work done in that year has made it desirable to include this report in the volume for 1912.

FIELD WORK.

Owing to the reconnaissance nature of the examination no attempt was made either to meander or to map accurately points on the outcrops of the coal beds. The only points at which the coal was studied are shown on the map (Pl. XXIX, p. 484) by the numbers 1 to 11 and the approximate position of the lower zone at which coal occurs is shown by a broken line. This position in T. 15 S., R. 2 E., was inferred from data given on the General Land Office plat, whereas the position in T. 16 N., R. 2 E., was roughly located by the writer from the near-by Government land corners. The position of the outcrop as shown on the map is therefore only approximately correct. The dip and strike observations recorded on the map are based on observations made with a Brunton compass at these points.

The field work also included visiting as many mines and prospects as time would permit and collecting a number of samples for analysis.

PREVIOUS REPORTS.

The area here described is shown on the map made by the Wheeler[1] Survey and lies at the northern extremity of the country studied and mapped by Dutton.[2] E. D. Cope[3] in 1880 published a short discussion on the Manti beds of Utah.

These reports deal only with the broad geologic features of the region and make no mention of the presence of coal or other geologic phenomena of local interest.

G. B. Richardson,[4] however, in 1906 published a report which not only deals with the general geology of Sanpete Valley but also treats of coal near Wales, in the northern part of the valley, and at Sterling, in the southern end of the valley. Richardson published a second report[5] in 1907, which deals with the general geology in its relations to underground water.

TOPOGRAPHY.

Sanpete Valley is a long, narrow, comparatively flat valley that lies between the Wasatch Plateau on the east and the Gunnison Plateau on the west. The general level of the Wasatch Plateau above the valley floor is about 5,000 feet and that of the Gunnison Plateau is about 3,000 feet. The west face of the Wasatch Plateau is a steeply dipping monocline, and the slopes in general follow the bedding planes of the underlying rocks except where they have been

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[1] Wheeler, G. M., U. S. Geog. Surveys W. 100th Mer., atlas sheets, expeditions of 1872 and 1873.

[2] Dutton, C. E., The geology of the high plateaus of Utah: U. S. Geog. and Geol. Survey Rocky Mtn. region, 1880.

[3] Cope, E. D., The Manti beds of Utah: Am. Naturalist, vol. 14, p. 303, 1880.

[4] Richardson, G. B., Coal in Sanpete County, Utah: U. S. Geol. Survey Bull. 285, pp. 280-284, 1906.

[5] Richardson, G. B., Underground water in Sanpete and central Sevier valleys, Utah: U. S. Geol. Survey Water-Supply Paper 199, 1907.

deeply cut by erosion. The east front of the Gunnison Plateau rises abruptly from the valley and is thoroughly dissected by numerous drainage channels, many of which are deep canyons. The valley floor slopes gently southward as well as toward its center, along which San Pitch River meanders. There are several small perennial streams in the dissected portion of the Gunnison Plateau, but only a few flow beyond the mouths of their canyons except during periods of flood.

STRATIGRAPHY.

The oldest rocks exposed in the vicinity of Wales are the beds of coarse reddish to gray conglomerate, which outcrop along the base of the east face of the Gunnison Plateau. This rock is composed of well-rounded pebbles of quartz, quartzite, and limestone of varying colors embedded in a well-cemented matrix of coarse sand. The rocks immediately associated with the coal are in general calcareous sandstone, calcareous shale, sandstone, shale, or clay. The strata exposed in the east face of the Gunnison Plateau above the coal are for the most part limestone, shale, and sandstone. The immediate association of coal with calcareous sandstone and shale both above and below it, though generally an unusual occurrence, is very common in this area. In Coal Canyon and southward the calcareous sandstone immediately associated with the coal is overlain by massive beds of conglomerate and conglomeratic sandstone aggregating 200 to 300 feet in thickness.

According to Richardson the rocks associated with the coal are Wasatch (Tertiary), whereas the heavy beds of conglomerate that underlie them are probably Mesozoic and may prove to be restricted to the Cretaceous. In the writer's study of the coal and the rocks associated with it no fossils or other evidence of the age of the rocks were found, but some doubt is thrown upon this interpretation by the fact that in Coal Canyon, in sec. 14 and southward, heavy beds of conglomerate, 100 to 200 feet in thickness, occur above as well as below the coal-bearing rocks. Although it is not definitely known it is believed that the coal occurs in only one general zone; if so, the occurrence of similar conglomerates above and below the coal suggests that these rocks are probably all of the same age, and may be Wasatch.

STRUCTURE.

In this area the rocks exposed in the east face of the Gunnison Plateau dip westward at angles ranging from a few degrees near the summit to about 15° near the base. Several places were noted along the base of the plateau where the structure changes abruptly from gently westward dipping strata to beds either perpendicular or overturned and dipping steeply to the east, making an almost right angled turn. The structure of the rocks was examined in detail only near the mouth of Coal Creek, where a thrust fault from the east, resulting from the breaking of a partly overturned fold, is very apparent. (See structure section A–B in Pl. XXIX.) It was not possible to determine the displacement of the strata at this point.

According to Richardson a well-defined fault extends along the base of the Gunnison Plateau on the west side of Sanpete Valley. This fault will not affect the development of the coal because all the coal lies on the west side of the fault plane. The abrupt fold in the strata near the base of the plateau above mentioned, however, has produced dips as steep as 64° in the coal bed at the outcrop, but these dips decrease to 15° and less within a short distance to the west.

THE COAL.

GENERAL CHARACTER.

The coal at the base of the Gunnison Plateau is bituminous and is locally supposed to possess coking qualities. It is black and in some places exhibits banded structure due to the alternation of dull and vitreous layers. The coal at some of the points visited occurs in hard and soft layers, but in general it is massive and hard to pick. The bed is usually badly split by bone and shale partings, as is well shown in the graphic sections (Pl. XXIX, p. 484).

The horizons at which coal is found are here designated coal zones for the reason that it is not definitely known whether the coal is present in one continuous bed or in a series of lenses, the points of which may or may not overlap at some places. The evidence at hand, however, seems to favor the assumption that the coal is more or less lenticular.

Ten detailed coal sections were measured along the outcrop of the lower coal zone, which is near the base of the mountains. The location of each section and its graphic representation are shown on Plate XXIX. The locations are numbered consecutively (1 to 10) from south to north.

MINES AND PROSPECTS.

At location 1 the coal bed had been faced up, but no development work has been undertaken. The coal here occurs in four benches as shown in the section in Plate XXIX. The upper bench is overlain by sandy shale and the lower bench is underlain by shale containing more or less carbonaceous matter that occurs as small lenses or as particles disseminated through the shale. Southward from a point about 1,500 feet south of location 1 the outcrop of this coal bed is concealed by material recently deposited near the foot of the mountains.

Location 2, on the north side of the gulch, marks the mouth of an old drift prospect, which follows the strike of the coal bed for about 60 feet. The coal is here 2 feet 3 inches thick and contains only two 1-inch shale partings. It is underlain by shale and overlain by carbonaceous shale.

The only locality in which the outcrop of the coal was actually meandered lies between locations 3 and 5, where the following facts were observed: The exposures at location 3 are poor and the coal is badly weathered at the surface, where only coal "smut" (coal highly disintegrated) is exposed. Northward from this point the exposures are good and midway between locations 3 and 4 the coal is replaced by bluish-gray clay. At location 4, about 500 feet north of location 3, the coal appears at the surface in two beds separated by 9 feet of bluish-gray, highly sandy, calcareous shale. The lower bed, 2 feet thick, is composed of layers of coal and bone interbedded. The upper bed is composed of 12 inches of good coal and has a 1-inch shale parting 4 inches from the bottom.

Location 5 marks the mouth of a mine in Coal Canyon which is operated during the winter by John Reese and others, the coal being hauled by wagon to supply the needs of near-by settlers. A sample for analysis representing the entire bench of clean coal was collected in this mine at a point 300 feet northeast from the mine mouth. The results of the analysis (No. 17715) are given on page 486. The coal at the point sampled (see section 5, Pl. XXIX) occurs in one bench 1 foot 8 inches thick, overlain by shale and underlain by 11 inches of bone that is mined but discarded when the coal is loaded into the mine cars. As may be inferred from the foregoing observations, made at near-by points along the outcrop, this coal is lenticular and uncertain in its occurrence.

At locations 6 and 7 in Indian Pete Canyon, in sec. 2, T. 16 S., R. 2 E., there are two abandoned mines, one on either side of the canyon. The bed in this vicinity is very irregular in thickness and character as shown by coal sections 6 and 7 (Pl. XXIX). The total thickness of coal at location 6 is 5 feet 2 inches, whereas at location 7, just across a narrow canyon bottom, it is only 3 feet 5 inches. The mine on the south side, at location 6, was one of the first coal mines opened in Utah and perhaps more coal has been removed from it than from any other mine in this area. The development was continued, it is reported, until the mine was flooded by water, when it was closed down and has never been reopened. Water almost completely filled the workings of the mine at the time of the writer's visit. The section of coal at location 6 was measured near the mouth of the mine just above the upper edge of the water. The mine at location 7 was opened some time after the one at location 6 and the development has not been so extensive. A sample for analysis was taken at location 7 and the results of this analysis (No. 17717) are given in the table on page 486. That portion of the bed included in the sample is shown in section 7 (Pl. XXIX).

The mine at locations 8 and 9, operated by H. R. Thomas, of Wales, is situated in sec. 35, T. 15 S., R. 2 E., in what is locally known as Old Canyon. The coal here mined is sold to the people of Wales and near-by small towns. The total production has been rather large for a local mine. Location 8 marks the mouth of this mine and location 9 the point in the mine at which the sample for analysis was collected. The results of this analysis (No. 17718) are given in the table on page 486 and that part of the bed included in the sample is shown in section 9 (Pl. XXIX). The sections measured at locations 8 and 9 show a great difference in the thickness of the coal, as well as in the thickness and arrangement of the coal benches and the partings between them, as is at once apparent on comparing them. The total thickness of coal at the mouth of the mine is about 5 feet, whereas at the point sampled it is only about 3 feet. The rocks immediately above and below the coal are calcareous sandstone and calcareous sandy shale.

At location 10, in sec. 26, T. 15 S., R. 2 E., the coal was examined in an unworked mine on the south side of what is locally called New Canyon. This mine is now abandoned and it is not known how much coal was removed. A mine has also been opened on the north side of the canyon, but the opening has been closed by caving. At practically all the mines and prospects visited the coal bed possesses a good roof, either a sandy shale, calcareous sandstone, or calcareous sandy shale. It is very firm and requires little or no propping. In mines which have been abandoned for years the roof is apparently as firm as ever.

The present examination, which terminated at location 10, suggests that the coal-bearing zone contains beds of workable thickness as far south as Coal Canyon. It is reported by H. R. Thomas that a coal bed of this zone is of similar thickness and character for a mile or two northward from New Canyon, but that beyond a point a few miles north of location 10 the coal decreases in thickness until in the vicinity of sec. 3, T. 15 S., R. 2 E., it is too thin to be of any economic importance.

It may be inferred from the foregoing observations made at points along the outcrop that this coal is more or less lenticular in character and uncertain in its occurrence, as well as badly split by partings. It is believed by some who are not wholly familiar with coal mining that any kind of surface "showing" of coal is sufficient to develop into a good bed if it be penetrated far enough. The chances are about equal, however, of its being either thinner or thicker or containing fewer or more impurities than at the outcrop. It is much safer to consider that the bed will be no thicker inward from the outcrop than to assume that it may greatly increase in value.

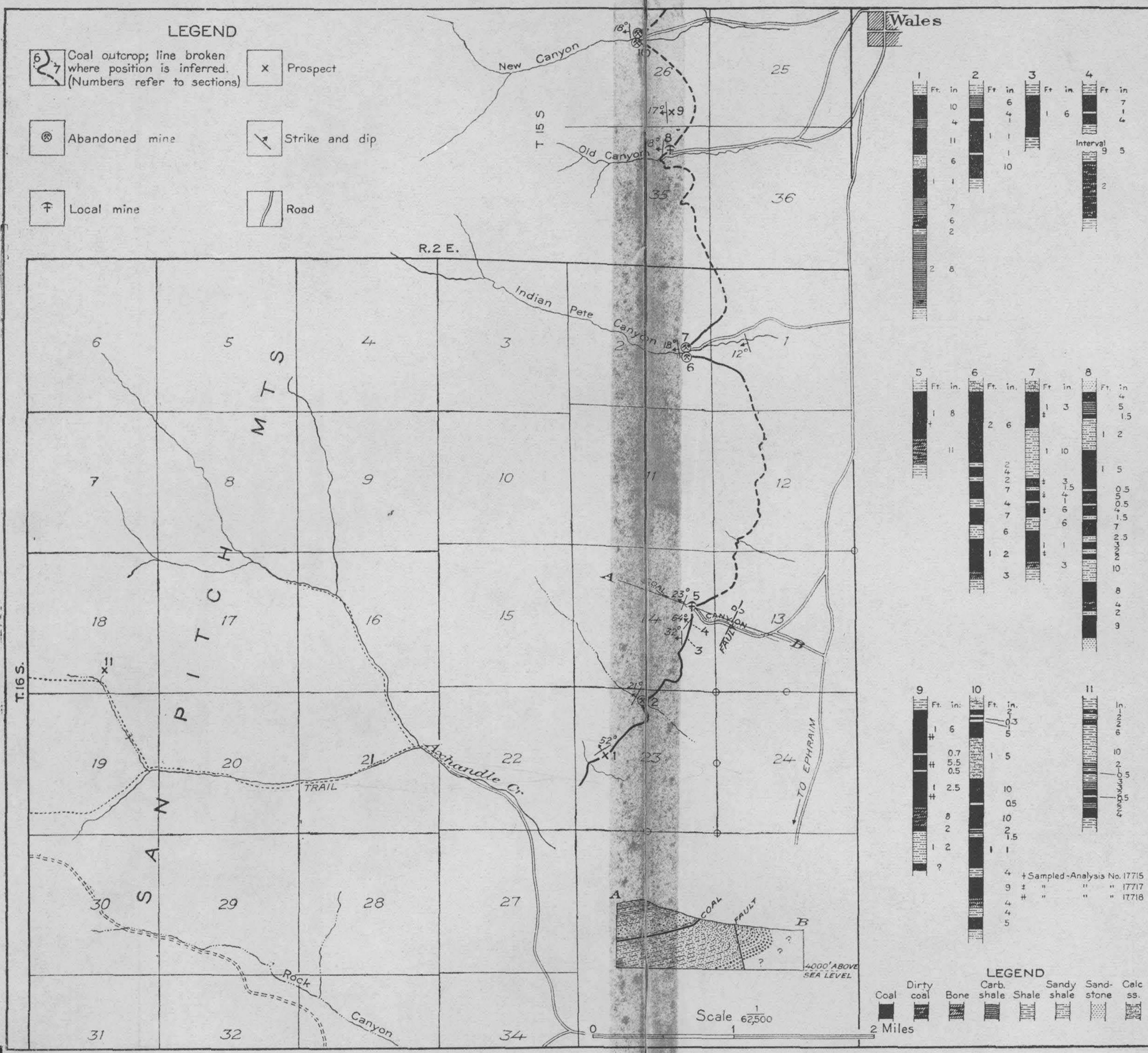
The coal which outcrops near the summit of Gunnison Plateau may belong to a coal-bearing zone composed of a series of lenses or it may represent a single stratigraphic horizon. It is here designated a zone. Only one measurement of the coal in this zone was obtained. This measurement was made at location 11 in sec. 18, T. 16 S., R. 2 E., in an old drift prospect which extended a few hundred feet into the hill along the supposed coal bed. It is reported that the prospectors hoped that as the bed was penetrated it would increase in thickness, improve in quality, and contain fewer and thinner partings. At the time of the writer's visit the drift was in places almost wholly filled with material that had caved from the sides and roof, and the presence of water prevented an examination of the drift at its farther end. Section 11 (Pl. XXIX) gives the character and thickness of the bed near the mouth of the drift. The shale near the middle of the section and overlying the 1-inch bench of coal contains many fragments of fossil shells which are too fragile to admit of collection for identification. The 10-inch bed of shale in the section also contains many fragile fossil shells. The coal is of poorer quality than that of the lower zone. The total thickness of coal here does not exceed 9 inches and this thin bed is split by partings into four benches. It occurs in such thin lenses that it gives little promise of ever being of economic value.

It was reported by residents of this region that another drift was opened a few miles northward in Axhandle Creek, in a bed of coal supposedly belonging to this same zone. Opportunity was not afforded to the writer to visit this prospect, but it was said that the indications of coal are not nearly so good as they are at location 11. If this report be true it is safe to assume that coal of economic importance will probably not be found at either of the above prospects.

The area south and east of location 11 was very hurriedly examined in search of additional outcrops at the horizon of the coal described above, but no signs of coal were found and it is quite probable that no coal of any commercial value will be found at this upper horizon.

CHEMICAL COMPOSITION.

The analyses given on page 486 show the composition of samples collected from three mines, which are well distributed over the area west and southwest of Wales. The analyses of coals from Carbon County, Utah, are also included in this table for convenience in making comparisons. The samples from the vicinity of Wales were made by cutting a channel across the bed and excluding those portions so indicated in the following sections:



MAP OF THE WALES COAL FIELD, SANPETE COUNTY, UTAH, AND SECTIONS OF THE COAL.

By F. R. Clark.

Section of coal sampled (No. 17715) in mine of John Reese, in sec. 14, T. 16 S., R. 2 E., at a point 300 feet northeast from opening.

	Ft.	in.
Shale, calcareous.		
Coal, bright, hard, and blocky		5
Coal, dull, flinty, and massive		5
Coal, bright, lustrous		2
Coal, dull, flinty, and massive		8
Bone [1]		11
Shale, brown	1	6
Total coal	1	8

Section of coal sampled (No. 17717) in North Tunnel mine, in Indian Pete Canyon, in sec. 2, T. 16 S., R. 2 E., at a point 300 feet from opening.

	Ft.	in.
Sandstone, calcareous.		
Coal, bright	1	3
Shale, brown, sandy [1]		4
Shale, thinly laminated, containing thin coal lenses [1]	1	6
Coal		3
Shale, sandy [1]		1½
Coal		4
Shale, sandy [1]		1
Coal, bright		6
Shale, grayish brown, sandy [1]		6
Coal, bright	1	1
Bone [1]		3
Shale.		
Total coal	3	5

Section of coal sampled (No. 17718) in mine of H. R. Thomas, in Old Canyon, in sec. 35, T. 15 S., R. 2 E., at a point 1,400 feet north from opening.

	Ft.	in.
Sandstone, calcareous.		
Coal, alternating dull and light bands		6
Coal, hard, massive, with few very bright bands	1	
Bone		¾
Coal, bright		5½
Bone		½
Coal, bright, massive	1	2½
Bone [1]		8
Coal, bright [1]		2
Shale, sandy, calcareous [1]	1	2
Total coal	3	4

After cutting the sample from the face of the bed, collecting it on a waterproof cloth, and breaking the coal small enough to pass a half-inch mesh screen, it was quartered down to about 3 or 4 pounds, sealed in an air-tight can, and mailed to the laboratory of the Bureau of Mines at Pittsburgh, Pa., where the analysis was made by standard methods.

[1] Excluded from sample.

The analysis of each sample is given in four forms, marked A, B, C, and D. Form A represents the character of the coal in the mine at the point from which the sample was cut. The moisture in this form is largely a matter of chance, and analysis A is therefore not well suited for comparison. Form B gives the composition of the coal after air drying at a temperature slightly above the normal room temperature until its weight remains constant. This form is the one best adapted for the comparison of two or more coals as regards their fuel value. Form C represents the condition of the sample after all the moisture has been expelled. Form D represents the coal free from both moisture and ash, and is supposed to represent the true coal substance free from the most important impurities. Forms C and D are obtained from the others by recalculation and should not be used for ordinary comparison, as they represent theoretical conditions that do not exist.

In analytical work it is not possible to determine the proximate constituents of coal with the same degree of accuracy as the ultimate constituents. Therefore the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only, whereas in the ultimate analysis the ash, sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. As the calorific determination to individual units is not reliable, in the column headed "Calories" the heat values are given to the nearest five units and in the column headed "British thermal units" they are given to the nearest 10 units.

Analyses of coal samples from the coal near Wales, Sanpete County, Utah, and adjacent coal fields.

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

Coal from mines near Wales, Utah.

Laboratory No.	Mine and bed.	Location.				No. on Plate XXIX.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.	Heating value.	
		Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	British thermal units.
17715	John Reese	NE.	14	16 S.	2 E.	5	0.1	A	3.6	29.2	44.7	22.5	6.79	5,715	10,290
								B	3.6	29.2	44.7	22.5	6.80	5,720	10,300
								C	....	30.3	46.4	23.3	7.05	5,935	10,680
								D	....	39.5	60.5	.....	9.20	7,740	13,940
17717	North Tunnel	SE.	2	16 S.	2 E.	7	.2	A	2.4	32.4	46.0	19.2	3.71	6,220	11,200
								B	2.2	32.5	46.1	19.2	3.72	6,235	11,230
								C	....	33.2	47.1	19.7	3.80	6,375	11,480
								D	....	41.3	58.7	.....	4.73	7,935	14,290
17718	H. R. Thomas	NE.	35	15 S.	2 E.	9	.8	A	2.7	35.7	45.9	15.7	4.63	6,585	11,860
								B	1.9	36.0	46.2	15.9	4.67	6,635	11,950
								C	....	36.7	47.1	16.2	4.76	6,770	12,180
								D	....	43.8	56.2	.....	5.68	8,075	14,530

Analyses of coal samples from the coal near Wales, Sanpete County, Utah, and adjacent coal fields—Continued.

Coal from adjacent fields in Utah.

Laboratory No.	Mine and bed.	Location.				No. on Plate XXIX.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.	Heating value.	
		Quarter.	Section.	Township.	Range.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	British thermal units.
12631	Utah Fuel Co. mine No. 3, Sunnyside (lower bed).	SW.	4	15 S.	14 E.	....	2.1	A	5.1	39.9	47.7	7.3	1.37	7,095	12,770
								B	3.0	40.8	48.7	7.5	1.40	7,245	13,040
								C	....	42.1	50.2	7.7	1.44	7,475	13,450
								D	....	45.6	54.4	.....	1.56	8,095	14,570
2097	Castlegate (Castlegate bed).	......	2	13 S.	9 E.	....	3.5	A	6.1	40.1	45.5	8.3	.56	6,785	12,220
								B	2.7	41.5	47.1	8.7	.58	7,035	12,660
								C	....	42.7	48.4	8.9	.60	7,230	13,010
								D	....	46.9	53.1	.....	.66	7,935	14,290
2541	Winterquarters mine No. 1 (Winterquarters bed).	N. ½	7	13 S.	7 E.	....	3.9	A	8.1	40.2	45.9	5.8	.86	6,760	12,160
								B	4.4	41.8	47.8	6.0	.89	7,030	12,660
								C	....	43.7	50.0	6.3	.94	7,355	13,240
								D	....	46.7	53.3	.....	1.00	7,845	14,130

No. 17715: Sample of coal from the John Reese mine in Coal Canyon, taken by F. R. Clark in September, 1913, at a point 300 feet north of mouth of mine. The coal in this sample may have been slightly weathered. Total thickness of bed, 1 foot 8 inches, was included in the sample.

No. 17717: Sample of coal from the North Tunnel mine in Indian Pete Canyon, taken by F. R. Clark in September, 1913, at a point 300 feet north of opening of the mine. The coal in this sample may have been slightly weathered. Section on page 485 shows part of bed included in sample.

No. 17718: Sample of coal from the mine of H. R. Thomas in Old Canyon, taken by F. R. Clark in September, 1913, from working face of room 6, about 1,400 feet north of mine mouth. The coal in this sample was fresh and unweathered and that part of the bed included in the sample is shown in the section on page 485.

No. 12631: Sample of coal from the Utah Fuel Co.'s mine No. 3, at Sunnyside, Utah, taken by F. R. Clark from the upper 6 feet 10 inches of the 8-foot bed of coal.

No. 2097: Sample of coal from Castlegate mine, Castlegate, Utah, taken by J. A. Taff in 1905 from the east part of mine, 10-foot cut.

No. 2541: Sample of coal from the Winterquarters bed, in the Winterquarters mine of the Pleasant Valley Coal Co., taken by J. A. Taff in 1905 from the southeast part of mine at a point 6,000 feet from mine mouth. The entire bed, 16 feet in thickness, was sampled.

It will be found on comparing the analyses of the coal near Wales with those of the coals from Carbon County, that there are marked differences in some of the constituents, namely: The air-drying loss and the moisture are very low in the Wales coal and much less than they are in the others; the volatile matter is appreciably less; and the fixed carbon is only 1 to 3 per less cent, showing probably an equal rank for the Wales coal, but its efficiency is impaired by the higher percentage of sulphur and ash. The ratio of the air-drying loss in the samples from the Wales coal is significant because as the degree of weathering of the coal increases the air-drying loss decreases. For instance, in sample 17715, the most highly weathered coal of the three samples, the air-drying loss was only 0.1 per cent, whereas in the perfectly fresh sample, 17718, the air-drying loss is 0.8 per cent. The ash and sulphur, however, are very much greater in the Wales coal than in the coals from Carbon County, and the heating value of the Wales coal in forms A, B, and C is much less than that of the other coals, but if found low in ash at some point it should show a high calorific value.

The rapidity with which a coal disintegrates and is reduced to slack depends largely on the percentage of moisture that it contains. Therefore a coal with a lower percentage of moisture has stocking qualities superior to those of a coal higher in moisture. On this basis the Wales coal, being lower in moisture, probably possesses better stocking qualities than any of the Carbon County coals here given. A high percentage of moisture in a coal is also objectionable because the moisture replaces its weight of combustible matter, and also the evaporation during the combustion of the coal uses up part of the available heat.

The ratio of the volatile matter to the fixed carbon indicates in a general way the type of furnace best adapted for burning a coal with a maximum efficiency. A coal low in volatile matter may be burned in the common type of furnace without throwing off much smoke (unburned carbon), but the smokeless burning of a coal high in volatile matter requires a specially constructed furnace.

The percentage of ash in a coal also materially affects its commercial value. The ash not only displaces its own weight of combustible matter but during combustion a part of the available heat is used in heating the ash. The high percentage of ash increases the cost of shipping as well as the cost of handling the coal in a power plant, and also decreases the efficiency of the furnace.

A high percentage of sulphur is objectionable in coal used for the manufacture of coke and gas as well as for ordinary steaming uses.

The relatively lower heating value of the Wales coal as compared with the Carbon County coals is chiefly due to the fact that in the Wales coal the percentage of impurities is as much as three times that in the Carbon County coals. Thus in form D, which represents the composition and heating value of the coal as it would be if it contained neither moisture nor ash, the Wales coal is fully as good as the Carbon County coal, but in its actual impure condition it is much inferior.

The high percentage of impurities, including sulphur, in the Wales coal is the principal factor which may affect its commercial value and future development as a shipping coal.

HISTORY AND DEVELOPMENT.

Although the production of coal at Wales is very small, the occurrence is perhaps of more than local interest. The coal at Wales and that in the vicinity of Coalville, Utah, was, it is reported, the first discovered by white men in the State. Wales, however, claims the distinction of having produced the first coal mined in Utah. It is reported that J. E. Reese and John Price, who had been coal miners in Wales, learned of the coal from an old Indian chief who called it "rock that would burn." These two men in 1857 founded the town of Wales, Utah, and were the pioneers in coal mining in the State. It was soon learned that this coal was a good blacksmithing coal, and in 1858 Reese and Price manufactured some coke, which they hauled by ox team to Salt Lake City. In 1873 the coal property passed into the hands of a Salt Lake company which in 1874 and 1875 built several coke ovens and manufactured coke, freighting it by team to York, the terminus of the Utah Central Railway, about 25 miles south of Provo. This company, after spending much money in experimental work, sold out to an English company, which in 1880 to 1882 built the first railroad to enter Sanpete Valley. This railroad connected the coal mines in Indian Pete Canyon, via Wales, with Nephi, the terminus at that time of the Utah Central Railway. It is reported that the English company also spent much money in experimenting with different types of coke ovens and in the development of the coal, but finally abandoned the work through lack of funds. Mr. Thomas reports that the coke from the Wales coal is one of the strongest he has ever seen, but that probably the quality of the coke might be improved if the coal were washed before going to the coke ovens.

No information is at hand regarding the length of time this railroad was in operation, but after a number of years it was extended toward Moroni down Sanpete Valley and was known as the California Short Line. The spur from Moroni to Wales was then abandoned and to-day only the remnants of the grade remain to show where the road once existed.

This early development work for one cause or another lasted only a few years and exploitation on a large scale has since been given little serious thought. This is probably due to the extensive development of the coals of Carbon County, Utah, as well as those of the adjoining States of Colorado and Wyoming. In all of these places the coals are much more extensive, occur in much thicker beds, and are freer from impurities than is the coal near Wales, and for these reasons they can be mined much more economically and at a greater profit than can the Wales coal. Local interest in the Wales coal has, however, never entirely died away, and some coal is mined each winter to supply the local demand. At present the principal activity in mining is in Old Canyon at location 8, where H. R. Thomas operates the mine and practically supplies the people of Wales with their fuel.