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PART II.—MINERAL FUELS

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GEOLOGIST IN CHARGE

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ILLUSTRATIONS.

CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1912.

PART II. MINERAL FUELS.

MARIUS R. CAMPBELL, *Geologist in charge.*

INTRODUCTION.

This volume is the seventh of a series that includes Bulletins 316, 341, 381, 431, 471, 531, and 541, "Contributions to economic geology (Part II)" for 1906, 1907, 1908, 1909, 1910, 1911, and 1912, respectively. Previous to 1906 the annual "Contributions" consisted of one part only and papers on mineral fuels were included with the papers on metals and nonmetals except fuels in a single volume. These earlier volumes are Bulletins 213, 225, 260, and 285, for 1902, 1903, 1904, and 1905, respectively.

As the subtitle indicates, the papers included are of two classes— (1) short papers giving comparatively detailed descriptions of occurrences that have economic interests but are not of sufficient importance to warrant a more extended description; (2) preliminary reports on economic investigations the results of which are to be published later in more detailed form. These papers are such only as have a direct economic bearing, all topics of purely scientific interest being excluded. They have been grouped according to subjects or general regions and each group has been issued as an advance chapter as soon as it was ready.

Brief abstracts of the Survey's publications of the year are given in the annual report of the Director. The complete list of Survey publications affords, by means of finding lists of subjects and of authors, further aid in ascertaining the extent of the Survey's work in economic geology.

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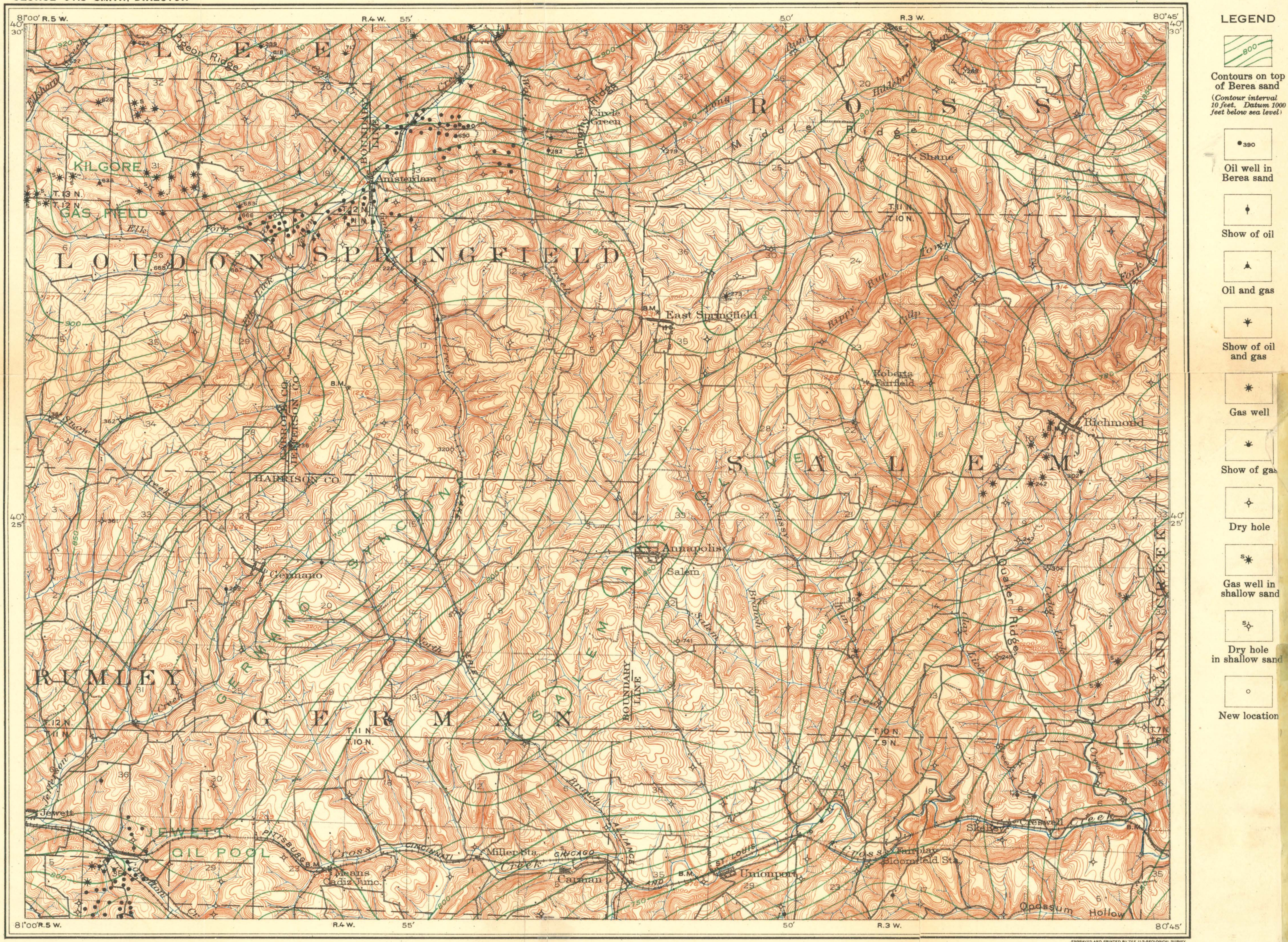


H. M. Wilson, Geographer in charge.
Triangulation and topography by W. T. Griswold.
Surveyed in 1901 in cooperation with the State of Ohio.

MAP OF THE NORTHERN PART OF THE CADIZ QUADRANGLE, OHIO

Showing structure contours on top of the Berea sand

By D. Dale Condit

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

PETROLEUM AND NATURAL GAS.

OIL AND GAS IN THE NORTHERN PART OF THE CADIZ QUADRANGLE, OHIO.

By D. Dale Condit.

INVESTIGATIONS IN THE AREA.

The Cadiz quadrangle lies in eastern Ohio and includes parts of Harrison, Carroll, and Jefferson counties. In 1902 the region was examined by W. T. Griswold, then of the United States Geological Survey,[1] who published a report that included a structural contour map of the Berea sand. A few years later the same author, associated with M. J. Munn, made a study of the Steubenville quadrangle, adjoining the Cadiz on the east, and of the Burgettstown and Claysville quadrangles of Pennsylvania.[2] These reports, the first in which an attempt was made to show accurately the attitude of deep oil sands by means of contours, have led to the extension of fields already known, the discovery of several new oil pools, and, what is equally important, have been of great educational value.

The present author during the later part of 1912 spent several months in field work in the Steubenville-Cadiz region, with the primary object of collecting data for a geologic folio. Considerable information concerning oil and gas was obtained with a view to determining, if possible, favorable areas for future prospecting. Detailed discussion of the geology of both the Cadiz and Steubenville quadrangles is reserved for a later report, this preliminary paper being published to bring immediately to the attention of oil operators and drillers the more important results of the work. Only the northern two-thirds of the Cadiz quadrangle is shown on the map (Pl. I), as only that area receives attention in this paper.

[1] Griswold, W. T., The Berea grit oil sand in the Cadiz quadrangle, Ohio: U. S. Geol. Survey Bull. 198, 43 pp., 1902.

[2] Griswold, W. T., and Munn, M. J., Geology of oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles: U. S. Geol. Survey Bull. 318, 196 pp., 1907.

GEOLOGY.

STRATIGRAPHY.

The stratigraphy of the area has been discussed in detail in previous reports and only a brief outline is needed here. The surface rocks belong in the Conemaugh and Monongahela formations of the Carboniferous system. The Pittsburgh coal, which is the basal bed of the Monongahela formation, appears near the top of the hills at Richmond, East Springfield, and Germano, and is the principal source of fuel for the country people.

Beneath the Pittsburgh coal lies the Conemaugh formation, which comprises about 470 feet of sandstone, sandy shale, and clay, much of which is brick red, and a few coal and limestone beds of little economic importance. The most noteworthy stratum is the Ames or "Crinoidal" limestone member, which lies 210 to 225 feet below the Pittsburgh coal. It consists of one or more layers, having a total thickness of 2 to 10 feet, and can easily be recognized by the abundance of crinoid stems it contains.

The Allegheny formation, underlying the Conemaugh, is known only from drill records in the Cadiz quadrangle, but its upper part may be seen in outcrop along the valley of Yellow Creek a little north of the area mapped. It is the great coal-bearing formation of the Appalachian coal basin, and, although only a little more than 250 feet thick in eastern Ohio, it includes numerous coal and clay beds of great economic importance. One of these coal beds is extensively mined at Amsterdam by shafting.

The knowledge of deeper strata is derived from well records. The Allegheny formation is underlain by the Pottsville formation, which comprises about 150 feet of sandstone and sandy shale, including a few coal and clay beds. The Pottsville is the basal formation of the Pennsylvanian series ("Coal Measures") and rests upon Mississippian (lower Carboniferous) strata.

The Mississippian strata in the region are probably somewhat less than 700 feet thick and consist of sandy shale and several porous sandstone beds, which constitute reservoirs for petroleum and natural gas. Near their top is a thick, coarse sandstone best known among drillers as the Big Injun sand, and about 350 feet lower is the Berea sand, which is the great oil sand of eastern Ohio. It is believed to be the same as the famous Berea sandstone quarried at Cleveland. Few wells have been drilled deeper than the Berea sand and knowledge of lower rocks of the region is slight.

The distance from the Berea sand to the Pittsburgh coal varies rather widely, ranging from 1,450 to 1,530 feet in the area mapped to over 1,600 feet a few miles beyond the southeastern border. This irregularity is due, in part, at least, to an unconformity at the base of the Pennsylvanian strata. Near the end of Mississippian time the surface was exposed to erosion for an indefinite period, developing an uneven surface upon which the Pottsville formation of the Pennsylvanian was laid down. This ancient land surface has been recognized at numerous places along the outcrop of these beds in central Ohio and northwestern Pennsylvania.

Two well records are given to illustrate the general succession of rocks as reported by the driller.

Well No. 273, on the L. D. Rhinehart farm, one-half mile from East Springfield, starts 71 feet below the Pittsburg coal, which outcrops along the road a few rods to the north.

Log of well No. 273 (No. 1 on L. D. Rhinehart farm at East Springfield).

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	10	
Sand, gray	145	1
Limestone, blue, hard	10	1
Fire clay	20	1
Shale, red and gray	115	300
Show of coal	....	....
Shale	50	350
Sand, white, soft	40	390
Shale, dark	35	425
Coal	4	429
Shale, gray	16	445
Sand, white	20	465
Shale, black	10	475
Coal	....	....
Fire clay	30	505
Shale, black	70	575
Sand, gray, hard (Second Cow Run)	30	605
Shale, black, soft	50	655
Show of coal	....	....
Fire clay, white, soft	20	675
Shale, black	45	720
Sand, dark, hard	25	745
Shale and sand	40	785
Sand, white, soft (Salt sand)	70	855
Shale and sand, dark, hard	115	970
Sand, Big Injun, yellowish, soft	100	1,070
Sand, gray, soft	40	1,110
Shale, and blue rock, hard	270	1,380
Shale, black, soft	35	1,415
Sand, Berea, bluish, hard, slight show of oil and gas	45	1,460
Shale, bluish, soft	37	1,497

The record of well No. 690 (No. 7 on the J. Rutledge farm in sec. 13, Springfield Township) is not complete, but it is given to show the position of the Berea sand with reference to the Salt sand and Big Injun sand, both of which are in eastern Ohio locally oil and gas bearing, although of far less importance than the Berea.

Log of well No. 690 (No. 7 on the J. Rutledge farm, sec. 13, Springfield Township).

	Depth to top.	Depth to bottom.
	Feet.	*Feet.*
Conductor	0	12
Coal	390	....
Coal	415	....
Salt sand (gas)	680	....
Big Injun sand	855	970
Berea sand:		
Lime cap	1,342	1,368
First pay (oil)	1,368	1,378
Break (shale)	1,378	1,386
Second pay (gas)	1,386	1,392
Total depth	....	1,395

OIL AND GAS SANDS.

The region included in the Cadiz quadrangle and the adjacent area in eastern Ohio is really a "one-sand" country, for practically all of the oil comes from the Berea sand. Other sands of local importance are the Second Cow Run, the Salt, and the Big Injun. Their positions with reference to the Berea sand are shown in the two well records given above. The Big Injun sand contains a small amount of oil and is productive at Osage in the northwestern part of the Steubenville quadrangle. The Salt sand yields gas a few miles south of Richmond. The Second Cow Run sand is supposed to contain a small oil pool near Unionport and is said to yield considerable gas in the Kilgore field, about 4 miles west of Amsterdam.

The Berea sand, as shown in the record of well No. 690, consists of several parts. At the top is the hard impervious "lime cap" of drillers, which has a variable thickness, measuring 5 to 10 feet at Richmond and 20 to 30 feet at the Amsterdam, Kilgore, and Jewett pools. Beneath the lime cap is the First sand—a white, even-grained sandstone 4 to 12 feet thick in producing wells. In many "dry" holes no pay sand is found, the entire Berea, 30 to 60 feet thick, consisting of dense, dark, impervious rock similar to the lime cap.

Throughout a considerable portion of the western half of the area mapped the Berea has two pay sands, which are designated First and Second by drillers and are separated by a shale "break" several feet thick. The Second sand, which lies about 45 feet below the top of the Berea, is much less persistent than the First sand, but has proved to be equally or even more productive where present. It is found in most of the wells in the vicinity of Amsterdam, is fairly persistent in the greater part of Springfield and Loudon townships, and has been found as far south as the Harrison-Carroll county line.

The development of the great Scio oil field, situated a few miles west of the area mapped, is of interest in this connection. At first oil was obtained there solely from the First sand, and the existence of the Second sand was unknown. Gradually the flow diminished, and in the hope of restoring it a number of the holes were cleaned, drilled a few feet deeper, and reshot. To the great surprise of the drillers the production was greatly increased, in some wells to an amount greater than ever before. Thus the existence of a second pay sand in the Berea became known.

It is possible that an undiscovered Second pay sand may exist in the Cadiz quadrangle also, even in areas where considerable drilling has been done. Scarcely a single well south of the Harrison-Carroll county line penetrates deeply enough into the Berea to prove the presence or absence of the Second sand; and it is significant that the Second sand is productive in the Maxwell pool near the town of Cadiz, about 12 miles south of the Carroll County line.

STRUCTURE.

By geologic structure is meant the attitude of the strata or their position with reference to a datum plane. The best method of showing the structure of coal beds and of oil or gas sands is by a map on which are drawn lines representing contours connecting points of equal altitude. The structure of the Berea sand is shown in Plate I by contours having intervals of 10 feet, the datum being a surface 1,000 feet below and parallel with sea level.

At many points in the Cadiz quadrangle the altitude of the Pittsburgh coal above sea level was determined by spirit leveling. In areas where this coal is not present, as where it has been removed by erosion along the structural arch known as the Salem anticline, its position is calculated from that of the Ames limestone, which outcrops about 220 feet lower. Altogether, its altitude was determined at hundreds of places and its structure or "lay" shown by contour lines drawn through points of equal altitude. From this structural map the structure of strata at and near the surface in this region may be inferred with considerable accuracy, because all of them lie approximately parallel to it. The Berea sand, however, lies so deep and its distance below the Pittsburgh coal varies so widely from place to place that its structure map of the coal will not apply to the sand directly. By taking account, however, of the ever-varying interval between the Berea and the Pittsburgh, as shown by well records, an accurate structural map of the oil sand differing considerably from that of the coal may be deduced. The difference in the position of the contours on Plate I and on Griswold's map [1] is due largely to corrections made possible by new well records.

The Appalachian coal field is a great canoe-shaped basin into which the rocks slope from all sides. Eastern Ohio lies on the west side of this basin, hence the prevailing dip is southeastward. Numerous wrinkles or folds in the strata along the slopes of the basin give anticlines and synclines which cause local flattenings and even reversals of the dip, but whose effects are very insignificant when the basin is considered as a whole. Their influence, however, in the accumulation of petroleum and natural gas has long been known and for this reason their accurate mapping is important to the oil operator.

In the Cadiz quadrangle the most important structures so far as oil is concerned are the Germano synclinal basin and the broad Salem anticline which occupies much of the central portion of the area mapped. These folds trend approximately northeast and southwest, thus according with the general direction of folds in the Appalachian region. The flank of the Salem anticline dips southeastward with fair regularity for many miles, being interrupted only by undu-

[1] The Berea grit oil sand in the Cadiz quadrangle, Ohio: U. S. Geol. Survey Bull. 198, Pl. I, 1902.

lations that suggest cross folding. Along the crest rise several minor domes, the highest of which is near the village of Salem. A promontory-like area extends eastward beyond Richmond, immediately north of which lies a shallow depression, adjacent to a low "saddle" in the Salem anticline.

The Germano basin lies west of the Salem anticline and is a canoe-shaped depression whose axis lies near the village of Germano. Its southwestern portion is constricted by a westward extension of the Salem arch, along which lies the Jewett oil pool. Northwestward from the basin the rocks rise rapidly to the crest of another arch about 2 miles beyond Amsterdam.

SALT-WATER SATURATION.

It is generally conceded that the structure of the rocks is an important factor in the accumulation of oil and gas and that a contour map showing the anticlinal and synclinal folds of a region is indispensable for the intelligent selection of favorable territory for drilling. But the extent to which the sand is saturated with salt water is also important and should be known to anyone making a location. It has been found that there is an upper limit of saturation of the various sands and that there has been a widespread accumulation of oil at this water line. In the Berea sand the water line varies considerably in altitude from place to place. Well No. 249 near Richmond, which struck the Berea a little above the 740-foot contour (260 feet below sea level) is reported to be water bearing. But well No. 242, which found the Berea a little above the 790-foot contour, gives gas. In the Hopedale field, 3 miles southeast of Cadiz Junction and beyond the area represented on the map, a strong flow of salt water is encountered in the wells reaching the Berea sand at the 730-foot contour and gas appears in wells reaching it at the 775-foot contour. In the Jewett pool the water line is somewhat higher, salt water being found at the 780-foot contour and gas at the 800-foot contour. Evidently the upper limit of salt water rises northward across the Germano basin, for well No. 225 (near Amsterdam), in which the top of the Berea sand lies near the 800-foot contour, yielded much salt water.

The altitude of the water line in the Berea sand thus varies considerably from place to place, but becomes progressively higher northward. Its rise is gradual along both sides of the Salem anticline, but differs considerably on the two.

The importance of knowing definitely the extent of saturation of the oil sand is demonstrated by the oil pools in the Cadiz and Steubenville quadrangles. Many of these, including the Island Creek, Pekin, Knoxville, and Osage, follow more or less closely the strike of the rocks and maintain a definite relation to the water-bearing portion of the Berea sand. Were it not for the impervious areas in the oil sand which prevent free circulation, the depth to the water line would be an almost unerring guide to the depth at which the pools should be sought. Unfortunately, however, the condition of the sand governs in part the location of the pools and must be considered in seeking them.

Many pools occur both above and below the water table, as is illustrated by a number of producing areas in the Steubenville quadrangle and elsewhere. It is noteworthy, however, that even in areas where the oil sand lies below the level of saturation, many oil pools closely follow the strike of the rocks for several miles. Such occurrences suggest that the water level fluctuated during former geologic ages, and that each hydrostatic condition was accompanied by the accumulation of oil.

From evidence obtained in areas not shown on Plate I the following generalizations can be made: (1) In areas where the sand lies well above the water line, the oil occurs in very irregular pools, the shapes and dimensions of which are controlled by the porosity of the sand rather than by the direction of dip. It is well known that the Berea sand is for the most part only slightly permeable and that the oil pools lie at favored places where it is locally of more open texture. Occurrences on anticlinal slopes above the water line represent permeable areas in which the oil is retained by an adjoining impermeable sand. (2) The greater number of oil pools found at or near water line lie in "embayments" along the flanks of anticlines rather than on anticlinal "noses" or promontory-like structures. This fact has an important bearing on prospecting and is also of considerable interest as suggesting that the water line has in comparatively recent geologic time receded from a higher level. (3) In pools below the water line the oil as a rule follows more or less closely the strike of the rocks for some distance, suggesting that the pools are the result of one or more ancient and lower water levels, each of which produced a corresponding accumulation of oil.

POOLS OF THE AREA.

AMSTERDAM AND VICINITY.

The Amsterdam pools are the most recently discovered in the Cadiz quadrangle, and the prospects for important extensions and new developments are good. Both the First and Second sands of the Berea are productive, some wells producing from both. The maximum production of wells in the First sand is about 30 barrels a day, but several in the Second sand are reported to yield 150 to 200 barrels.

The wells along the Yellow Creek valley southwest of Amsterdam are in the First sand, but some in the northwest corner of sec. 24, Springfield Township, draw from both sands. Nearly all of the oil produced in sec. 30, London Township, comes from the Second sand. The same is true of the gas wells to the northwest in secs. 25, 31, and 32, and also farther west near the village of Kilgore, which lies just beyond the edge of the area mapped. About one-fourth mile beyond Kilgore is another oil pool.

Much of the gas in the Kilgore field comes from the Second Cow Run sand.

The Second sand of the Berea has been noted in wells 2 miles south of the gas field in secs. 25 and 31, London Township. A slight "showing" of gas and oil was found in well No. 362. The Second sand was recorded in well No. 361, but was not found in well No. 364. Northward from the gas field the occurrence of the Second sand is uncertain. It is productive in well No. 628, in sec. 2, but is missing in well No. 627. Some gas has been found in wells Nos. 624, 239, 618, and 717, near the north edge of the quadrangle, but is said to come from the First sand of the Berea in all of them.

South of the above-mentioned gas field lies an untested area which appears structurally favorable for yielding both oil and gas. The sand in the Kilgore oil pool lies at about the 870-foot contour. The productive area is located on the west flank of the anticlinal "nose," which separates it from the Amsterdam pool. An extension of the Amsterdam pool along the same level would lead southwestward between the dry holes Nos. 667 and 668. Wells Nos. 643, 653, and 666 are said to have a good development of the First sand in the Berea; hence there is a possibility of production from it as well as from the Second sand. Well No. 636, although lying considerably higher on the anticline than the oil wells to the east and west, is reported to yield considerable oil along with the gas. The valley of Elk Fork in sec. 36 and the northern part of sec. 6 to the west are suggested as favorable territory for the search for both oil and gas. Gas may also be expected in sec. 25, provided the sand is good.

All the wells in the immediate vicinity of Amsterdam, as well as those a mile northeastward along the valley of Yellow Creek, probably draw from the First sand of the Berea. All are moderate producers, and start at 2 to 10 barrels. A good development of the Second sand, which is gas bearing, was found in well No. 690 and in several others near by. In the oil wells to the southeast, near Wolf Run, the Second sand likewise has gas, but is also oil bearing, and is said to furnish much of the yield. Apparently it is only a matter of time until the Wolf Run area is joined with that to the northwest by a continuous line of producing wells. The structure in the territory toward the east in sec. 1 appears favorable for prospecting, and may yield from both sands. Well No. 282 was drilled only to the First sand, and gave a showing of oil. Much untested territory lies farther east. Well No. 279 found a hard sand. Well No. 266 is dry in the Berea, but gave a showing of oil in the Big Injun sand. Well No. 269, in sec. 14, Ross Township, gave a showing of oil 28 feet below the top of the Berea.

RICHMOND AND VICINITY.

The pay sand of the Berea in the gas wells at Richmond is less than 4 feet thick, and lies 5 to 10 feet below the top of the Berea. The structure to the south appears the most favorable for oil, but a poor sand is reported in the several dry holes that have been drilled. Well No. 302 gave a showing of oil and gas, and Nos. 305 and 306 a showing of gas. Well No. 247, of which no record was obtained, was drilled at a location theoretically good, but penetrated a sand reported as dense and impervious, and found no oil. Considerable drilling has been done recently on the Kilgore and neighboring farms east of Richmond and just beyond the edge of the area mapped, and both oil and gas have been found. On the Kilgore farm a 2-barrel oil well, from which 2 barrels of salt water were also pumped daily, found the sand at about the 730-foot contour. Oil and gas are associated in a well half a mile north and a little higher structurally. The failure to obtain oil or gas in holes drilled a little southwest of this well is attributed to the hardness of the sand. These facts give little encouragement for the finding of much oil in the vicinity of Richmond.

Drilling near East Springfield and Salem has given uniformly unfavorable results, disclosing at best only a slight showing of oil or gas. Well No. 741, recently completed near Salem, is added to the long list of dry holes in that region, and the sand is reported as very inferior and compact. It seems improbable that either oil or gas will be found in the higher portion of the Salem anticline. The east and west slopes of the Germano basin are suggested as more likely territory for prospecting, although locations can not be definitely specified. There should, however, be an accumulation of oil at the upper limit of salt water, which is at or near the 800-foot contour. A showing of oil has been reported in wells Nos. 209, 236, and 320.

GAS FROM MUD LUMPS AT THE MOUTHS OF THE MISSISSIPPI.

By E. W. Shaw.

MUD LUMPS.

The development of "mud lumps" at the mouths of the Mississippi is generally, if not always, accompanied by the formation of mud springs, from which considerable quantities of combustible gas escape, suggesting that gas is the primary agent of mud-lump upheaval and that it may exist in large and valuable pools beneath the surface. Several companies have considered sinking test wells, and one company has sunk a well designed as a test to a depth of about 2,000 feet at "The Jump," a few miles above the Head of the Passes. Small amounts of gas were found at several different depths in this well, but not in commercially important quantities. However, the well was not located on a recently active lump and perhaps not even on or near an old one.

The present report, which is based on a preliminary examination of the mud lumps, made by the writer in November, 1912, sets forth the principal facts which seem to have a bearing on the possible existence in these places of valuable accumulations of gas.

The mud lumps of the Mississippi are great swellings of soft bluish-gray clay which rise in the shallow water near the mouths of the river, commonly forming islands with a surface extent of an acre or more and a height of 5 to 10 feet. The lumps are rounded or elliptical at first, but are soon carved into irregularity and are sometimes cut in twain by wave action. Their period of growth ranges from a few hours to several years and is commonly irregular. Generally a mud lump rises in a few weeks or months to a height of 4 or 5 feet above the surface of the water. Then it remains quiescent and is beaten down by the waves in the course of a few years. Those which rise slowly are, of course, considerably worn before they stop growing. Those which rise more rapidly and in protected places bear a cap of laminated silt having a maximum thickness of 10 or 15 feet.

The structure of the mud lumps appears to be comparable to that of bysmaliths. A dark bluish-gray clay of medium stiffness and great stickiness forms the central core. Upon and around this core is a series of faulted and folded strata of sand and silt which have been carried up from the sea bottom and deformed in the upheaval. Fissures are numerous and faults are normal, beautiful examples of block faults being common. A peculiarity of many of the new mud lumps is that the surface resembles a plowed field with irregular furrows in every direction. This effect, which has excited much wonder, appears to be the result of slight erosion of an extensively fissured surface.

MUD SPRINGS.

Among the most conspicuous and impressive features of the lumps are the mud springs, which are active on many, though not on all, of the lumps. The discharge from these springs consists of salt, watery mud (sludge) and gas. The amount of sludge discharged is very small and the flow of gas is less than 10 cubic feet an hour. The mud accumulates around the vents and forms cones ranging from a few inches to several feet in height and having a rather striking resemblance both in form and explosiveness to miniature volcanoes.

Careful examination reveals the fact that many and perhaps all of the gas-mud springs are closely associated with fissures. Commonly the fissures are so obliterated that it is difficult to make sure of this fact, but on the freshest lumps both the association and the absence of mud springs between fissures are evident. It seems, therefore, that when a lump is pushed up, the upper part, especially the sand and silt cap, is somewhat extensively fissured. Water rises in the fissures at least to the level of the sea, and gas bubbles rise through the water, causing erosion of the sides of the fissure. In certain favorable locations, along fissures where conditions are just right, the rise of gas bubbles through the water causes sufficient erosion to keep a vent open long after the remainder of the fissure closes entirely. The delta materials contain a large amount of both marsh gas and water, so that wherever a hole a few feet deep is made it almost immediately fills with water and bubbles with gas.

COMPOSITION OF THE GAS.

Two samples of gas were collected from mud springs and on analysis were found to consist principally of marsh gas (CH_4) with some oxygen, nitrogen, and carbon dioxide.

Analyses of gas from mud lumps at mouth of Mississippi River.

[George A. Burrell, Bureau of Mines, analyst.]

	Laboratory No. 3149. 2½ miles southeast of Pass a Loutre lighthouse. Size of sample at atmospheric pressure about 0.1 cubic foot.		Laboratory No. 3150. 3 miles west of Burrwood, La. Size of sample at atmospheric pressure about 0.5 cubic foot.	
	As received.	Air free.[1]	As received.	Air free.
CO_2	4.98	5.22	2.14	2.42
O_2	1.38	.00	2.70	.00
CO	.00	.00	.00	.00
CH_4	77.05	82.50	84.50	97.02
N_2	16.59	12.28	10.66	.56
	100.00	100.00	100.00	100.00
Heating value per cubic foot at 0° C. and 760 mm. British thermal units		879		1,033

[1] Assuming that the O and part of the N got into the sample in the form of air, either before or after the sample was collected.

The samples were collected with considerable care by displacement of water from a large bottle, which was held inverted over the vent with the mouth just below the water surface. A 6-inch funnel was used to guide the gas into the bottle.

Sample No. 3149 was taken from a spring about the middle of the south half of the eighth lump southeast of Pass a Loutre lighthouse. The surface of the sludge in the spring was about 4 feet above mean tide. The other sample, No. 3150, was taken on the west side of Big Cactus lump from a vent which is barely covered at low tide. No water or mud seemed to be flowing from this vent.

The results of the analyses are believed to show correctly the general composition of the gas at the particular vents where the samples were taken. It should be borne in mind, however, that gas from other vents may possibly have a very different composition. Even in the analyses given it may be that owing to the fact that different gases have different degrees of solubility in water the amounts stated are not exactly correct. Water under ordinary conditions of temperature and pressure dissolves about 2 per cent of nitrogen, 4 per cent of oxygen, and 179 per cent of carbon dioxide. For this reason the bottles were filled with water from the throats of the vents, for that was probably nearly saturated with gas, particularly the water used in collecting sample No. 3149. If pure water had been used, the results, especially for those gases present in relatively small amount, would, no doubt, have been very different.

The analyses seem to indicate that the gas is not of deep-seated origin, but has developed within a few feet of the surface, for certain hydrocarbons commonly present in gases found deep in the earth are lacking. The principal constituent, methane (CH_4), emanates from most if not all marshes and generally carries with it minor and variable amounts of nitrogen, oxygen, and carbon dioxide, all of which are produced in the decay of vegetable matter. Natural gas associated with petroleum generally contains other hydrocarbons, particularly ethane, the amount of which ranges from a trace up to 15 per cent or more. Some gases found in deep wells are, however, practically pure methane. Ethane and ethylene, on the other hand, have rarely if ever been found in marshes. Hence, it appears probable, though not certain, that the gas from the mud lumps is produced in the ordinary reduction process, which affects plant material in marshes.

CONCLUSIONS.

It seems improbable that the mud lumps are forced up by natural gas for the following reasons:

(1) As Lyell and Hilgard long ago pointed out, the amount of gas given off seems too small to accomplish such results. There is no reliable report of a flow more rapid than about 10 cubic feet an hour.

(2) If the mud lumps were forced up by gas one might expect the rate of growth to increase rapidly and explosions to be common.

(3) The lumps are composed largely of clay, which seems to be present nowhere else in the delta in such thick beds. If their upheaval were due to natural gas the more fluid beds, such as clay, would probably be thinned instead of thickened.

(4) The lumps seem to have a close relation to the mouths of the river, being most common to the west and within 2 or 3 miles of the end of a pass. They are also more active at and following times of high water.

Though the mud lumps and gases probably can not be taken as indicating valuable pools of gas below, neither they nor any other known circumstance in the region can be taken as contrary evidence. It is very probable that only a part of the marsh gas escapes and that some is entrapped in the silt which is continually accumulating on the delta. The gas which has thus been buried in the thousands of years during which the delta has been growing seems to be now in part disseminated and in part collected into more or less definite pools. Several deep wells have been sunk in the lower end of the delta 70 to 125 miles west of the Passes and most of them have found considerable amounts of gas. One well in sec. 51, T. 19 S., R. 19 E., became uncontrollable from gas found at a depth of about 1,700 feet. Gas escapements of considerable size are numerous, particularly in Terrebonne Parish. Prospecting is difficult because of the softness of the materials, which make the control of gas under any considerable pressure a serious task. Perhaps an economical way will be found to collect the marsh gas from many shallow wells, each yielding only a few hundred cubic feet a day.

STRUCTURE OF THE FORT SMITH-POTEAU GAS FIELD, ARKANSAS AND OKLAHOMA.

By Carl D. Smith.

INTRODUCTION.

The region described herein lies south of Arkansas River in Arkansas and Oklahoma and embraces an area about 40 miles square extending across the outcrops of the main coal-bearing formations of Oklahoma and Arkansas. As shown on the map, the area is traversed by several railway systems, all of which pass through or have connections with Fort Smith.

Natural gas was discovered in Massard Prairie 5 miles southeast of Fort Smith and also about 2 miles southeast of Mansfield, Ark., a number of years ago, and more recently it has been found 4 miles east of Poteau, Okla. This particular area has been selected because it has been more extensively prospected for gas than any other part of the Arkansas Valley trough, and because geologic structures here are typical of a great deal of untested territory in Arkansas and Oklahoma. Further details of structure in a part of this general region are given in other publications.[1]

In the construction of the map accompanying this report free use has been made of reports on the coal fields of Oklahoma and Arkansas by J. A. Taff and A. J. Collier, whose formational boundaries and descriptions of strata have been copied with but little change.

As the purpose of this report is to outline in a general way the region in which geologic structures and formations are similar to those in the smaller area shown on the map, little attention has been given to the depth and thickness of possibly productive sands, well logs, and other detailed information usually contained in such a report.

TOPOGRAPHY.

The character of the topography in the field is determined largely by the attitude and varying degrees of hardness of the strata which make up the geologic section. The geology and topography are so

[1] Collier, A. J., The Arkansas coal field: U. S. Geol. Survey Bull. 326, 1907. Taff, J. A., and Adams, G. I., Geology of the eastern Choctaw coal field, Indian Territory: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, 1900.

closely related that reference from one to the other is necessary to an understanding of either.

The most conspicuous topographic features in the area are Cavanal, Sugarloaf, and Poteau mountains, which reach altitudes ranging between 2,000 and 2,300 feet and are separated by broad valleys, where the general level of the country ranges between 450 and 750 feet. Cavanal, the highest of the three mountains, lies wholly in Oklahoma, 3 to 4 miles west of the town of Poteau. Sugarloaf is crossed by the Arkansas-Oklahoma State line and has its greatest length in a northeast-southwest direction. Poteau Mountain lies near the southern border of the area shown and extends from the vicinity of Heavener, Okla., eastward for a distance of 25 miles, into Arkansas.

The mountains occupy structural basins in which the alternating layers of hard and soft strata lie much like a stack of dishes, gradually diminishing in circumference upward.

GEOLOGY.

STRATIGRAPHY.

The formations which make up the geologic section discussed in this report belong to the Pennsylvanian series of the Carboniferous system, as proved by both fossil shells and plants. That part of the section lying above the top of the Hartshorne sandstone contains a number of coal beds 1 to 7 feet thick; below the Hartshorne no coal of economic importance has yet been found.

The section of rocks exposed in the area shown on the map (Pl. II) is about 12,700 feet in thickness and is made up of shale, sandstone, and beds of coal. This mass of sedimentary rocks has been subdivided and each formation given a name. The composition and character of the formations, named in order from lowest to highest, are described below, and the areal distribution of each is shown by appropriate symbols on the map.

Atoka formation.—The thickness of the Atoka formation, measured across the upturned edges of the formation in an anticline a few miles northwest of Heavener, ranges between 6,000 and 7,000 feet, and its base is not exposed. So far as shown, the whole thickness is made up of shale and sandstone, the sandstone constituting but a small part of the formation and lying in zones about 100 feet thick separated by beds of shale 1,000 to 1,200 feet thick. However, sandstone in more or less abundance is interbedded with the shale; likewise beds of shale occur in the zones prevailingly sandy.

The sandstone beds are medium to fine grained in texture and brown to light gray in color. The shale beds are rarely exposed naturally, but wherever seen they are bluish in color and contain a few ironstone concretions.

Study of the Atoka formation for many miles along its outcrop indicates that the inclosed sandstone beds are somewhat variable in thickness and lateral extent. There are areas in which the formation consists almost entirely of shale, whereas in other areas the beds of sandstone are abnormally thick and massive. The irregularity of the sandstones has an important economic bearing because they form the reservoirs in which gas is found in Massard Prairie near Fort Smith and in the area southeast of Mansfield. The gas obtained east of Poteau seems to come from the Hartshorne sandstone, described below.

Hartshorne sandstone.—The Hartshorne sandstone varies in thickness from 100 to 200 feet and is made up generally of massive beds at the top and thinner beds below, with layers of shale between, gradually giving place to shale of the Atoka formation at the base. The Hartshorne as a rule makes a low ridge and is one of the most easily recognizable and economically important formations in the field, important because of its value as an index to the position of two extensive coal beds, one of which lies just above the sandstone and the other from 50 to 100 feet higher.

McAlester shale.—In areal extent the McAlester shale far surpasses any of the other formations. On account of the relative softness of its constituent materials the McAlester forms the surface rock of most of the lowlands and prairies, which are interrupted here and there by local developments of ridge-making sandstone beds occurring in the shale. The thickness of the McAlester has been estimated at 2,000 to 2,500 feet.

In Arkansas the McAlester shale has been subdivided into several formations, but in order not to complicate the map these subdivisions have been omitted.

Savanna formation.—Three prominent zones of sandstone, each ranging in thickness between 100 and 200 feet, separated by masses of shale, constitute the Savanna formation. Its total thickness is estimated at 1,200 to 1,500 feet.

Boggy shale.—To the casual observer the term "shale" as applied to the Boggy would seem inappropriate, but close investigation reveals the fact that out of a total of about 2,300 feet of the formation exposed in Cavanal Mountain not more than 400 feet is made up of sandstone. The sandstone in relatively thin beds is so interspersed throughout the shale that, on weathering, the superior hardness of the sandstone leaves it in the form of talus, covering the slopes and concealing the shale. In areal distribution the Boggy is confined to the crests of Cavanal, Sugarloaf, and Poteau mountains.

Lack of definite information as to the position of the contact of the Savanna formation and the Boggy shale in Sugarloaf and Poteau mountains has made it undesirable to attempt to represent the Boggy on the map, all strata above the McAlester being shown as Savanna, though remnants of the Boggy 500 to 600 feet thick outcrop in narrow bands along the crests of these mountains.

STRUCTURE.

GENERAL CHARACTER.

The area herein described is a part of a large region occupied by the same or similar formations lying between the intensely folded and faulted rocks of the Ouachita Mountains to the south and the slightly disturbed rocks of the Ozark uplift to the north, and extending from the latitude of Atoka in southern Oklahoma, northeastward and eastward to the vicinity of Little Rock, Ark.

The structure of the region, broadly speaking, is unsymmetrical, in that the folding south of the central part of the trough or basin has been more intense than to the north. Between the latitudes of Atoka and McAlester in Oklahoma the trend of the folds is northeast-southwest; from the vicinity of McAlester eastward the folds trend generally east-west. Some of the anticlinal folds, especially near the south side of the area, have comparatively steep dips on their north sides, and are in places overturned in that direction.

In Oklahoma the area is bounded sharply on the south by the great Choctaw fault, which extends from the vicinity of Atoka northeastward and eastward into Arkansas. Toward the northwest, in Oklahoma, Canadian and Arkansas rivers may be taken as marking approximately the northern limit of the Arkansas Valley type of structure. Northward the folds die out into a monocline with a gentle westward dip.

In Arkansas the belt of folded rock extends approximately 50 miles in width to the vicinity of Little Rock, across which Arkansas River flows diagonally southeast.

At places the compressive force or forces which caused the rumpling of the strata has been more than the strength of the rocks could withstand, and as a result they have been broken, especially along or near the axes of upward folds, thus allowing one limb to override the other, producing what is known as a thrust fault. The axes of anticlines and synclines and the positions of faults are shown by appropriate symbols on the map.

FOLDS.

Backbone anticline.—One of the best-known structural features in the field is Backbone anticline, so named because of its association with a prominent ridge formed by the outcropping edge of an upturned stratum of sandstone, known as Backbone Ridge. This upward fold of the strata extends from the vicinity of Greenwood, Ark., to a point about 1½ miles southeast of Bokoshe, Okla., a distance of about 30 miles. Along the greater part of this fold is a fault, south of which the southward-dipping beds have been thrust to the north, overriding and concealing corresponding beds north of the fault. The outcrop of the Hartshorne coal bed surrounds the anticline.

Biswell Hill anticline.—Biswell Hill, an elliptical domelike eminence northeast of Greenwood, which is mantled over by the Hartshorne sandstone, is the topographic expression of a broad anticline whose axis lies parallel to and a short distance northeast of the east end of the faulted Backbone anticline. The fold is slightly unsymmetrical, the dips to the north being steeper than those to the south. Like the Backbone anticline, of which it is an irregular continuation, the Biswell Hill anticline marks an area without coal surrounded by the outcrop of the Hartshorne coal bed, which dips away from it to the north and to the south. The structure of Biswell Hill, though not so pronounced as that from which gas is obtained southeast of Mansfield, seems to be as good as if not better than that southeast of Fort Smith for the accumulation of gas. What effect the Backbone fault, which ends against the west side of the anticline, may have had on the reservoir-forming, deeply buried strata is problematic; it is possible that this break may have disturbed the rocks in such a way as to form an outlet to the surface, thus allowing any gas that may have collected to escape.

Massard Prairie anticline.—The axis of the Massard Prairie anticline trends northeast-southwest through Massard Prairie about 5 miles southeast of Fort Smith. The surface indications here suggest a broad elliptical uplift with low dips both to the north and to the south. Many wells that have been sunk in and near the summit of the dome furnish the natural gas used in Fort Smith.

Poteau anticline.—The axis of the Poteau anticline trends northeast between Cavanal and Sugarloaf mountains from the vicinity of Howe to the Arkansas-Oklahoma line, thence east for a distance of 6 or 8 miles, where its identity is lost in a broad upward fold lying between Greenwood and Huntington. The productive gas wells east of the town of Poteau are located near the axis of this fold. The part of the anticline which lies in Arkansas has been described by Collier in United States Geological Survey Bulletin 326 as the Montreal anticline. It has been considered advisable to change the name of the anticline, however, because it is more pronounced near the town of Poteau, Okla., than at Montreal, a small town in Arkansas near the east end of the fold.

Hartford anticline.—The axis of the Hartford anticline trends east-northeast and west-southwest through the town of Hartford, Ark. The lowest rocks brought to the surface by the upward fold are exposed in Coops Prairie, a flat area almost completely surrounded by elongated or elliptical encircling ridges made by sandstones of the Atoka formation. In this prairie are located the productive gas wells which furnish fuel for Mansfield and vicinity. From the crest of the axis the strata dip away in all directions. To the west the plunge of the axis of the fold continues for a longer distance than toward the east, hence rocks successively higher in the geologic column appear at about the same level. A few miles northeast of Howe the axis of this fold seems to join with the Poteau anticline in rising toward the Heavener anticline.

Heavener anticline.—The upward fold of the Heavener anticline is peculiar both in its form of development and its trend. From a point near the big bend of Poteau River in the north-central part of T. 5 N., R. 24 E., the axis of the fold rises steeply southeastward to a high arch and descends as abruptly within a mile northwest of Heavener. Should the beds of sandstone which have been worn away and whose edges now crop out in the plain around the elliptical border of this domelike fold be restored, they would form a mountain more than a mile high, 6 miles long, and 3 miles wide. The trend of the axis of the Heavener anticline is slightly south of east and almost directly in line with that of the Poteau syncline, against which it abuts.

Milton anticline.—Only part of the Milton anticline is included in the area here described. It is comparatively narrow and bears a little east of northeast. The axis rises from the vicinity of the southward bend of Arkansas River north of Spiro to the neighborhood of Bokoshe and again descends toward the southwest. The anticline is surrounded by the outcrop of the Hartshorne coal bed, which, however, is concealed by alluvium near the river. It is understood that some wells have been sunk on or near the crest of the fold northwest of Spiro, but with what success is not known.

Cavanal syncline.—The axis of the Cavanal syncline trends east-northeast through Cavanal Mountain, just south of Cameron, Hackett, Excelsior, and Greenwood across the area shown on the map. The deepest part of the basin lies beneath Cavanal Mountain, where the Hartshorne coal bed, a convenient datum plane for comparison of elevations, is probably 4,000 feet below sea level or 6,400 feet below the highest peak of the mountain.

Sugarloaf syncline.—The Sugarloaf syncline is a comparatively shallow structural basin lying between the Poteau anticline and the Hartford anticline. The deepest part of the basin is probably near the point where the Arkansas-Oklahoma line crosses the mountain. From this point its rising axis trends east-northeast just north of the town of Huntington. In the deepest part of the basin the Hartshorne coal is probably 1,700 feet below sea level, or 3,700 feet below the highest peak of the mountain.

Poteau syncline.—The Poteau syncline is a long synclinal trough, which stretches more than 100 miles along the south side of the Arkansas coal field and extends into Oklahoma to a point a few miles northeast of Heavener, where its axis is deflected and swings to the southwest around the south limb of the Heavener anticline. This basin is occupied for the most part by Poteau Mountain, beneath which the Hartshorne coal bed reaches an unestimated depth, possibly almost as great as beneath Cavanal Mountain.

Bokoshe syncline.—The position of the axis of the Bokoshe syncline is not well known except between Spiro and Bokoshe. From the vicinity of Spiro the axis of the fold may trend northeast through Fort Smith or east and join the basin between Massard Prairie and the Backbone anticline.

FAULTS.

Choctaw fault.—The Choctaw fault extends from the vicinity of Atoka, in southern Oklahoma, northeast and east along the south side of the coal field, passing into Arkansas just south of Poteau Mountain, and continuing eastward for an undetermined distance. It separates the coal-bearing rocks on the north from the older rocks of the Ouachita Mountains on the south. Prior to the faulting the rocks lying south of the Choctaw fault were closely folded and in many places the folds were overturned toward the north. Then, as the pressure which produced the folding continued, the strata broke along lines parallel to the axes of the folds and the rocks on the south side of the fracture were pushed upward and over those on the north side. The vertical displacement increases from a few hundred feet at the Arkansas line to several thousand feet farther west.

Backbone fault.—The Backbone fault extends from a point about 2 miles northwest of Greenwood, in a west-southwest direction, paralleling and lying just south of the north outcrop of the Hartshorne coal bed, to a point somewhere between Panama and Bokoshe, where it dies out in the westward-plunging end of the Backbone anticline. This fault represents an overthrust of the strata from the south and shows a displacement of about 5,000 feet at the Arkansas-Oklahoma line. The rocks brought to the surface by the fault consist mainly of sandstone and shale of the Atoka formation, so that the beds of sandstone which produce gas in the various parts of this field probably here come to the surface.

STRUCTURAL RELATIONS.

A prominent theory as to the source of oil and gas is the one which ascribes its origin to the slow distillation of organic matter buried with shale and sandstone at the time of their deposition. If this be the origin of these fuels they must have been disseminated in small quantities throughout the containing sediments, and in order to be concentrated into "pools" as they are now found they must have been transported and collected by some agent. The agent most likely to have accomplished such transportation is water, driven either by capillary attraction or by hydraulic pressure, moving through the formations containing the oil or gas in small particles. When once a reservoir of sufficient porosity, like a sandstone, is reached, where interchange of position is least hindered, the oil, gas, and water would separate by difference in weight, the water occupying the lowest point available, overlain successively by oil and gas, if all three be present. It thus appears that gas would occupy the highest available part of a given reservoir, and would be underlain by oil, if present; if not, by water.

It is evident that bodies of gas under great pressure, unless effectually sealed in by some means, would disseminate throughout the containing porous reservoir until no appreciable pressure would be perceptible. We must conclude, then, that the gas is prevented from escaping upward by some impervious medium—for instance, fine-grained shale—and that it is prevented from spreading laterally along the containing bed of sandstone either by impervious material or by some other means, if impervious material should not be present. Among other means may be mentioned the termination of the porous sandstone bed, the sealing of the porous medium by asphaltic material, and by oil, water, or both, occupying different parts of the sandstone.

In order that the oil or water may be effective, certain structures in the reservoir stratum are necessary. The simplest structure favorable for the accumulation of oil or gas is the anticline or upward fold of the porous reservoir and an overlying impervious layer, which is in effect a dome or elongated fold under which the gas collects and is prevented from escaping or disseminating through the reservoir by the presence of bodies of oil or water occupying lower levels in the same stratum. There are, of course, a number of factors that would and do modify these ideal conditions, but a consideration of them can not be undertaken in this paper.

Anticlinal structures are present in all three of the gas-bearing areas shown on the map of the Fort Smith-Poteau gas field. The best-defined upward fold or anticline produces gas in the region southeast of Mansfield. Here the outcropping edges of the upturned upper part of the Atoka and higher formations encircle the gas-producing area in concentric elliptical ridges, which slope or dip away from the central point in every direction.

Although the Massard Prairie anticline southeast of Fort Smith is not so pronounced as the one near Mansfield, it is fairly well defined, and the gas-producing area there is located at the summit of the dome.

The gas obtained from the area east of the town of Poteau, according to the interpretation of the records of two wells, seems to be derived from the Hartshorne sandstone, as a bed of coal, supposedly the Hartshorne, is penetrated from 100 to 200 feet above the gas-producing sand. It will be noted on the map that these wells lie on or near the axis of the Poteau anticline, along or near which further prospecting in the vicinity will reach the same sand at the shallowest possible depth. To the northeast and southwest the Hartshorne sandstone comes to the surface, hence the areal extent over which it may be gas bearing is rather small. However, it should be remembered that a number of sands occur in the Atoka formation at varying depths below the Hartshorne, and these may contain gas in some part of the fold.

The question as to the probability of striking oil at some point down the dip of the strata below the gas has been asked. It is not known, of course, whether the gas is underlain down the slope of the sand by oil or water, nor how far down the slope the contact of the water and gas or the oil and gas would be found, but toward Sugarloaf and Cavanal mountains the strata dip at the rate of 200 to 300 feet to the mile; hence to reach a given bed it would be necessary to drill deeper and deeper as either of these mountains is approached. It is estimated that the top of the Hartshorne sandstone lies at a depth of 3,000 to 3,500 feet below the town of Poteau.

The production of the wells east of Poteau is reported to be 12,000,000 cubic feet per day, with a gas pressure averaging about 400 pounds to the square inch.

Log of gas well, 3½ miles east of Poteau, Okla.

	Thickness.	Depth.	Remarks.
	Feet.	*Feet.*	
Conductor	6	6	
Hard shell	18	24	
Shale	136	160	Water at 60 feet.
Shell	30	190	
Black slate	80	270	
Hard shell	5	275	
Black slate	60	335	
Shell	20	355	
Black slate	290	645	Small "showing" of water.
Sandy shale	60	705	
Black slate	145	845	
Sandy shale	15	860	
Black shale	210	1,070	
Lime	7	1,077	
Black shale	553	1,630	
Black sandy shell	25	1,655	
Black shale	42	1,697	
Coal	3	1,700	Small "showing" of gas in coal.
Hard shell	2	1,702	
Black shale	94	1,796	
Black hard shell	4	1,800	
Black sand shell	20	1,820	
Gray sand	15	1,835	
Black and gray sand	33	1,868	
Gray sand, gas	32	1,900	

According to well records now in hand, gas wells in Massard Prairie, about 5 miles southeast of Fort Smith, range in depth between 1,312 and 2,845 feet. The log of the deepest of these wells shows that 17 different sands, ranging in thickness from 9 to 263 feet, were encountered in drilling to a depth of 2,845 feet. By no means all of these sands are productive. In some of the wells as many as four sands produce gas, but usually the greatest volume of gas is obtained from one sand in each well. The most productive sands are found between 1,000 feet and 2,100 feet below the surface. The initial closed pressure of the gas varies between 145 and 280 pounds to the square inch, and the daily volume of gas obtained from each well varies between 140,000 and 4,250,000 cubic feet.

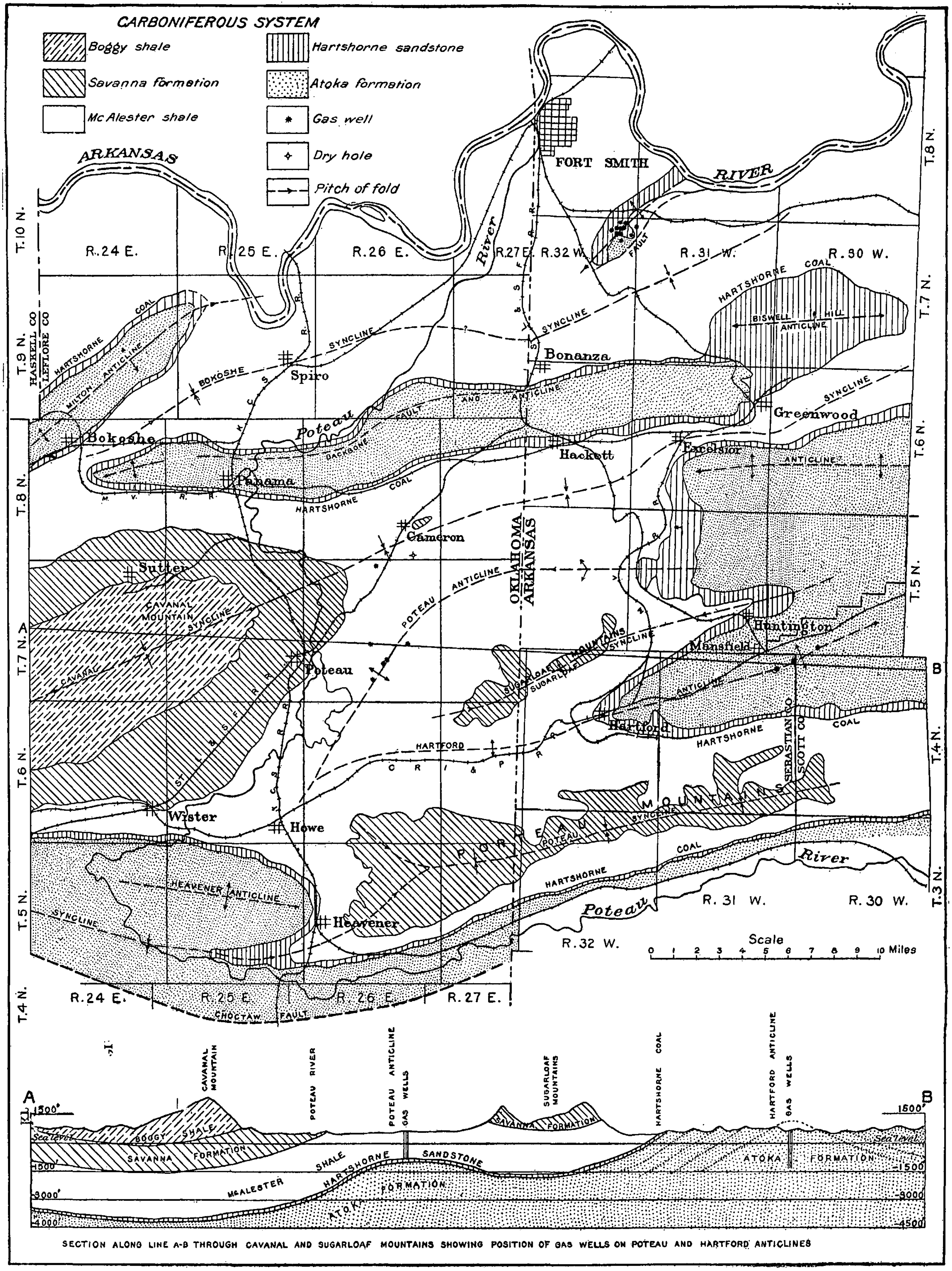
All of the wells in Massard Prairie start in or near the Hartshorne sandstone, hence all the gas is obtained from sands in the Atoka formation.

Log of well in Massard Prairie, 5 miles southeast of Fort Smith, Ark.

	Thickness.	Depth.
	Feet.	*Feet.*
Top and shale	150	150
Sand	19	169
Shale	221	390
Sand	15	405
Shale	20	425
Sand	25	450
Shale	245	695
Sand	40	735
Shale	10	745
Sand	25	770
Shale	235	1,005
Sand	15	1,020
Shale	95	1,115
Sand	253	1,378
Shale	122	1,500
Sand	52	1,552
Shale	393	1,945
Sand	30	1,975
Shale	45	2,020
Sand	185	2,205
Shale	47	2,252
Sand	28	2,280
Shale	90	2,370
Sand	15	2,385
Shale	150	2,535
Sand	25	2,550
Shale	5	2,555
Sand	8	2,563
Shale	44	2,607
Sand	30	2,637
Shale	16	2,653
Sand	20	2,673
Shale	172	2,845

The fault in the Backbone anticline makes prospecting there rather precarious, because the fracturing of the strata may have furnished an outlet to the surface, thus preve[illegible]ny large accumulation of gas.

No detailed information concerning the number, thickness, and depths of producing sands in the Hartford anticline southeast of Mansfield is at hand. It is [illegible]n from geologic evidence, however,



SECTION ALONG LINE A-B THROUGH CAVANAL AND SUGARLOAF MOUNTAINS SHOWING POSITION OF GAS WELLS ON POTEAU AND HARTFORD ANTICLINES

MAP OF FORT SMITH-POTEAU GAS FIELD, ARKANSAS AND OKLAHOMA.

By Carl D. Smith.

that the wells start in the Atoka formation 3,000 feet or more below the Hartshorne sandstone. If gas there is obtained at approximately the same depth as in the Massard Prairie field, a thickness of nearly 6,000 feet of the Atoka formation is to be regarded as containing good prospective gas strata.

As explained under the heading "Stratigraphy," the sandstone beds of the Atoka formation as seen in outcrop are variable in thickness, texture, and lateral extent. This condition undoubtedly holds true where the deeply buried sands in the Atoka are penetrated by the drill. A study of the records in hand indicates considerable variability even in near-by wells. But when the number of sands is taken into account it is thought that, in areas of favorable geologic structure, deep drilling may be resorted to with good chances of successful outcome.

It seems that, if other things are equal, the chances of striking gas are better in the upward folds or anticlines than in other localities. Of course, if a porous medium be not present in the anticline, then the chances there are no better than elsewhere; but as the presence or absence of the porous medium can not be foretold, that chance must be taken as a part of the risk of drilling.

THE GLENN OIL AND GAS POOL AND VICINITY, OKLAHOMA.

By Carl D. Smith.

INTRODUCTION.

On account of its phenomenal production the Glenn oil pool in Oklahoma is well known, but so far as the writer is aware no detailed report of the geology of the pool has ever been published. To determine, if possible, the reason for the accumulation of this wonderful body of oil and gas, one week in December, 1912, was spent by the writer in studying the geologic structure of the field as shown by outcropping formations. This work was supplemental to the investigations that have been carried on in adjacent regions for several years.

The unpublished results of investigations by the writer and others in contiguous territory have been drawn upon freely, as a study of the small area shown on the map would throw but little light on the geology or the conditions governing the accumulation of oil in this pool.

The Glenn pool area as here described is located in Creek and Tulsa counties, Okla., near the towns of Sapulpa and Tulsa, and includes several minor pools known as the Taneha, Red Fork, and Perryman. (See map, Pl. III.) Glenn pool proper was discovered in 1906 and since its discovery its boundaries have been gradually extended until at present it merges with the other pools and no lines can be drawn between them.

It is not the purpose of this report to give any opinion as to the probable future extension of the Glenn pool, but to point out the relation existing between accumulations of oil and gas and the geologic structure as shown by the attitude of surface strata, with a view to ascertaining some general relations that may be applicable to fields yet untouched or only partly developed.

TOPOGRAPHY.

The topography of the Glenn pool area is determined by the attitude and varying degrees of hardness of the strata which make up the geologic section. The most conspicuous features of relief are roughly parallel zones of comparatively rugged sandstone highlands trending northeast-southwest, separated by belts of smoother lowlands developed in softer strata. As a general rule the irregular escarpments have steep slopes facing east and gentle slopes stretching westward from the crests to the base of the next belt of highland. One of these belts of rugged country, trending slightly west of south, lies about 6 miles west of Sapulpa; another passes just west of Sapulpa; still another, which first makes its appearance about 2 miles southwest of Red Fork, passes 2 to 3½ miles east of Sapulpa, and continues to the southwest, passing just west of Kiefer and Mounds. Another highland zone of more or less continuity passes 2 to 3 miles east of the town of Glenpool, and probably should be considered the southern continuation of the hilly country east of Arkansas River and southeast of Tulsa. The regularity of the areas of low relief is interrupted in places by the presence of hard, hill-making sandstone beds in the soft shale which underlies the lowlands. Turkey Mountain, northwest of Jenks, and the hilly country east of Arkansas River and southeast of Tulsa are examples of the local development of sandstone beds in zones which are usually characterized by soft material and marked by comparatively small differences of altitude. Altitudes in the Glenn pool area range between about 600 and 950 feet.

GEOLOGY.

STRATIGRAPHY.

GENERAL RELATIONS OF THE FORMATIONS.

In order to understand conditions that probably prevail beneath the surface in the Glenn pool, it is necessary to consider the character and attitude of formations 35 to 40 miles to the east, where the deeply buried strata of the Gleen pool area come to the surface and can be studied in outcrops. (See cross section, Pl. III.) The section of rocks exposed in the area represented by the map is about 850 feet in thickness and comprises alternating beds of shale, sandstone, limestone, and coal, named in the order of their relative thicknesses. These formations are Carboniferous in age and constitute a part of the Pennsylvanian or middle series of the Carboniferous, which outcrops in northeastern Oklahoma, on the west flank of the Ozark uplift, extends as a broad northeast-to-southwest trending belt from Kansas into Oklahoma, and dips gently westward beneath the Permian series ("Red Beds"). (See fig. 1, p. 43.)

The contact of the Pennsylvanian series with the Mississippian series below, which lies near and roughly parallels Grand River, is unconformable, but the angle of unconformity between the two series is so slight that the discordance in strike and dip of the strata is scarcely perceptible. It is probable that the Pennsylvanian sediments were deposited upon a slightly eroded and gradually sinking land surface composed of the Mississippian series, and were derived, in part at least, from the Mississippian and older rocks which form the core of the Ozark dome. No unconformities of more than local development have been noted in the Pennsylvanian series above the base of the Cherokee formation, which is described below.

Section showing relations, character, and thickness of formations exposed in and to the east of the Glenn pool area, Okla.

	Feet.
Carboniferous system:	
Pennsylvanian series:	
Limestone, bluish gray; locally known as the "Lost City limestone"	1–40
Shale and sandstone	350
Limestone, bluish, hard; checkerboard lime of the drillers	2½
Shale, with variable beds of sandstone	215
Coal, Dawson	1⅔–2½
Shale, with irregular beds of sandstone	210–350
Limestone, massive gray; big lime of drillers	0–40
Shale, with irregular beds of sandstone	200±
Limestone, Fort Scott, Oswego lime of drillers; bluish-gray limestone with 3 to 5 feet of shale near middle	10–30
Shale, sandstone, limestone, and coal; Cherokee formation	1,000±
Unconformity.	
Blue to white limestone, with some shale and thin sandstone; Morrow formation	100–120
Unconformity.	
Mississippian series:	
Limestone, blue and brown, locally sandy and shaly; Pitkin	60±
Black shale with thin beds of limestone and sandstone; Fayetteville formation	20–60
Unconformity.	
Limestone, Boone; flinty limestone and flint	200±

On account of their greater hardness the sandstone and limestone beds are much more conspicuous in their outcrops than the shale, but probably the shale constitutes four-fifths to nine-tenths of the geologic column. The shale is generally soft and friable and disintegrates rapidly on exposure, thus giving rise to valleys or lowlands where unprotected by caps of harder material. The sandstone varies greatly in hardness. Many beds are so loosely cemented that they weather as easily as shale, thus giving the impression that they are extremely variable or lenslike in development, whereas others are of sufficient hardness to form bold escarpments many miles in length.

FORMATIONS NOT EXPOSED IN THE GLENN POOL AREA.

Information regarding strata that underlie the Glenn pool area but are not exposed in it has been obtained from well logs, from geologic reports on adjacent areas, and from personal study of regions to the northeast, east, and southeast, where the formations penetrated by the drill in the Glenn pool area come to the surface. The thickness of these formations is about 2,000 feet and is described in some detail below.

PRE-CARBONIFEROUS FORMATIONS.

The strata below the Boone limestone, the lowest formation of the Carboniferous system, belong to the Devonian, Silurian, and Ordovician systems, which outcrop in the central part of the Ozark uplift to the east. They consist mainly of limestone, and some sandstone and shale, and are so deeply buried in the Glenn pool area that they probably have not been reached by the drill.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

Boone limestone.—The lowest formation considered in detail in this report is the Boone limestone, which outcrops mainly east of Grand River and is known to drillers as the "Mississippi lime." It ranges in thickness from 100 to 350 feet and is made up of limestone, cherty limestone, and layers of chert or flint. The outcrop of the Boone forms a flint-covered surface in which the purer beds of limestone are in few places exposed. It is usually easy of recognition in drilling because of its great hardness, thickness, and cutting action on the drill bit. The Boone is usually regarded as the formation in or below which oil and gas do not occur in paying quantities, but whether or not this conclusion is correct remains to be proved.

After the deposition of the Boone and its consolidation into hard rock there was a period of uplift and erosion. That is, the present surface of the Boone shows evidence of having been a land area at some time in its former history and of having undergone partial destruction prior to the submergence which permitted the deposition of later sediments now found upon its irregular surface.

Fayetteville formation.—Above the Boone is a blue-black shale 20 to 60 feet thick, which generally contains two thin bluish-white limestone members, one near the base and the other near the top. Lenticular beds of dark ferruginous sandstone are present locally in the shale. The Fayetteville formation as a whole is comparatively soft and its base in contact with the Boone below is usually easy to recognize in drilling because of the difference in character and hardness of the two formations.

It is of course practically impossible to recognize in drill records the exact positions of the contacts of formations whose outcrops are so far removed from the point where they are penetrated by the drill as those are in this area. However, after a close study of records of wells in the Glenn pool area and to the east, it is believed that the Fayetteville formation thickens from about 60 feet near Grand River to 275 feet at Glenn pool and that two comparatively thick sandstone beds are present in the formation under cover that do not reach the surface in outcrop.

Pitkin limestone.—Conformably on the Fayetteville formation lies the Pitkin limestone. As described in the Muskogee folio,[1] the Pitkin varies but little from 50 feet in thickness and consists of layers of light-blue to brown granular limestone interbedded with fine-textured harder limestone and some thin layers of shale.

The Pitkin is considered the uppermost formation of the Mississippian series and is separated from the overlying Morrow formation of the Pennsylvanian series by an unconformity similar to the one between the Boone limestone and the Fayetteville formation. But for fossil evidence and detailed study of the formations elsewhere the existence of these unconformities would scarcely be detected in regions contiguous to the Glenn pool area. It is only when large areas are studied that the discordance in strike and dip can be ascertained. North of the Muskogee quadrangle and northeast of the Glenn pool area the Pitkin limestone is thin, and in the southeast corner of Kansas it is absent.

PENNSYLVANIAN SERIES.

In the general region of northeastern Oklahoma a notable change takes place in the character and thickness of the Pennsylvanian formations. In Kansas the Pennsylvanian consists mainly of shale and limestone, sandstone constituting but a minor part of the section, whereas to the south, in Oklahoma, most of the limestones are thin and disappear from the section, very few reaching as far south as Arkansas River. On the other hand, sandstones appear, growing thicker and more regular in development toward the south. Notwithstanding the disappearance of the limestones, the Pennsylvanian section as a whole is thicker to the south.

Morrow formation.—As described in the Muskogee folio, the Morrow formation, the basal formation of the Pennsylvanian series, consists chiefly of limestone, with a lesser amount of shale, and in places thin beds of sandstone. The thickness of the Morrow ranges between 100 and 120 feet and at the top of the formation is an unconformity similar to the one at the top of the Boone. Eastward from the Muskogee quadrangle the limestone in the Morrow is

[1] U. S. Geol. Survey Geol. Atlas U. S., Muskogee folio (No. 132), 1906.

gradually displaced by shale and sandstone. What changes may take place in its composition under cover west and northwest of its outcrop in the Muskogee quadrangle are of course problematical and can be inferred only from the logs of deep wells. North of the Muskogee quadrangle and northeast of the Glenn pool area the Morrow formation is thin, and in the southeast corner of Kansas it has not been recognized as a separate formation in the geologic section.

Cherokee formation.—For purposes of discussion in this report the upper contact of the Morrow formation is assumed as the base of the Cherokee formation, although in southeast Kansas the Cherokee as described probably includes the Morrow or its representative. The base of the Fort Scott limestone forms the upper boundary of the Cherokee. According to the interpretation of well logs, the Cherokee thickens from 850 feet near Tulsa to 1,080 feet near Mounds. In outcrop the lower 500 feet of the Cherokee consists mainly of shale, with interbedded thin sandstone, limestone, and coal, whereas the upper part contains a greater proportion of sandstone. According to the interpretation of well logs, a number of oil and gas sands, which do not appear to reach the surface in outcrop, are penetrated between the middle and the base of the Cherokee in the Glenn pool area. Several sands are productive below the Cherokee, but as that formation contains the sands from which the bulk of the oil and gas is obtained a detailed description of the sandstone beds of the Cherokee, as observed in outcrop, may be of interest.

Study of the outcropping edges of the beds of sandstone in the Cherokee formation east and northeast of the Glenn pool area has thrown much light on their probable character under cover in the oil and gas area. Of course the conclusions are based on the observation of a narrow strip of outcrop, at some distance from the Glenn pool, but without positive evidence to the contrary it may be inferred that similar conditions hold true to the westward, where the sandstones are deeply buried. The sandstones have been described as lenslike masses completely inclosed in shale, or as irregular bodies giving place horizontally to shaly sandstone and finally to shale. In the outcrops of the sandstones the correctness of this conclusion is borne out to a certain extent, but it has also been found that a number of sandstones have comparatively wide distribution, one particular layer having been followed continuously for 50 miles or more along its outcrop. This bed is, however, not regular in texture, being thin or shaly or indurated at some places, and at others thick and massive. Other beds, though not so prominent as the one above referred to, show evidence of considerable lateral extent. Another factor that has probably led to the idea of small lenses and extreme local variability is the influence of an irregular system of folds of the strata.

The result of such folds is that the same sand may be found at different levels in near-by wells. It is believed that the sands are not so lenticular as they have been represented, and that their apparent lenticularity is due to local variations in texture and to structure.

Fort Scott limestone.—In its outcrop east and northeast of the Glenn pool area the Fort Scott limestone is made up typically of two members separated by 3 to 5 feet of shale, the whole ranging in thickness between 10 and 30 feet. Just below the lower limestone, and separated from it by a foot or so of shale, there is generally a bed of coal 12 to 20 inches thick, though between the town of Broken Arrow and Arkansas River the coal bed pinches out. In this locality also the Fort Scott limestone is thin and inconspicuous in outcrop.

The Fort Scott limestone is known to drillers as the Oswego lime, and is one of the most constant and extensive formations in the developed oil and gas region of northern Oklahoma. The top of the Fort Scott has been used as a datum surface for the construction of a structure contour map of the Glenn pool region, which is shown on Plate III and discussed below.

Formations above the Fort Scott limestone.—Between the top of the Fort Scott limestone and the top of a limestone exposed and quarried in the bluff just south of Arkansas River, southeast of Sand Springs, there are between 1,030 and 1,130 feet of beds made up of shale, sandstone, limestone, and coal.

Near Tulsa a limestone known to drillers as the Big lime occupies a position in the geologic section from about 200 to 240 feet above the top of the Fort Scott limestone. To the north and northeast of the Glenn pool area this limestone is extensive and conspicuous, both in outcrop and in the logs of wells. About the latitude of Broken Arrow the limestone disappears in outcrop and, judging by the logs of wells in the Glenn pool area, it is believed that the deeply buried edge of the limestone extends in a southwest direction across the field somewhere between Red Fork and Mounds, and that the limestone noted in well logs in the southern part of the field as Big lime is really the Fort Scott limestone or Oswego lime. In the vicinity of Tulsa the presence of a thin bed of coal just below the Fort Scott serves to distinguish it from the Big lime, but this coal does not seem to extend as far south as the southern part of the Glenn pool area.

FORMATIONS EXPOSED IN THE GLENN POOL AREA.

From 210 to 350 feet above the Big lime is a coal bed 20 to 30 inches thick, whose outcrop passes through Dawson, thence southeast of Tulsa, 3 miles northwest of Jenks, just west of the town of Glenpool, thence southwestward to a point a mile or so east of Mounds. For convenience of discussion it is called in this paper the Dawson coal. This coal is an excellent datum surface for working out details of structure but is noted in only a few well logs. In the neighborhood of Tulsa the coal bed lies about 465 feet above the Fort Scott limestone. Near Mounds it should be found about 550 to 570 feet above the Fort Scott limestone.

About 215 feet above the Dawson coal and 680 to 780 feet above the top of the Fort Scott is a thin hard limestone of remarkable persistence and uniformity, which outcrops in a number of places in the Glenn pool area. This bed is exposed in Tulsa at the junction of the St. Louis & San Francisco and Missouri, Kansas & Texas and Midland Valley railroads, near the north end of the St. Louis & San Francisco Railroad bridge over Arkansas River, at a number of places between Red Fork and Jenks, at many places in Glenn pool proper, and a short distance northeast of Mounds. It varies little from 2 feet 6 inches in thickness and is an excellent datum surface for working out details of structure. It is known to drillers as the Checkerboard lime.

Another recognizable bed in the Glenn pool area is a limestone which outcrops at Lost City and is locally known as the "Lost City limestone." It lies stratigraphically about 350 feet above the Checkerboard lime and 1,030 to 1,130 feet above the top of the Fort Scott limestone. Its maximum measured thickness is about 40 feet, where it is exposed at the site of a proposed cement plant near the northeast corner of sec. 18, T. 19 N., R. 12 E. From this point, both northeast and southwest, the thickness of the limestone diminishes in short distances to a foot or so. It is quarried northeast of Sand Springs and at Lost City, in the south bluff of Arkansas River southeast of Sand Springs. From this latter point the outcrop of the limestone trends south and southwest, passing west of Sapulpa. Above this limestone, in the area shown on the map, is an unmeasured thickness of shale and sandstone that has not been examined in detail and will receive no further consideration in this report.

DEPTH OF THE BOONE LIMESTONE IN THE GLENN POOL.

About the latitude of Tulsa the Boone limestone or Mississippi lime, which is a widespread and easily recognizable formation in drill holes to the north, either changes greatly in character or plunges steeply to the south, causing more or less confusion in well logs. A thickness of about 250 feet of strata variously interpreted by drillers as "very hard black lime and black sand," "mixed ground," and the like, at a depth of 950 to 1,200 feet below the top of the Fort Scott, has been taken by many drillers to be the Boone, but when the known divergence of the various recognizable beds and the probable thickening of the Morrow and Pitkin to the south are taken into account, it is believed that the interpretation is erroneous, and that the Boone lies still deeper, say at a depth of about 1,300 feet below the Fort Scott at Tulsa or about 2,000 feet below the Checkerboard lime, which outcrops in Tulsa. It is believed that the formation usually interpreted in the Glenn pool area as the Mississippi lime is really the combined Morrow and Pitkin.

As nearly as can be ascertained from study of the logs of wells drilled in the Glenn pool area the thickness of the section between the base of the Cherokee and the top of the Boone limestone (Mississippi lime), in which interval three unconformities exist, is about 550 feet. This interval includes the Fayetteville formation, the Pitkin limestone, and the Morrow formation, and no attempt is here made to differentiate them in the columnar section shown on the map.

STRUCTURE.

DEFINITIONS.

By structure is meant the "lay" or attitude of the strata composing the geologic section with reference to a given level. An upward fold or arch is called an anticline and a downward fold a syncline. Where strata have been tilted so as to dip in only one direction the structure is called a monocline. The axis of a fold is a line passing through the highest points along the crest of an anticline or through the lowest points along the trough of a syncline. If some particular stratum of rock be taken as a datum surface, a line representing this surface will rarely be level but will plunge and rise or curve in various directions.

STRUCTURE OF THE REGION.

The Glenn pool area lies in the region known as the Prairie Plains monocline, which extends as a broad belt from Iowa across northwestern Missouri, eastern Kansas, and central Oklahoma. To the east of this monocline in Oklahoma lies the Ozark dome of older rocks toward which the strata rise and outcrop in roughly parallel zones; to the west strata successively higher in the geologic section are exposed in northeast-southwest trending belts. The westward dip of these formations is variable in amount, increasing from 15 feet to the mile in southern Kansas to nearly 50 feet to the mile in the Glenn pool area. The westward inclination of the strata is neither constant nor constantly variable, but is interrupted by areas in which the formations lie flat or nearly so, whereas in other areas the dip is greater than normal. The structure is further complicated by a system of disconnected folds whose axes parallel roughly the direction of general dip—slightly north of west. These folds are not well defined, but seem to be elongated, westward-plunging rumples, which merge both to the east and west with the prevailing westward dip.

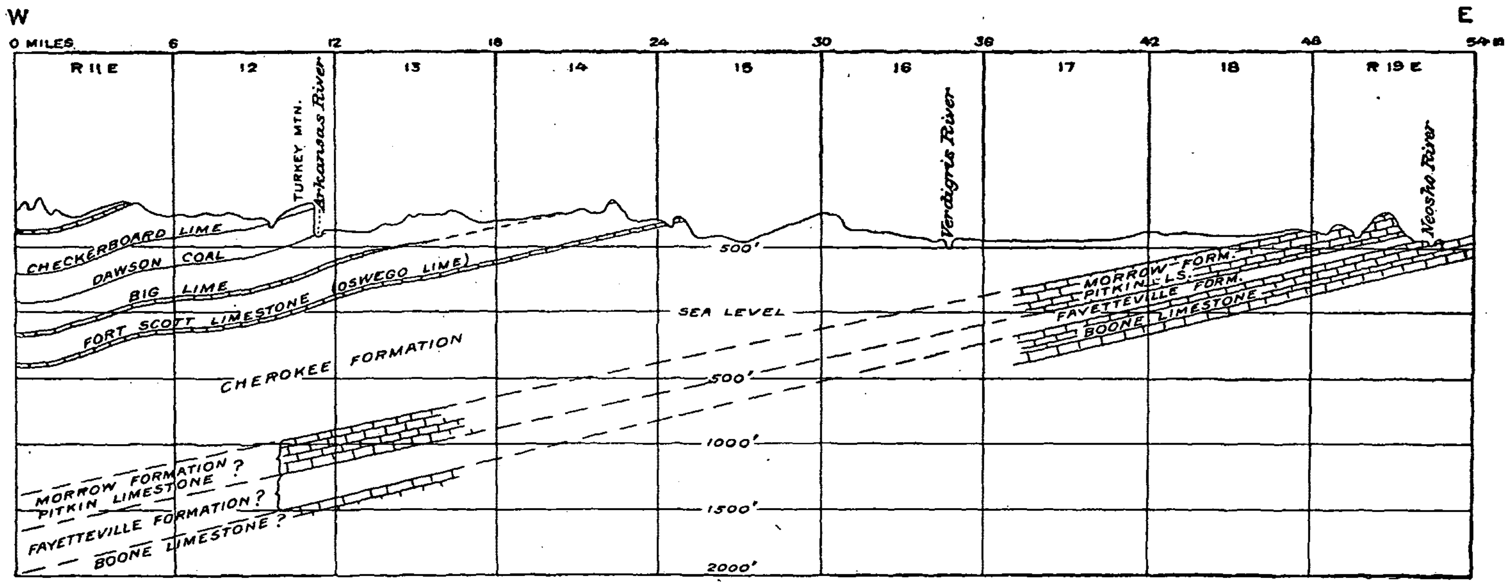


FIGURE 1.—Cross section along line between Tps. 18 and 19 N., Oklahoma, showing westward dip of strata and probable correlation of the Morrow formation, Pitkin limestone, Fayetteville formation, and Boone limestone from their outcrop near Grand River, with formation penetrated by the drill in the Glenn pool area.

Investigation of the strata between the top of the Morrow and the top of the Boone, where they outcrop northward from the Muskogee quadrangle, indicates that the three unconformities embraced in that section converge toward the north, finally merging into one in the southeast corner of Kansas, thus eliminating the Fayetteville, the Pitkin, and possibly the Morrow from the section, and allowing the Cherokee to rest on the eroded surface of the Boone. This seems to be the case also under cover along the ninety-sixth meridian, where, from a study of well logs, nothing that can be interpreted as representing these three formations can be recognized more than a few miles north of the latitude of Tulsa. Southward from Tulsa the limestone beds in the Morrow and Pitkin probably become thicker, and, as discussed above, are likely to be mistaken for the Boone limestone. As a number of sandstone beds occur between the top of the Morrow and the top of the Boone it is believed that a great many wells that are productive at comparatively shallow depths in the Glenn pool area might be deepened with good chances of reaching still lower productive sands.

STRUCTURE CONTOUR MAP.

On the map (Pl. III) an attempt has been made to represent by contour lines on the top of the Fort Scott limestone (Oswego lime) the various structural features involving the oil and gas sands and associated strata in the Glenn pool area. The Fort Scott overlies the most productive sands of the area, hence its value as a datum surface for the construction of a structure contour map depends upon its known relation to the formations below and to the formations exposed at the surface. The projection of the structure of surface formations to underlying strata necessarily presupposes that no unconformity or break in the regular sequence of formations exists within the geologic section under consideration and that they are all parallel or nearly so. A study of the logs of wells that penetrate formations above and below the Fort Scott, and investigation of the same formations in outcrop, indicate that, although the strata are not exactly parallel, there is a more or less regular convergence toward the north and possibly a slight convergence of the formations above the Fort Scott toward the west. In other words, the thickness of the investigated rock section as a whole is less toward the north, although individual members may vary irregularly.

In the construction of a contour map with the top of the Fort Scott as a datum surface all available information, such as the known relation of the limestone to other outcropping formations, the depths at which it was penetrated in wells, and the known convergence of strata toward the north, has been taken into consideration. The accuracy of the map depends, therefore, on the accuracy with which the structure of the area has been worked out, using the outcrops of associated formations as criteria, and on whether or not the logs of wells have been correctly interpreted. As stated in the introduction, the work in the Glenn pool area was done hurriedly, with a view to ascertaining the general conditions, and it is expected that detailed work in the area would doubtless bring out inaccuracies in the map, but it is believed that in the main the features shown are correct.

A contour interval of 25 feet has been taken as best adapted for showing the structure, and the elevations on the top of the Fort Scott are given with reference to sea level. To arrive at the depth of a certain sand at a given place, its distance from the Fort Scott must be known, also the altitude of the surface of the ground at the desired locality.

Below the top of the Fort Scott for a depth of 800 feet at Tulsa to a depth of 1,200 feet near Mounds it is believed that the underlying formations conform to the Fort Scott in structure, though with increasing depth there seems to be an increase in the rate of divergence of the strata toward the south. Below the depths named a number of factors of undetermined value may enter and completely negative any conclusions that might be drawn from a study of the surface formations. Among the most potent of these factors are the great thickening and change in the character of the formations from north to south; the presence of three unconformities or breaks in the natural sequence of rocks between the top of the Morrow and the top of the Boone limestone ("Mississippi lime"); the thinning of the Pitkin and Morrow formations toward the north; and the possible existence of a complex system of faults and folds which involved the Mississippian and the lower part of the Pennsylvanian prior to the deposition of the main mass of the Pennsylvanian.

RELATION OF OIL AND GAS ACCUMULATIONS TO FOLDS IN THE STRATA.

Study of the Glenn pool area, as well as numerous other localities in the same general region, has served to strengthen the writer's belief that in this area geologic structure controls, to a large extent, the accumulations of oil and gas. Where gas, oil, and water, which have different specific gravities, occur in a porous medium like a sandstone, where interchange of position is but slightly hindered, the tendency is that the gas should be forced to the highest available point, whereas the oil would lie below the gas and the water below the oil. This relationship would obtain, provided the containing medium was uniformly porous, but in fact it is not, hence a number of modifying factors, some of undeterminable importance, enter into the list of possibilities that must be considered.

As the presence or absence of sands and their degree of porosity can not be foretold by a study of surface formations, all that remains for the geologist is to work out the geologic structure and to say that, provided a porous medium is present at a certain structurally favorable point, the chances of obtaining oil and gas at that point are far superior to the chances of obtaining oil and gas at some structurally unfavorable point. In the oil and gas region of northern Oklahoma it is unsafe to say positively that oil or gas will not be found at any particular place, but it can be said positively that certain localities are much more favorable than others.

By reference to the map (Pl. III) it will be noted from the deformation contours on the top of the Fort Scott limestone that the axis of a syncline trends approximately east-west through the town of Sapulpa, rising and dying out toward the east until finally it merges with the general rise of the formations in that direction. To the south of this basin the Fort Scott rises to a broad area lying mainly between and to the south of the towns of Kiefer and Glenpool.

From the vicinity of Kiefer the formations dip at comparatively steep angles to the west and northwest, whereas to the east and southeast there is an area which has the appearance of a westward-tilted elongated dome. From a point about a mile south of the middle of T. 17 N., R. 12 E., the formations dip to the southwest, thus indicating a depression or basin in the vicinity of Mounds. Eastward from the line between ranges 12 and 13 the formations seem to dip either slightly to the east or lie nearly flat, but this part of the field has not been studied in sufficient detail to warrant definite statements concerning its structure.

To the north and northeast of the syncline through Sapulpa there is a fairly well defined anticline whose axis trends approximately east-west a mile or so south of the line between Tps. 18 and 19 N. Along the crest or on the flanks of this anticline are a number of producing areas, notably Red Fork, Taneha, Turkey Mountain, and the Perryman pool east of Arkansas River.

The region east and southeast of Tulsa is anticlinal in a general way, the structure resembling an irregular, westward-tilted dome.

CONCLUSIONS.

In the northern Oklahoma oil and gas belt it is almost an infallible rule that where oil is found in a certain sand, salt water will be found down the dip at some place in that particular sand, and gas is likely to be found at some point up the rise from the oil. There are modifying conditions, of course, such as lack of continuity of the sand in one direction or another, irregular "pay streaks," and various other factors undeterminable from mere study of the surface strata.

In wildcatting, a knowledge of geologic structure would be of great value. If sands occur beneath a certain chosen area, and if those sands contain oil and salt water, then it is almost certain that the oil will be found in the upward folds or anticlines and the water in the basins or synclines. The presence or absence of the sands can be ascertained only by drilling.

It is probably fortunate for the northern Oklahoma oil and gas field that the productive sands are either not continuous or not continuously of sufficient porosity from deeply buried pools to the outcrops of the sands on the east to permit free passage of oil and gas, because infiltering surface water would gradually displace these minerals and they would be driven up the slope of containing sands, finally to be dissipated in the air or to come to the surface as asphalt deposits. But reservoirs are produced as effectively by a combination of monoclinal dip and lack of porosity or absence of a sand as by anticlinal structure. The gas and oil, followed by water, will travel up the rise until a zone in the containing sand is reached, where the sand either pinches out or becomes impervious or "tight." Thus, an accumulation of oil and gas in a given sand is likely to have an irregular or ragged boundary on the east and, provided the sand be continuous in that direction, a boundary of salt water on the west. To the north or south the productivity of a sand may be terminated either by lack of porosity, absence of the sand, or, if the structure is favorable, by salt water.

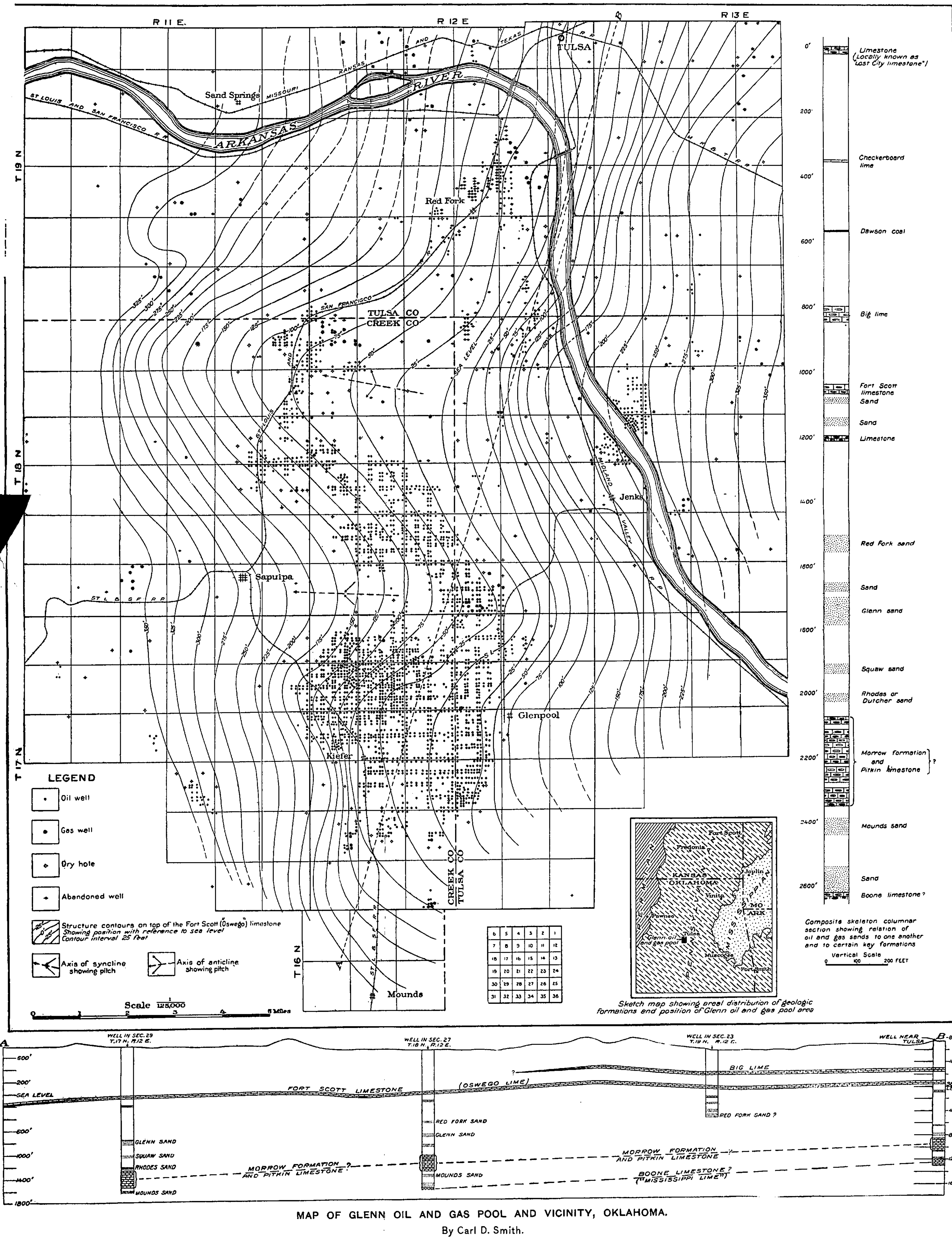
It appears, therefore, that vagaries in the development of porous parts or "pay streaks" in a sand may produce reservoirs where little favorable geologic structure is evident. Very favorable conditions exist in the Glenn pool—a combination of a thick porous sand with anticlinal structure.

QUALITY OF THE OIL.

In the following table partial analyses of several samples of crude oil from the Red Fork, Glenn, and Mounds pools are shown. These samples were analyzed by D. T. Day, of the United States Geological Survey. For a description of the method used and the analyses of many other samples from the Mid-Continent field see United States Geological Survey Bulletin 381.

Analyses of crude oil from Oklahoma.

Sample collected from—	Location of well and pool.	Number of well.	Depth of well.	Physical properties.		Paraffin.	Asphalt.
				Gravity at 60° F.	Color.		
	TULSA COUNTY.						
	Red Fork pool:		*Feet.*	*Baumé.*		*Per ct.*	*Per cent.*
Well	J. I. Yorgee lease, Robt. Galbreath, Tulsa.	3	638	37.3	Green	2.60	0.0
Do	do	5	601	38.2	Dark green.	4.39	.05
Leader pipe	Van Yorgee lease, Robt. Galbreath, Tulsa.	1–7	1,240	36.4	do	6.37	.05
Well	Missouri Lincoln Trust Co. lease, L. E. Mallory & Son, Tulsa.	1	1,200	37.5	Black	3.92	.35
Pipe line	Pump station at Red Fork, Prairie Oil & Gas Co., Independence, Kans.			32.9	do	4.88	.15
	CREEK COUNTY.						
	Glenn pool:						
Well	Grace Berryhill lease, Oklahoma State Oil Co., Kiefer.	9–13	1,500	35.5	do	5.41	.11
Do	Pittman farm, sec. 7, T. 17 N., R. 12, Argue & Compton, Tulsa.	11	1,500	35.5	do	6.98	.45
Pipe line	Pump station, Prairie Oil & Gas Co., Kiefer.			35.4	do	5.99	.24
Well	Thos. Berryhill lease, Indiana Oil & Gas Co., Kiefer.	7	1,518	35.9	do	7.53	.90
Do	Wm. Berryhill lease, Indiana Oil & Gas Co., Kiefer.	15	1,529	38.0	do	11.46	.35
Do	W. B. Self lease, Prairie Oil & Gas Co., Tulsa.	23	1,523	37.2		3.12	.21
Do	do	7	1,553	36.2	Black	9.70	.51
	Mounds pool:						
Do	Corndoffer lease, sec. 18, T. 16 N., R. 12, Swasey Oil Co., Fort Worth, Tex.	1	2,340	32.2	Bright green.	8.44	.62



MAP OF GLENN OIL AND GAS POOL AND VICINITY, OKLAHOMA.

By Carl D. Smith.

THE DOUGLAS OIL AND GAS FIELD, CONVERSE COUNTY, WYOMING.

By V. H. BARNETT.

LOCATION AND DEVELOPMENT OF THE FIELD.

The region discussed in this paper comprises about 180 square miles south of North Platte River and west of Douglas in Converse County, Wyo., and includes portions of Tps. 32 and 33 N., Rs. 72 to 74 W. of the sixth principal meridian. (See fig. 2.) The Chicago

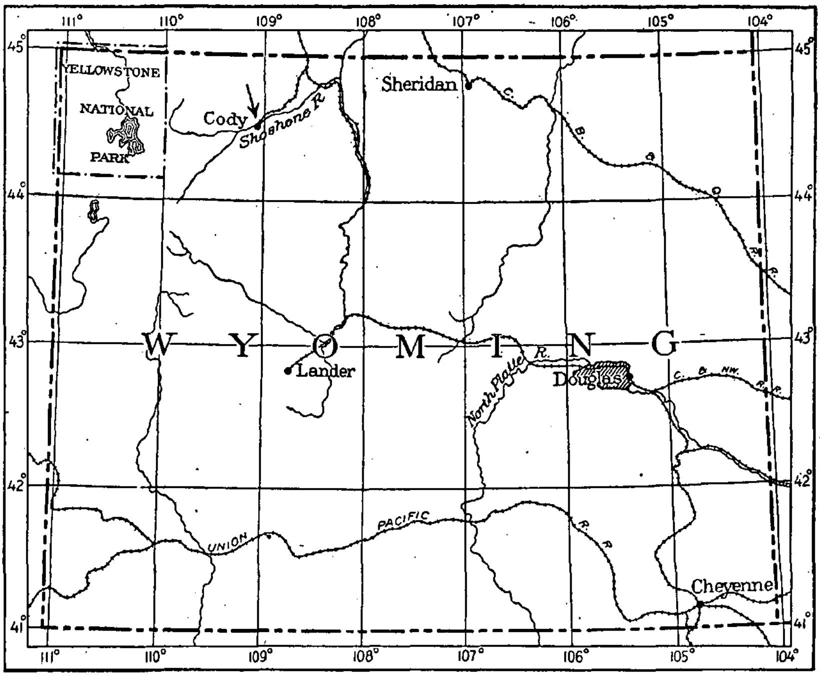


FIGURE 2.—Index map showing location of Douglas oil and gas field, Wyoming. Arrow indicates location of section shown on Plate V (p. 108).

& Northwestern Railway traverses the area in an east-west direction, and surveys have been made through the field for a branch line of the Chicago, Burlington & Quincy Railroad, which will connect the branch line to Orin with the line to Powder River.

The first discovery of oil in this field was probably made in 1894, when in the construction of an irrigation tunnel in the NW. ¼ sec. 16,

T. 32 N., R. 73 W., a sandstone more or less saturated with heavy oil was found in the top of the "Cloverly" formation. Since this discovery several companies have put down wells at different times until at present some 50 or 60 borings are scattered over the Brenning Basin. When drilling began the presence of gas in the basin was little suspected, but a number of the wells have proved to contain more gas than oil. In December, 1904, gas was struck at a depth of 435 feet in a well (No. 18, Pl. IV) in sec. 4, T. 32 N., R. 73 W., in which, according to a statement of J. B. Phillips in applying for title for mineral claim, a pressure of 50 pounds to the square inch was obtained when tested two days later. The Douglas Oil Fields Co. piped the gas to the adjoining claim and used it for several months under a boiler for drilling and for camp purposes. Gas from this well in 1912 was still used at the nearest house. Oil is reported to have been found in 32 wells, gas in 20 wells, and water in 24 wells in this basin. All the 66 wells indicated by numbers on the map (Pl. IV) have corresponding numbers in the list of wells on pages 73–74.

VEGETATION, FUEL, AND WATER SUPPLY.

Farming is carried on extensively in favorable localities, where alfalfa, timothy, and small grain are profitably raised by irrigation. The part of the area not under cultivation yields a good growth of grass which supplies perennial range for stock.

The rainfall is not sufficient to support a growth of timber, except scattered cottonwood and boxelder trees along the streams and a few scrubby pine and cedar on some of the rocky hills. However, marketable pine timber grows in isolated areas in the mountains to the south, especially along the precipitous walls of Boxelder Creek in T. 32 N., R. 75 W. This area was included in one of the wood reserves of the old Fort Fetterman Military Reservation.

The domestic fuel, for the most part, consists of pine and cedar wood, which is hauled from the mountains, and coal, which is mined in the northern part of the area near Inez or at Glenrock, just northwest of the field. Oil and gas have also been utilized to a slight extent as fuel. In 1912 a number of ranchmen in Brenning Basin were using gas for lighting and heating and in one place crude oil was used for heating.

The several streams which rise in the mountains and flow across the field to North Platte River yield a good supply of fresh water for domestic use. For a number of years water from La Prele, Boxelder, and Little Boxelder creeks has been utilized for irrigating small tracts along these streams, but within the last few years irrigation on a larger scale has been made practicable by the completion of the La Prele dam. This dam is so located that the water may be used to generate electricity before it is allowed to flow into the irrigation canals. With this end in view the Platte Valley Development Co. has constructed a power plant below the dam and proposes to transmit electricity to a pumping station on the North Platte, where water for irrigation is to be taken from that stream.

Several good springs of water seep from the gravel and sand beds of the White River formation, notably from the thick conglomerate covering the higher hills in T. 32 N., R. 72 W. A perennial spring with a flow of water several inches in diameter, coming from the sandstone or limestone of the Casper formation, rises at the foot of the mountain in sec. 2, T. 32 N., R. 74 W. Other springs of minor importance come from the granitic rocks or the Casper formation along the foot of the mountain ridge.

ACKNOWLEDGMENTS.

In presenting this report the writer wishes to express his thanks for courtesies extended during the progress of the field work by the people of Douglas and vicinity, and to Messrs. Consaul & Heltman, attorneys for the Wyoming Oil & Development Co., and Douglas Oil Fields (Ltd.). Especial credit is due to Mr. A. W. Phillips, who gave well logs and other information, and to Mr. L. C. Bishop, a local surveyor, who loaned a map of a part of the field.

The field work was done in September and October, 1912, by a party consisting of Frank A. Herald, R. Z. Pierce, Frank Elliott, Bernard Jackson, and the writer.

PURPOSE OF THE INVESTIGATION.

The primary object of the investigation of this field was to ascertain the mineral resources, especially oil, gas, and coal, for the purpose of classifying the land by legal subdivisions into mineral land and nonmineral land. A secondary object and one closely connected with the first was to determine, so far as possible, the geologic structure, the various formations involved, and the conditions which have resulted in the accumulation of oil and gas.

METHOD OF FIELD WORK.

The Douglas field was mapped on a scale of 2 inches to the mile by means of a plane table and telescopic alidade, the township being the unit represented by each field sheet. A complete system of triangulation was established covering the field, and the stations of this system served the purpose of horizontal and vertical control and as a means of tying the different plane-table sheets together. In beginning the primary control or triangulation a base line 11,200 feet in length was measured with a steel tape along a level road between two intervisible points. The line extended from the north quarter corner of sec. 8, T. 32 N., R. 73 W., eastward to a point a short distance west of the northeast corner of sec. 10 of the same township. The land net of T. 32 N., R. 73 W., having been drawn on the plane-table sheet before entering the field, the plane table[1] was set up at the west end (the north quarter corner of sec. 8) of the base and approximately oriented by compass. The telescopic alidade was then sighted on the station at the opposite end of the base, a line was drawn along the edge of the alidade, and the distance as determined by the steel tape scaled off. The exact position of the base line having thus been determined on the plane-table sheet, lines were drawn in the direction of a great number of prominent points, such as houses, trees, derricks, and buttes, and the vertical angles read. After sighting at as many points as were desired from this end of the base the other end was occupied and the table oriented by a back sight on the first station. A second line was then drawn in the direction of as many of the points first sighted as could be seen, thus locating these landmarks on the plane-table sheet. Many of the newly located points were in turn occupied and other points throughout the field were located that were invisible from either end of the original base line. This system was continued throughout the field by transferring points on the margin of one sheet to an adjoining sheet. Wherever a section corner was found it was located on the map with respect to triangulation stations. Altitudes were determined in a large part of the area by means of vertical angles, and in addition a line of levels was carried by the same method from Douglas, at an altitude of 4,800 feet, to each well. (See p. 73.) Stadia traverses were employed in conjunction with triangulation for mapping formation boundaries and locating wells. The map, Plate IV, was assembled after returning to the office by joining the individual plane-table sheets, using the points common to two or more of them.

LAND SURVEYS.

The positions of the Government land corners shown on the map were determined by triangulation and therefore are correct so far as the scale of the map would permit. No attempt was made to find all the section corners, but in the vicinity of the oil and gas wells a considerable number were found. The net shown on the map is based on section corners located in the field and from the alignment map of the Chicago & Northwestern Railway and the General Land Office plats. The net of R. 72½ was drawn from plats in the files of the General Land Office and from three corners shown on the map (Pl. IV), which were located by triangulation in the field and agree with the Land Office record. R. 72½ was surveyed in 1907, as well as

[1] A 15 by 15 inch plane table was used for mapping individual townships, but for carrying locations the larger 24 by 24 inch plane table was employed.

sec. 18, T. 32 N., R. 72 W., the net of which is copied from the Land Office data.

TOPOGRAPHY.

The Douglas oil field may be described in a general way as a rolling prairie dotted with a few prominent buttes and ridges that stand above the general level and inclosed on the south by a low range of mountains. Several small streams which emerge from the mountains through deep canyons cross the area in flat-bottomed valleys and flow into North Platte River. The main part of the oil field lies in the so-called Brenning Basin, a basin-like area in the northern part of T. 32 N., R. 73 W., which is surrounded on three sides by an upland of considerably greater altitude.

The elevation along North Platte River is about 4,800 feet above sea level, but the land rises gradually toward the south until at the foot of the mountains it is 5,400 feet above sea. Thence to the summit of the range, a horizontal distance of less than a mile, the surface rises about 600 feet.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The rocks of the Douglas oil field and vicinity include about 10,000 feet of Paleozoic and Mesozoic formations, ranging in age from Carboniferous to late Cretaceous, and extensive beds of Tertiary (Cenozoic) age, as shown by the following table:

Generalized section of rocks in the Douglas oil and gas field and vicinity, Wyoming.

System.	Series.	Group.	Formation and member.	Character.	Thickness.
Quaternary.				Alluvium, gravel, and sand.	*Feet.* 25±
			Unconformity		
Tertiary.	Oligocene.		White River formation.	Clay, conglomerate, and sandstone.	1,070
			Unconformity		
	Eocene.		Fort Union formation.	Friable sandstone and shale with beds of coal.	(?)
Cretaceous or Tertiary.	(?)		Lance formation.	Friable sandstone and shale with local bed of coal.	4,000+

Generalized section of rocks in the Douglas oil and gas field, Wyoming—Continued.

System.	Series.	Group.	Formation and member.		Character.	Thickness.
						Feet.
Cretaceous.	Upper Cretaceous.	Montana.	Pierre formation.	Probably includes Fox Hills sandstone.	Friable sandstone and shale with local beds of coal near top.	1660
				Parkman (?) sandstone member.	Massive buff sandstone.	150
					Friable sandstone and shale.	1,100
				Shannon (?) sandstone lentil.	Buff to brown sandstone.	300±
					Dark shale with sandstone and calcareous concretions.	1,900
		Colorado.	Niobrara shale.		Gray calcareous shale.	100
			Benton shale.		Dark shale.	300
				Wall Creek (?) sandstone lentil.	Gray and buff sandstone.	100
					Dark soft shale.	870
				Mowry shale member.	Dark-bluish hard shale; weathers light bluish gray to yellowish.	175
					Dark soft shale.	220
	Lower Cretaceous.		"Cloverly" formation.		Buff sandstone and dark shale with black shale near base.	115
Jurassic or Cretaceous.	(?)		Morrison formation.		Green, gray, buff, and maroon shales, and thin sandstone.	200+
Jurassic.	Upper Jurassic.		Sundance formation.		Greenish-gray limestone and sandstone. Largely concealed by White River formation.	300+
Triassic (?).			Chugwater formation.		Largely concealed by White River formation, but lower part where exposed consists of red sandy shale.	1500
Carboniferous.	Pennsylvanian.		Forelle (?) limestone.		Gray thin-bedded limestone.	29
			Satanka (?) shale.		Red shale with thin beds of limestone.	60
			Casper formation.		White, pink, and blue limestones, and gray, white, and buff sandstones.	1,100±
	Mississipian.				Coarse sandstone, interbedded in upper part with calcareous shale.	80
			Unconformity			
Archean or Algonkian.					Crystalline rocks cut by dikes.	

The map (Pl. IV) shows the limiting boundaries of each formation listed in the table, so far as they could be traced. These boundaries have been extended across the territory covered by the White River formation and represent the position which the formations would probably occupy if the overlapping White River formation was removed. In drawing boundaries across the White River formation the writer has used the data afforded by well records, which, however, if taken alone would be of very little use, but combined with other data are of considerable value. A fair estimate of the thickness of the several formations under the overlap is afforded by a measured section of the rocks exposed in T. 33 N., R. 74 W. In this township the Cretaceous formations strike east and west and pass under the White River formation east of Boxelder Creek. As shown on the map, there is an outcrop of the "Cloverly" formation in the extreme southeast corner of the area. This, with the other outcrops of the formation (indicated on the map), gives data for determining the general strike of the "Cloverly" across the entire field from east to west. Other formation boundaries, where concealed by the White River, are drawn approximately parallel to the "Cloverly." It should be borne in mind, however, that the location of the formation boundaries under the White River is more or less hypothetical and that the possible error may be half a mile.

CARBONIFEROUS SYSTEM.

CASPER FORMATION.

The term Casper formation was proposed by Darton[1] for limestone and sandstone constituting the greater part of the sedimentary rocks in the Casper and Laramie Mountains. Darton says that "these rocks represent the southeastward extension of the Amsden and Tensleep formations but are so changed in character and indefinite in statigraphic limits that correlation is not desirable."

The Casper formation in the Douglas field is a thick mass of limestone and sandstone interbedded locally with red calcareous or gypsiferous shale. It is the oldest sedimentary formation of the region and rests upon the uneven surface of the granite.

The lowest member of the Casper formation in this area consists of 80 to 100 feet of very hard coarse-grained sandstone interbedded in the upper part with calcareous shale. This sandstone resembles the Deadwood formation of the Black Hills and it has been so called by Jamison,[2] but in the present discussion it will be included in the Casper formation, as was done in Darton's original description. The following detailed section of the rocks was measured in Box-

[1] Darton, N. H., Geol. Soc. America Bull., vol. 19, pp. 418-430, 1908.

[2] Jamison, C. E., The Douglas oil field and the Muddy Creek oil field, Wyoming: Wyoming Geol. Survey Bull. 3, ser. B, 1912.

elder Canyon, where the exposures are good. Fossils determined by George H. Girty to be of Mississippian age were collected from the base of the top member and include five species given in the table of Casper fossils (station No. 70 in list, p. 57).

Section of lower part of Casper formation in Boxelder Canyon, sec. 6, T. 32 N., R. 74 W.

	Ft.	in.
Sandstone, pink, calcareous, with quartz pebbles and brachiopods	15	
Conglomerate of quartz pebbles the size of a pea	7	6
Shale, pink, calcareous	6	6
Limestone, thin bedded	1	6
Shale, greenish blue, calcareous, with beds of impure limestone 4 inches thick	13	
Sandstone, heavy bedded, very hard, locally contains white quartz pebbles, generally about as large as a pea but a few 1½ inches in diameter	55	
Granite.		
	98	6

The Casper formation is the surface rock throughout a large part of the Laramie Mountains just south of the Douglas oil field, where its thick resistant beds are folded and faulted about the core of igneous rocks. It outcrops as a narrow strip along the south side of the Douglas oil field, where a thickness of over 1,100 feet was measured by the writer. This section is given below:

Section of Casper formation in sec. 23, T. 32 N., R. 73 W.

	Feet.
White River formation.	
Sandstone, upper 20 feet very hard, quartzitic and cherty	40
Limestone, hard, compact, impure	15
Sandstone, buff, cross-bedded	150
Sandstone, reddish, readily breaking into slabs in lower part; upper half calcareous	310
Dolomite, hard	10
Sandstone, yellowish	12
Dolomite, light buff, hard	211
Limestone, blue, hard, compact	16
Shale, red, calcareous, sandy	97
Sandstone, white and red, saccharoidal	81
Dolomite, pink and gray, impure, hard and cherty	150
Sandstone, conglomeratic, with some very small white quartz pebbles	81
Granite.	
	1,173

Fossils collected from the Casper formation are given in the accompanying list. Three of these species are referred by Mr. Girty to the Pennsylvanian; the rest belong to the Mississippian series. It might be added that the three species referred to the Pennsylvanian were found near the top of the Casper, and the others at lower horizons in the formation.

Fossils from Casper formation in the Douglas oil field.

[Determined by George H. Girty.]

	Station No.	Township N.	Range W.	Mississippian.	Pennsylvanian.
Camarotœchia aff. metallica	70	32	74	×	
Camarotœchia sp	67, 68	32	73	×	
Chonetes illinoisensis	70	22	74	×	
Composita subtilita	69	32	73		×
Derbya crassa?	69	32	73		×
Enteletes? sp	69	32	73		×
Eumetria? sp	68	32	73	×	
Schuchertella chemungensis?	70	32	74	×	
Spirifer centronatus	67	32	73	} ×	
	70	32	74		
Spirifer sp	68	32	73	×	
Syringothyris sp	70	32	74	×	
Zaphrentis sp	68	32	73	×	

SATANKA (?) SHALE.

The name Satanka shale was given by Darton and Siebenthal[1] to the red sandy shale which lies between the Casper formation and the Forelle limestone in the Laramie region. The shale is a red calcareous and gypsiferous rock, closely resembling the shale of the Chugwater formation, but it is separated from the Chugwater in the Laramie Basin for the reason that Pennsylvanian fossils were obtained from the overlying Forelle limestone, and this would necessarily mean that the Satanka shale belongs to that series, whereas the Chugwater is probably Triassic. No fossils were collected by the writer in the Douglas oil field either from the Satanka (?) shale or from the Forelle (?) limestone, but the lithology and stratigraphic position of the shale and limestone agree with those of the Satanka shale and Forelle limestone of the Laramie region, as described by Darton and Siebenthal, and for this reason these terms are provisionally applied here rather than the terminology employed in the Black Hills.

The soft Satanka (?) shale lying between the more resistant Casper strata below and the Forelle (?) limestone above is usually eroded into shallow, narrow valleys. It is not differentiated from the Forelle (?) limestone on the accompanying map, however, because the scale would not permit. The Satanka (?) shale, on account of its softness, is in few places well exposed, but with the Forelle (?) limestone it outcrops in a very narrow strip in the southern part of T. 32 N., R. 72 W., and a similar strip in T. 32 N., Rs. 73 and 74 W. Darton and Siebenthal state that in the Laramie Basin the Satanka shale varies in thickness from a thin film to 240 feet. There are but one or two places in the Douglas oil field where the shale is wholly exposed, and here a thickness of only 50 feet was observed. The following

[1] Darton, N. H., and Siebenthal, C. E., Geology and mineral resources of the Laramie Basin, Wyo.: U. S. Geol. Survey Bull. 364, p. 22, 1909.

section, which includes the Satanka (?) shale, Forelle (?) limestone, and a part of the Chugwater formation, was measured on La Prele Creek:

Section of Satanka (?) shale, Forelle (?) limestone, and a part of the Chugwater formation near natural bridge in sec. 16, T. 32 N., R. 73 W.

	Ft.	in.
Chugwater formation:		
Shale, red, sandy	8	
Limestone, red, sandy, crushed	10	
Shale, red, sandy	15	
Sandstone, slabby in lower half, upper part locally saccharoidal	2	
Shale, red, calcareous, sandy	12	
Sandstone, calcareous	4	
Forelle (?) limestone:		
Limestone, with red shale bands 2 or 3 inches thick near base	10	
Limestone, bluish gray on fresh surface, slabby, thin bedded	19	
Satanka (?) shale:		
Shale, red, calcareous	45	
Limestone, gray		3
Shale, red		10
Limestone		4
Shale, red, calcareous	5	
Sandstone, red, massive, top of Casper formation.		
	131	5

FORELLE (?) LIMESTONE.

The name Forelle limestone, from a station on the railroad near Laramie, was applied by Darton and Siebenthal[1] to a limestone exposed along the west slope of the Laramie Mountains. From their description of the formation and its stratigraphic position there seems little doubt that the formation described by them as showing on the west slope of the Laramie Mountains is the same as the limestone found in this field on the north slope of the same range. The strata consist of thin-bedded compact bluish-gray limestones with a slight pinkish tint and an average thickness of about 25 feet. The individual beds are from half an inch to 2 or 3 inches thick and in places are so closely cemented that they present the appearance of a single heavy bed of limestone.

The exposures of the Forelle (?) limestone are not numerous, but wherever seen along the south side of Brenning Basin they present the same thin-bedded or laminated character and are weathered into low sharp ridges.

[1] Loc. cit.

TRIASSIC (?) SYSTEM.

CHUGWATER FORMATION.

The Chugwater formation, according to Darton,[1] "ranges in thickness from 900 to 1,200 feet and consists of sandy shales or soft massive sandstones, nearly all of bright-red color. Gypsum deposits occur in most places."

The Chugwater formation is almost wholly concealed in this field by the overlap of the White River formation. The only exposure noted is in sec. 16, T. 32 N., R. 73 W., where about 50 feet of the lower part is exposed (shown in the top of the section on p. 58). The strata consist of red sandy shale, limestone, and sandstone. It is probable, however, that some of the Chugwater strata are also exposed in sec. 1, T. 32 N., R. 74 W. The thickness of the formation is estimated at about 1,500 feet. This estimate is based on a calculation of the thickness of the beds concealed along La Prele Creek in sec. 16, T. 32 N., R. 73 W., and controlled by the dip of the "Cloverly" formation on the north and the outcrop of the Forelle (?) limestone on the south. As a section of the overlying Sundance and Morrison formations was measured near the southeast corner of the field, the remaining thickness after subtracting this measurement gives the probable thickness of the Chugwater formation.

JURASSIC SYSTEM.

SUNDANCE FORMATION.

The marine Sundance formation (of Upper Jurassic age) and the overlying fresh-water Morrison formation (of Jurassic or Cretaceous age) are poorly exposed in this area on account of the overlap of the White River formation, but in the east bluff of North Platte River, about 6 miles south of Douglas, the full thickness is exposed and about 180 feet of Morrison formation and 250 feet of Sundance were measured. The two formations are similar lithologically, each consisting predominantly of shale interbedded with sandstone and limestone, but the Sundance is marine and contains more limestone than the fresh-water Morrison formation.

Section of Morrison and Sundance formations in east bluff of North Platte River, in sec. 9, T. 31 N., R. 71 W.

	Feet.
Morrison formation:	
Shale, blue and red, with a 6-foot carbonaceous shale near top.	180
Limestone, compact, fossiliferous	3

[1] Darton, N. H., Paleozoic and Mesozoic of central Wyoming: Geol. Soc. America Bull., vol. 19, p. 432, 1908.

Sundance formation:	Feet.
Shale, blue and pink, calcareous and sandy, fossiliferous in lower part	60
Sandstone	10
Shale, bluish gray, sandy, with few bands of sandstone	60
Sandstone	12
Shale, bluish gray, sandy	30
Sandstone, gray, heavy bedded	75
	430

Fossils were collected at two horizons in the foregoing section, about 50 feet apart. In the collection from the upper horizon T. W. Stanton determined a single species, *Planorbis veternum* M. and H., which he refers to the Morrison. He also determined from the collection from the lower horizon two species, Nucula sp. and *Tancredia warrenana* M. and H., which are referred to the Sundance formation. The latter collection is from the top member of the Sundance formation, whereas the other is from the 3-foot bed of limestone at the base of the Morrison formation. The formation boundary, therefore, between the Morrison and Sundance formations is determined in the section within 50 feet.

Of the four small areas of outcrop of the Sundance formation shown on the map (Pl. IV) two are verified by fossils, one in sec. 34, T. 33 N., R. 74 W., and the other in sec. 1, T. 32 N., R. 74 W. (See table of fossils below.) The other two areas, one in T. 32 N., R. 73 W., and the other in sec. 28, T. 33 N., R. 74 W., may be partly or wholly Morrison.

The fossils collected from the Sundance formation are given in the following list:

Fossils from the Sundance formation.

[Determined by T. W. Stanton.]

	Station No.	Township N.	Range W.
Belemnites densus M. and H	91	31	71
	72	33	74
Camptonectes sp	72	33	74
Eumicrotis curta Hall	71	32	74
	72	33	74
Gryphæa calceola var. nebrascensis M. and H	72	33	74
Nucula sp	91	31	71
Ostrea strigilecula White	72	33	74
	71	32	74
Tancredia? inornata (M. and H.)	91	31	71
Tancredia sp	72	33	74
Tancredia warrenana M. and H	91	31	71
Trigonia conradi M. and H	71	32	74

JURASSIC OR CRETACEOUS SYSTEM.

MORRISON FORMATION.

The Morrison formation, which is discussed in connection with the Sundance formation, is mapped with the overlying "Cloverly" formation, as it could not be differentiated in the field. The "Cloverly"-Morrison contact is so poorly exposed throughout the field that little evidence was obtained regarding the true relations of the two formations. Future field work in surrounding areas may throw some light on this subject. The scale of the map is so small that it would not permit much more detail than is already included on it, even if the data were at hand.

CRETACEOUS SYSTEM.

"CLOVERLY" FORMATION.

The "Cloverly" formation is partly exposed along Boxelder Creek in secs. 27, 28, 29, and 30, T. 33 N., R. 74 W.; secs. 6, 7, 17, and 16, T. 32 N., R. 73 W.; sec. 36, T. 32 N., R. 71 W. of the sixth principal meridian, and at several other localities as shown on Plate IV. The excavation for an irrigation ditch has removed the cover in one place (sec. 27, T. 33 N., R. 74 W.), where the full thickness of the formation appears to be exposed. This section is as follows:

Section of "Cloverly" formation in SW. ¼ sec. 27, T. 33 N., R. 74 W.

	Ft.	in.
Sandstone, gray to buff	25	
Shale, dark, light, and sandy in upper half	25	
Sandstone, firm, hard	3	
Shale, blue, sandy, and carbonaceous	1	2
Sandstone, hard, coarse	1	
Sandstone, gray to buff, saccharoidal (not well exposed)	50±	
	105	2±

The sandstones of the "Cloverly" form a low ridge where they outcrop. They are brown, buff, or gray in color and locally conglomeratic and ripple-marked. As described by Darton and Siebenthal[1] the "Cloverly" formation of the Laramie Basin consists of sandstone and clay, representing the Dakota sandstone, Fuson formation, and Lakota sandstone, and lies unconformably upon the Morrison formation. As shown in the foregoing section, in the Douglas field the formation consists of two thick sandstones separated by a shaly member. At the "Cloverly" type locality, however, it is understood, no Dakota sandstone is present, and the rocks are wholly of Lower Cretaceous age. The application of the name, therefore, in other regions to include strata of Upper Cretaceous age is not regarded as good usage, and for that reason the name is now quoted.

[1] Loc. cit.

COLORADO GROUP.

BENTON SHALE.

The Benton shale consists of about 1,600 feet of dark and light shale with a thick sandstone member near the top. It lies directly upon the "Cloverly" formation and is followed above by about 100 feet of hard chalky shale of the Niobrara. The Benton shale comprises at the base about 220 feet of dark soft shale overlain by about 175 feet of dark-bluish hard shale, the Mowry shale member, which weathers light bluish gray to yellowish and produces low ridges. Above the Mowry member is some 870 feet more of dark soft shale which is overlain by 100 feet of gray to yellowish-brown sandstone containing locally abundant Benton fossils. Above the sandstone member and below the Niobrara shale there is about 300 feet of dark shale similar to the dark shale in the lower part of the formation.

Section of the Benton shale measured in sec. 29, T. 33 N., R. 74 W.

	Feet.
Shale, dark	300
Sandstone, forming ridge, fossiliferous	100
Shale	867
Shale, dark, weathering light bluish gray; yellowish gray in upper half, and locally forming pine-clad ridges (Mowry shale member)	175
Clay (bentonite?), gray and yellow mottled, gummy, interbedded in darker clay (one bed of the light clay 8 inches thick)	3
Shale, dark	215
	1,660

A collection of invertebrate fossils from the sandstone member of the Benton yielded nine species, which T. W. Stanton assigned to the Benton shale. These fossils are included in the list on pages 64–65, where they are designated by station No. 74. The fossiliferous sandstone member of the Benton shale in the foregoing section corresponds with the Wall Creek sandstone lentil of the section in the Salt Creek field, as described by Wegemann.[1] The Mowry shale member of the Benton, about 175 feet thick, is shown in the section, but its limits are not defined on the map, Plate IV, because the scale will not permit. The base of the Mowry in sec. 29, T. 33 N., R. 74 W., is marked by some thin beds of bentonite, a compact clay which has the property of absorbing great quantities of water. The Mowry contains numerous fish scales, a characteristic feature of the member, and locally produces low rounded pine-clad ridges, another feature characteristic of the Mowry member in this vicinity.

[1] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, 1911, pp. 37-83.

NIOBRARA SHALE.

The Benton shale is overlain in sec. 25, T. 33 N., R. 75 W., by about 100 feet of hard chalky Niobrara shale, which contains a few *Ostrea congesta* (Conrad) and some fragments of an Inoceramus characteristic of the Niobrara. The outcrop of the shale was traversed for a distance of a little over a mile, as indicated on the map (Pl. IV) by a solid line at the top of the Benton shale, in T. 33 N., R. 75 W. East and west of this outcrop the position of the Niobrara is inferred, as indicated on the map by the broken line. It is continued eastward across the White River formation (indicated by dotted line on the map) approximately parallel to the line marking the top of the "Cloverly" formation, which projects through the White River in T. 32 N., R. 73 W., and outcrops in the bluff of North Platte River in the southeast corner of the field.

MONTANA GROUP.

PIERRE FORMATION AND FOX HILLS (?) SANDSTONE.

The Niobrara shale is succeeded by about 5,000 feet of interbedded shale and sandstone, which is largely marine. There is, however, in the upper part a few coal beds above which marine fossils were collected. Besides *Halymenites major* Lesquereux, the collection includes about 10 species of invertebrates, which according to Mr. Stanton probably belong to the Fox Hills. The species include those in the list (pp. 64–65) bearing locality Nos. 85 and 86. In the area discussed in this report the Montana group is exposed only in the western part of the field, mainly in T. 33 N., Rs. 74 and 75 W., but one little exposure was noted in sec. 19, T. 33 N., R. 73 W., as indicated on the map. The following section was measured in T. 33 N., R. 74 W., and compares favorably (except in the upper part) with the section of the Montana group in the Salt Creek oil field described by Wegemann.[1]

Section of Montana group in T. 33 N., R. 74 W.

	Ft.	in.
Sandstone, brown, friable, with *Halymenites major* and other marine forms and with a thin bed of oysters near middle.	50	
Shale, brown, carbonaceous	4	11
Coal	2	2
Shale, brown, carbonaceous	1	5
Coal	1	9
Shale, brown, carbonaceous	1	9
Sandstone, friable	1	6
Coal, bony		8

[1] Loc. cit.

	Ft.	in.
Clay	2	
Shale, brown, carbonaceous		10
Coal	1	9
Sandstone, friable, interbedded with shale, carbonaceous and sandy	1,600	
Sandstone, buff, massive bedded	150	
Sandstone and shale	1,100	
Sandstone, buff and brown	300	
Shale, dark, with calcareous concretions	1,900	
	5,118	9

In the foregoing section the following comparisons may be made with the section of the Montana group in the Salt Creek oil field. The lower 1,900 feet of dark shale with inclusions of sandstone and calcareous concretions is typical of the Pierre. Overlying this shale is a thick sandstone (300±feet) which seems to occupy the same stratigraphic position as the Shannon sandstone lentil of the Salt Creek field. At 1,100 feet above this is another sandstone about 150 feet thick occupying the stratigraphic position of the Parkman sandstone member. The Fox Hills sandstone is probably represented in the upper 1,600 feet of the section, but it can not be differentiated from the lower beds of the Montana group until more detailed field work is done. Further detailed work may prove also that the 150-foot sandstone here referred to the Parkman is a much higher sandstone and the 300±feet of sandstone referred to the Shannon sandstone lentil is the Parkman member, the Shannon sandstone lentil being absent. The following list of fossils includes all invertebrates from the Colorado and Montana groups collected in the field.

Fossils from Colorado and Montana groups.

[Determined by T. W. Stanton.]

	Station No.	Township N.	Range W.	Benton shale.	Montana group.	Montana group probably Fox Hills.
Actæon sp	78,81	33	75	......	×	......
Anchura? sp	80	33	74	......	×	......
Anomia sp	81,83	33	75	......	×	......
Avicula linguiformis E. and S.	80	33	74	......	×	......
	78,81,83	33	75	......	......	......
Avicula nebrascana E. and S.	88	33	73	......	......	......
	80	33	74	......	......	......
	81,83	33	75	......	×	×
Baculites ovatus Say	77,80	33	74	......	×	......
	78,81	33	75	......	......	......
Baculites compressus Say	84	33	75	......	......	×
Baculites sp	76,83	33	75	......	×	......
Callista sp	85,86	33	74	......	......	×
Corbulamella gregaria M. and H.	77	33	74	......	×	......
Cardium n. sp	74	33	74	×	......	......
Cardium speciosum M. and H.	78,84	33	75	......	......	......
	86	33	74	......	×	×
Chætetes? dimissus White	83	33	75	......	×	......
Cyprina? sp	83	33	75	......	×	......
Dentalium sp	86	33	74	......	......	×

Fossils from Colorado and Montana groups—Continued.

	Station No.	Township N.	Range W.	Benton shale.	Montana group.	Montana group; probably Fox Hills.
Donax? sp. related to D.(?) oblonga Stanton	74	33	74	×		
Donax? sp	74	33	74	×		
Fasciolaria? sp	80	33	74		×	
Haminea? sp	86	33	74			×
Inoceramus barabini Morton	77	33	74		×	
	82	33	75			
Inoceramus fragilis H. and M. variety	74	33	74	×		
Inoceramus oblongus Meek	78	33	75		×	
Inoceramus sagensis Owen ?	78,81	33	75			
	80	33	74		×	×
Inoceramus sp	83	33	75		×	
Leda sp	78	33	75		×	
Lucina sp	78	33	75		×	
Lunatia sp	74,86	33	74	×		×
Mactra gracilis M. and H.	79	33	74		×	
Mactra huerfanensis Stanton	74	33	74	×		
Mactra sp	88	33	73			
	84	33	75			×
Mactra warrenana M. and H. ?	78,81	33	75			
	80,86	33	74		×	×
Micrabacia americana M. and H.	83	33	75		×	
Modiola sp	83	33	75		×	
Modiola galpiniana E. and S.	78,81	33	75		×	
Nucula cancellata M. and H.	86	33	74			×
Nucula sp	84	33	75			×
Ostrea pellucida M. and H.	85	33	74			×
Ostrea soleniscus Meek	74	33	74	×		
Ostrea sp	80,85	33	74			×
Protocardia subquadrata E. and S.	78,81,83, 84	33	75		×	×
Protocardia? sp	88	33	73			×
Pyrifusus sp	83	33	75		×	
Scaphites sp	88	33	73			
	80	33	74			
	83	33	75		×	×
Scalaria? sp	74	33	74	×		
Shark's tooth	76	33	75		×	
Syncyclonema rigida H. and M.	78	33	75		×	
Syncyclonema sp	83	33	75		×	
Tellina scitula M. and H.	86	33	74			×
Tellina sp	74,80	33	74	×	×	
Thetis circularis M. and H.?	84	33	75			×
Turris minor M. and H.	81,78	33	75		×	
Vanikoro ambigua M. and H.	80	33	74		×	

Fossils from stations 83 and 84 were identified by F. H. Knowlton as *Halymenites major* Lesq. and were assigned to the Fox Hills.

CRETACEOUS OR TERTIARY SYSTEM.

LANCE AND FORT UNION (?) FORMATIONS.

The Montana group is overlain within the limits of the area represented on Plate IV by about 4,000 feet of strata which include the Lance formation and possibly some of the Fort Union formation, but no attempt is made by the writer to differentiate the two formations, as the field work was confined mainly to older rocks. The scope of this paper does not permit a discussion of these formations in detail, but as two lots of fossil plants were collected, the fossils are included in the list below. All these species are referred by Mr. Knowlton to the Fort Union. Station 89 is near the top of the Inez group of coal beds, about 3,000 feet stratigraphically above the top of the Montana. Station 90 is at a little higher horizon.

Fossil plants from the Douglas oil and gas field.

[Determined by F. H. Knowlton.]

	Station No.	Township N.	Range W.
Aralia notata Lesq	89	33	73
Aralia, perhaps new	89	33	73
Ficus artocarpoides? Lesq	90	33	72
Ginkgo sp	90	33	72
Platanus, probably P. haydenii Newb	89	33	73
Platanus raynoldsii Newb	90	33	72
	89	33	73
Quercus? sp	89	33	73
Sapindus sp	89	33	73

TERTIARY SYSTEM.

WHITE RIVER FORMATION (OLIGOCENE).

As stated in a previous paragraph and shown on the map, a large part of the Douglas oil field is covered with a thick mantle of the White River formation, which rests unconformably on all the lower formations. It is composed largely of clay, with fine sand, limestone, and conglomerate occurring at various places in the formation. The total thickness of the formation exposed from the top of Table Mountain to the bed of La Prele Creek, including the 90-foot cap of conglomerate, is 580 feet. The exposures are poor, but so far as can be seen the 490 feet below the conglomerate is composed largely of clay, mostly of drab and gray shades, but some of pink or green. The conglomerate is made up largely of quartz or quartzite pebbles, with here and there a bowlder of granite, the whole cemented together with calcium carbonate. The pebbles average about half an inch in size, though many are much larger. One granite bowlder was noted having a diameter of 18 or 20 inches. The most prominent bed of conglomerate noted is on the east side of Brenning Basin and is 90 feet thick, capping Table Mountain and extending over a large part of T. 32 N., R. 72 W.

QUATERNARY SYSTEM.

Alluvium along the streams and some local deposits of unconsolidated gravel and sand constitute the only beds of Quaternary age in the Douglas field. An attempt was made to map the alluvium along North Platte River and Boxelder and La Prele creeks, as shown on the map (Pl. IV), but the gravel and sand were not mapped. These materials were laid down unconformably upon the White River formation, from which it is in places difficult to distinguish them. The thickest bed of Quaternary material observed in the field is in the east bank of Little Boxelder Creek in the NE. ¼ sec. 25, T. 33 N., R. 74 W., where there is a cliff 40 feet high, the upper half of which is gravel and sand of Quaternary age, and the lower half the White River formation.

IGNEOUS ROCKS.

Underlying the Casper formation just south of the Douglas oil field and forming the core of the Laramie Mountains is red granite, which is cut by basic dikes of various kinds. Only one little area of the granite is indicated on the map, but it forms the surface rock of a large part of T. 32 N., Rs. 74 and 75 W., just south of the area treated in this report. The granite exposed in secs. 23, 26, and 27, T. 32 N., R. 73 W., is cut by several parallel dikes, as indicated on the map. The dike rock is a hornblende gneiss, as determined in the laboratory of the United States Geological Survey by J. Fred Hunter, from microscopic slides. The dikes have been prospected for copper by local mining companies, one prospect having been extended into the largest of the dikes to a depth of about 75 feet. A little copper in the form of chalcopyrite was found, but it is hardly probable that it will ever be found in paying quantities.

STRUCTURE.

The overlap of the White River (Tertiary) formation renders the interpretation of the structure of the older beds very difficult, yet it is apparently monoclinal, with a general dip toward the north. This interpretation is based on the observed dips of the older beds north, west, and south of the overlap. At all these places the dip is uniformly toward the north, northeast, or northwest, with the exception of a narrow belt in T. 33 N., Rs. 74 and 75 W., where the beds are slightly overturned to the north. If the great fault described by Darton,[1] as striking eastward in the vicinity of Casper Mountain (20 or 30 miles west of the Douglas oil field), extends under the mantle of the White River formation, it probably has no great throw, as the structure seems to resemble a fold more than a fault. That this flexure was produced by compressive forces is evident, however, from the fact that there are numerous small thrust faults and some overturned strata at a number of places in the field. The displacement in most of the small faults is only a few inches. Such an overthrust was observed in sec. 25, T. 33 N., R. 75 W., where a sandstone in the Benton shale, dipping at a high angle, has been broken by a series of parallel faults, as shown in figure 3. There are also overturned strata in secs. 31, 32, 33, and 34, T. 33 N., R. 75 W.,

[1] Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey, Prof. Paper 32, pp. 53-55, 1905.

and secs. 28 and 34, T. 33 N., R. 74 W. The fault in T. 32 N., R. 73 W., is distinct in the White River formation and is indicated on the map by a solid line. No data are at hand bearing upon the amount of throw of the fault, but it is believed to be small.

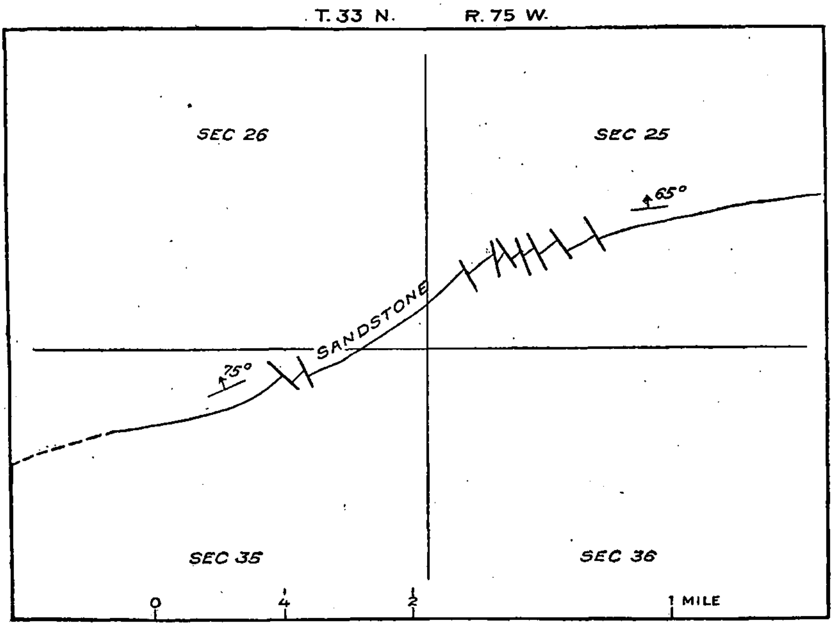


FIGURE 3.—Faults cutting sandstone in Benton shale, T. 33 N., R. 75 W., Wyoming.

OIL AND GAS.

OCCURRENCE.

There are several localities in the Douglas field where oil finds its way to the surface in the form of seeps or springs. About 1894, while a tunnel was being dug for an irrigation ditch in the NW. ¼ sec. 16, T. 32 N., R. 73 W., a sandstone in the top of the "Cloverly" formation was penetrated and found to be saturated with oil. At another place in sec. 6, T. 32 N., R. 74 W., in the bed of Boxelder Creek, oil seeps from the top of the Casper formation, appearing on the surface of the water. Still another oil seep is reported by Jamison[1] in a small ravine near the northwest corner of T. 32 N., R. 73 W. Oil is obtained from wells in secs. 8 and 9, T. 32 N., R. 73 W., and a small quantity from a well in sec. 31, T. 33 N., R. 74 W. In the last-mentioned well the oil seems to come from the same horizon as the oil that appears on the water in Boxelder Creek about a mile south of the well. Oil in the wells in secs. 8 and 9, T. 32 N., R. 73 W., seems to come either from the top of the "Cloverly" formation or

[1] Jamison, C. E., Wyoming Geol. Survey Bull. 3, ser. B, 1912.

from the lower part of the Benton. The wells in sec. 8, however, yield a much lighter oil than those in sec. 9. This suggests different horizons or at least different conditions of accumulation. It is probable that in sec. 8 the oil is held in a reservoir formed either by a small anticline, suggested by the curve in the outcrop of the "Cloverly" and the Chugwater formations, or by the White River formation, which overlies the older rocks and on account of its water-saturated condition is impervious to oil. In sec. 9 the wells are near the seeps and also near a fault, so that the lighter elements of the oil may have escaped, leaving a heavy oil behind.

It is difficult to determine with any degree of certainty the geologic structure under the heavy mantle of the White River formation. Jamison [1] has assumed an anticline striking in an east-west direction through the northern part of T. 32 N., R. 73 W., but the writer is inclined to the view that the beds dip rather uniformly toward the north and that the accumulation of oil and gas is due to the thick impervious mantle of clay of the White River formation. The base of the White River seems to contain conglomerate and other porous material in which the oil and gas might accumulate after migrating from the underlying older rocks. Such a relationship exists in the Coalinga district, California, described by Arnold and Anderson [2] as follows:

> Within the tested territory of the Coalinga district it has been found that the areas of Miocene sediments (either Vaqueros, Santa Margarita (?), or Jacalitos) immediately underlain by the shales of the Tejon are oil bearing; that the productiveness of these beds varies roughly inversely with their distance from the shales of the Tejon; that the productiveness is greatest where the Tejon occupies a position of angular unconformity with the Miocene sands or is more or less disturbed, as near the axis of an anticline such as the Coalinga anticline.

The White River formation in the Douglas field rests unconformably on the upturned edges of the older rocks, which include nearly all the beds of the Colorado and Montana groups, both of which are known to yield oil in the Salt Creek field and near-by areas. It is believed by the writer that the oil in migrating upward along bedding planes and through porous sandstone finds a barrier when it reaches the White River formation, so that oil and gas accumulate near this line, penetrating the White River only where they encounter lenses of porous material or fault planes. There are at least two parallel faults cutting the White River formation in T. 32 N., R. 73 W. (see Pl. IV), and others are believed to exist. In sec. 6, T. 32 N., R. 72 W., heavy oil is reported in a water well at a depth of 175 feet. The White River formation is almost certainly over 175 feet thick at this

[1] Loc. cit.

[2] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga district, California: U. S. Geol. Survey Bull. 398, p. 186, 1910.

place, so that probably the oil is in the White River, having migrated from older underlying beds.

Oil is found in the Salt Creek field, according to Wegemann,[1] as high in the section as the Shannon sandstone, a lentil in the Pierre formation. If the boundaries of that formation where it extends under the White River are as indicated on the map, then the wells in the northern part of T. 32 N., R. 73 W., if extended entirely through the White River formation, would penetrate shale of the Pierre formation below the horizon of the Shannon sandstone lentil. The writer holds that less than half of the wells in the Brenning Basin, except those near the outcrop of the "Cloverly" formation, have gone deep enough to enter the older formations. If this is granted, another hypothesis must be postulated, namely, that the White River formation occupies an old valley, the bottom of which is near the same elevation as the present bed of North Platte River above Douglas. To illustrate, the elevation of the bed of North Platte River at Douglas is about 4,750 feet. The altitude of the surface at well No. 2 in sec. 1, T. 32 N., R. 73 W., is 5,140 feet, and the depth to the bottom of the White River formation in this well (according to the writer's interpretation of the well log) is at least 412 feet, making the base of the White River formation 4,728 feet above the sea, or 22 feet lower than the bed of the North Platte at Douglas. From other calculations, the elevation of the base of the White River varies in different wells from about 4,600 to 5,244 feet; therefore, to account for this variation, it is held that prior to the deposition of the White River there was a valley extending eastward from the Brenning Basin and passing just south of Douglas.

CHARACTER OF THE OIL.

There are two grades of oil in the Douglas field. One of these is a heavy oil, having a specific gravity ranging from 0.9309 to 0.9743, and the other is comparatively light and has a specific gravity of 0.8439. The light oil is of good quality, as shown by the analysis below. The well from which this oil comes (No. 30, Pl. IV) is reported to have yielded about 40 barrels a day for a long time, the oil being used in connection with the construction of the La Prele dam. The heavy oil is said to be a good lubricating oil in the crude state, having been used on the machinery of drilling outfits.

The following analyses of oil from the Douglas field were made in the laboratory of the United States Geological Survey under the direction of David T. Day:

Sample No. 1, from well No. 30, is evidently the best oil in the field. This sample was unoxidized, having been pumped direct from

[1] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 37-83, 1911.

the well and at once soldered in a can. Mr. Day says that it "would be classed as regular Pennsylvania crude and evidently consists entirely of paraffin hydrocarbons. It gives an amount of gasoline and kerosene sufficient to constitute a good refining oil, and the residue would be satisfactory for cylinder oils."

Sample No. 2, from well No. 49, was procured from a tank where it had stood partly exposed to the weather for two or three months.

Sample No. 3, from well No. 66, was procured from oil floating on the water, which fills the casing nearly to the surface of the ground. This oil is so stiff that the sample was wound about a stick in order to lift it from the casing.

Analyses of oils from Douglas oil field, Wyoming.

[Made in the laboratory of the United States Geological Survey, David T. Day in charge.]

Wells.		Depth (feet).	Physical properties.			Distillation.							Paraffin (per cent).	Asphalt (per cent).	Sulphur (per cent).	Water.
			Gravity.		Color.	Begins to boil at (° C.)—	To 150° C.		150–300° C.		Residuum.					
Sample No.	Well No.		Specific.	Baumé (°).			Per cent.	Specific gravity.	Per cent.	Specific gravity.	Per cent.	Specific gravity.				
1	30	328	0.8439	35.9	Olive-green	80	8.0	0.7205	38.5	0.7928	53.5	0.9340	2.0	None.	0.2	None.
2	49	440	0.9309	20.4	Dark green	225	...	...	6.0	0.8605	...	...	...	None.	.3	Considerable.
3	66	600	0.9743	13.7	Dark brown, greenish cast.	225	...	...	2.0	...	...	...	None.	None.	.5	About 4 per cent.

CHARACTER OF THE GAS.

The following analysis of gas from the Douglas field was made by Frederick Salathe, of Casper, Wyo., in 1904:

Analysis of sample of natural gas from the Douglas oil and gas field, Wyoming.[1]

[Analyzed by F. Salathe, formerly in charge of the oil refinery at Casper, Wyo.]

Specific gravity		0.5890
Hydrogen	per cent	3.89
Marsh gas (methane)	do	87.75
Ethane, propane, butane	do	7.23
Illuminating hydrocarbons	do	.92
Carbon dioxide	do	.21
Carbon monoxide		Trace.
Oxygen		Trace.
Nitrogen		Trace.
		100.00

The above analysis was made with the improved Hempel-Winkler gas analysis apparatus.

[1] Published by permission of Consaul & Heltman, attorneys in 1911 for the Wyoming Oil & Development Co. and Douglas Oil Field (Ltd.).

The calorific value of this natural gas as compared with coal at $5 per ton (Rock Springs, Wyo., coal) is as follows: 9.2 cubic feet of natural gas is equal to 1 pound of coal or 18,400 cubic feet of natural gas is equal to 1 ton (2,000 pounds) coal, which will give this natural gas a value of 27.2 cents per 1,000 cubic feet.

ORIGIN OF THE OIL.

No definite data bearing on the origin of the oil in the Douglas field are available. At present oil appears to be found at the top of the Casper formation, in the "Cloverly" formation, in the lower part of the Benton shale, and in the White River formation. Whether the oil originates from a single source or from several the writer is unable to state, but be that as it may, it seems certain that the oil now occurs in porous rocks into which it has migrated. The conditions in this field are good for the segregation of oil and gas into local small bodies by the combination of hydraulic pressure and capillarity, a mode of accumulation discussed by Munn.[1] The theory of this mode of accumulation is founded on the fact that rocks of different densities permit the passage of water through them freely if the capillaries are large and less freely if they are small. Water entering an oil-bearing shale from every side will force the oil into a segregated mass or pool. It will also find certain zones through which friction is less so that into these zones the oil and water will penetrate faster than into others. The zones of rapid capillary movement will admit the water so much faster than those in which the rock is denser that after a time certain bodies of the rock may become inclosed by rock saturated with water, the oil having been driven into the unsaturated mass. In the Douglas field conditions are favorable for this sort of segregation of oil and gas. The older rocks dip at high angles away from the mountains (toward the north) and their upturned edges, where not concealed by the White River overlap, form excellent intakes for meteoric water, but the White River formation overlaps and conceals these older beds north of the intake area. The White River formation also affords an excellent reservoir for water and generally almost all its members are saturated. The water which enters the older beds works upward underneath the White River formation, forcing the oil and gas ahead of it; when the oil encounters a dry sandy lens in the White River it doubtless fills the lens and remains there on account of the water-saturated rock above. The oil in the bed of Boxelder Creek exudes from the bedding planes and although the rock itself is a porous sandstone, the oil does not seem to have saturated the rock. At the time the oil migrated to this place the sandstone must have been saturated with water, thus compelling the oil to confine itself to the bedding planes and other larger cracks.

[1] Munn, M. J., The anticlinal and hydraulic theories of oil and gas accumulation: Econ. Geology, vol. 4, pp. 509-529, 1909.

WELLS IN THE DOUGLAS OIL FIELD.

The data contained in the following table are taken largely from Jamison's report [1] on the Douglas oil field, but the altitudes of wells and some items under "Remarks" are derived from data collected by the writer. The locations of all wells [2] marked by an asterisk (*) are taken from Jamison's map, these wells not having been visited by the writer.

Wells in Douglas oil field, Wyoming.

No.	Section.[a]	Owner.	When drilled.	Depth.	Altitude of surface.	Remarks.
				Feet.	Feet.	
1	1	Wyoming Oil & Development Co.			5,140	Dry.
2	1	do		1,575	5,140	Casing collapsed and well abandoned.
3	2	do	1906	200		Well unfinished.
4	2	La Prele Oil Co.		542	5,260	Gas.
5	2	do				Abandoned.
6	3	do			5,230	Gas.
7	3	do			5,230	Do.
8	3	do			5,210	Abandoned gas well.
9	3					Abandoned.
10	3	Douglas Oil Fields (Ltd.)	1905	436	5,210	Abandoned gas well.
11	3					Abandoned.
12	3	Douglas Oil Fields (Ltd.).	1904	526		Gas reported.
*13	3	do	1904	563	5,240	Abandoned; water.
14	3	do	1904	526	5,200	Small amount of oil and gas.
15	4	do	1905	507	5,210	Small amount of oil.
16	4	do	1905	1,705	5,210	Small amount of oil and gas.
17	4	do	1902	485	5,200	Gas at 457 feet; abandoned.
18	4	do	1904	435	5,175	Producing gas well.
19	4	do	1907	578		Crooked hole.
20	6	do	1905	624		Small amount of oil reported.
21	6	do	1905	161	5,380	Do.
22	6	do	1905	693	5,370	Do.
23	6	do	1905	159	5,390	Do.
24	7	do	1905	110	5,440	Well unfinished; abandoned.
25	8	Wyoming Oil & Development Co.	1905	655	5,360	Small amount of oil; abandoned.
26	8	do	1905	302	5,400	Small amount of oil; flowing water well.
27	8	do	1904	215	5,350	Abandoned oil well.
28	8	do	1905	325	5,360	Do.
29	8	do	1905	365		Small amount of oil.
30	8	do	1906	328	5,340	Producing oil by pumping.
31	8	do	1905	632	5,330	Small amount of oil; abandoned.
32	8	do		393	5,320	Do.
33	8	do	1905	602	5,280(?)	Do.
34	8	do		930	5,290(?)	Abandoned.
35	8	do		725	5,300(?)	Light oil to top of casing.
*36	8	do		510		Small amount of oil; abandoned.
*37	8	do	1907	390		Do.
38	8	do	1907	236	5,320	Do.
39	8	do	1906	670	5,320(?)	Do.
40	8	do	1907	374	5,320	Do.
41	8	do	1906	401	5,320	Producing light oil by pumping.
42	8	do	1906	428	5,320	Abandoned oil well.
44	9	Douglas Oil Fields (Ltd.).	1902	342	5,300	Abandoned.
45	9	Wyoming Oil & Development Co.	1907	780	5,340	Abandoned; dry.
46	9	do		742	5,330	Small amount of oil and gas; abandoned.
47	9	do	1907	320	5,300	Abandoned oil well.
48	9	do	1906	425	5,290	Oil well with pump jack attached.

[a] In T. 32 N., R. 73 W., unless otherwise stated.

[1] Loc. cit.

[2] The writer found some difficulty in attempting to identify some of the wells mentioned by Jamison, as his descriptions do not invariably agree with the locations of the wells on his map.

Wells in Douglas oil field, Wyoming—Continued.

No.	Section.[a]	Owner.	When drilled.	Depth.	Altitude of surface.	Remarks.
				Feet.	*Feet.*	
49	9	Douglas Oil Fields (Ltd.).	1908	440	5,300	Oil well with pump jack attached.
50	9	.....do	1908	475	5,290	Small amount of oil reported.
*51	9	Wyoming Oil & Development Co.	1907	767	....	Small amount of oil.
52	9	.....do	1907	765	5,250	Small amount of gas.
*53	9	.....do	1907	970	....	Small amount of oil and gas.
54	9	.....do	....	406	5,250	Producing gas well.
55	9	Douglas Oil Fields (Ltd.).	1902	466	5,200	Small gas well.
*56	9	.....do	1904	388	....	Drilling stopped by order of court.
57	9	.....do	1903	470	5,210	Small gas well.
*58	9	.....do	1905	600	....	Water well.
59	11	Wyoming Oil & Development Co.	1907	515	5,220	Small gas well.
60	11	Douglas Oil Fields (Ltd.).	1904	498	5,230	Producing gas well.
61	12	.....do	1908	493	5,220	Small gas well.
62	12	.....do	1906	520	5,260	Crooked hole.
63	Lot in T. 32 N., R. 72½ W.	Wyoming Oil & Development Co.	....	665	5,316	Small gas well.
64	Sec. 35, T. 33 N., R. 74 W.	....	....	....	....	Abandoned; no data.
65	Sec. 29, T. 33 N., R. 74 W.	Wyoming Oil, Gas & Power Co.	(b)	....	5,150	
66	Sec. 31, T. 33 N., R. 74 W.	.....do	1912	600	5,350	A little heavy oil collects on the water, which rises to top of casing.

[a] In T. 32 N., R. 73 W., unless otherwise stated. [b] Unfinished.

DETAILS OF WELLS AND WELL LOGS.

INTERPRETATION OF THE LOGS.

In the well logs that follow there are five columns. In the first is given the name of the geologic formation as interpreted by the writer; in the second the driller's description of the rock; in the third information as to whether gas, oil, or water was found; in the fourth the thickness of beds; and in the fifth the depth from the surface of the ground to the base of each bed.

It should be borne in mind that the interpretation of well logs is difficult at best, but when the logs are complicated, as many of these are by starting in the White River formation and then passing into some other formation unconformably underlying it, the difficulty is greatly increased. Another source of possible error is the lithologic similarity between the Benton and Pierre formations. When these are encountered under the White River, the geologist can determine which is which only by the assumption that the strike of the older rocks continues under the mantle of White River in the same direction as it is where these rocks have been removed.

The logs of wells Nos. 2, 4, 16, 17, 18, 30, 35, 41, 44, 48, 49, 50, 55, 59, 60, and 63 were obtained from A. W. Phillips, of Douglas, Wyo., and the remainder are taken from the report of C. E. Jamison (State geologist of Wyoming) on the Douglas oil field, published in 1912.

WELL NO. 2.

Well No. 2 is located on the south bank of La Prele Creek in sec. 1, T. 32 N., R. 73 W. It is 1,575 feet deep, the first 500 feet of which seem to be in the White River formation, and the remaining 1,000 feet are quite certainly in the lower shale of the Pierre formation. The well is abandoned but is marked by the casing projecting a few feet above the surface of the ground. The log follows:

Log of well No. 2, sec. 1, T. 32 N., R. 73 W.

[Altitude of surface, 5,140 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Shale	Water at 40 feet	412	412
	Sand	"Showing" of gas and oil at 412 feet, water at 525 feet.	128	540
	(?)			
Pierre formation.	Black shale	"Showing" of oil at 1,575 feet	1,035	1,575

WELL NO. 4.

Well No. 4 is in the SW. ¼ sec. 2, T. 32 N., R. 73 W., and is cased and capped. A good flow of gas is reported from a sand at 542 feet below the surface, which was used for a time at a driller's camp about half a mile away.

Log of well No. 4, SW. ¼ sec. 2; T. 32 N., R. 73 W.

[Altitude of surface, 5,260 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Pale-blue, gray, and greenish shales		468	468
	Red shale		37	505
	Sand		3	508
	Red shale		5	513
	Sand		5	518
	Red shale	Gas at 515 feet	17	535
	Sand	Strong flow of gas at 538 feet	7	542

WELL NO. 14.

Well No. 14 is about 700 feet northeast of well No. 16. It is cased and capped, but apparently only a small amount of oil or gas was obtained in it. The lower 10 feet of the well undoubtedly is in the Pierre formation, the White River formation being 516 feet thick.

Log of well No. 14, SW. ¼ SW. ¼ sec. 3, T. 32 N., R. 73 W.

[Altitude of surface, 5,200 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	White, gray, and bluish shales		440	440
	Red shale		11	451
	Coarse sand	Gas	6	457
	Red shale		19	476
	Green and white sand	Gas and oil	40	516
Pierre formation.	Black shale		10	526

WELL NO. 16.

Well No. 16 is one of two deep wells in the Brenning Basin. The writer believes that it penetrates the Pierre formation to a depth of 1,000 feet. In the sand at the base of the White River formation small amounts of gas and oil are reported, but none below that level.

Log of well No. 16, SE. ¼ SE. ¼ sec. 4, T. 32 N., R. 73 W.

[Altitude of surface, 5,210 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.		Surface water	57	57
	White, grayish shale formation		363	420
	Red rock		53	473
	Coarse and loose sand		11	484
	Coarse sand	Gas	3	487
	(?)	First "showing" of oil	1	488
	(?)	Good "showing" of oil	10	498
	Coarse sand	Oil	3	501
	Finer sand	do	3	504
	Harder and finer sand	do	20	524
Pierre formation.	Black shale, with small streaks of sand.	Water at 815, 1,420, and 1,448 feet.	896	1,420
	Streaks of sand and black shale		285	1,705

WELL NO. 17.

Well No. 17 is about 800 feet west of No. 16. It is cased and is plugged with wood. It probably does not extend more than a few feet, if at all, below the White River formation, as it is less than 500 feet deep. In well No. 16 the base of the White River was probably reached at 524 feet.

Log of well No. 17, SW. ¼ SE. ¼ sec. 4, T. 32 N., R. 73 W.

[Altitude of surface, 5,200 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.		Water at 12 and 38 feet.	38	38
	Blue and gray formations		334	372
	Gray sand	Fair flow of water.	4	376
	Blue and gray shale		34	410
	Pink shale		37	447
	Blue rotten shale		7	454
	Gray soft sand		1	455
	Do	"Showing" of gas.	2	457
	Coarse and pebbly sand		3	460
	Hard white sand		14	474
	(?)	Oil with water	3	477
	Harder gray sand		8	485

WELL NO. 18.

Gas from well No. 18 is used in the nearest house, about 2,000 feet away, for fuel and light. The source of the gas, as in the other wells, appears to be the sandstones or bands of conglomerate in the White River formation.

Log of well No. 18, NW. ¼ SE. ¼ sec. 4, T. 32 N., R. 73 W.

[Altitude of surface, 5,175 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Surface formation	Water at 25 feet	345	345
	Soft green shale		45	390
	Pink shale		37	427
	Soft blue-gray shale	"Showing" of gas	1	428
	Soft gray sand		2	430
	Soft pink shale		3	433
	Hard mixed sand	Large flow of gas and some oil.	2	435

WELL NO. 19.

Well No. 19 almost certainly reaches the Pierre formation at a depth of 525 feet. Above this depth the formation is believed to be White River. The well was not visited by the writer.

Log of well No. 19, SE. ¼ NW. ¼ sec. 4, T. 32 N., R. 73 W.

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Surface loam and shale	At 105 feet sand streak and water.	105	105
	Gray and bluish shales		295	400
	Red shale		70	470
	Sand		20	490
	Green-brown shale		5	495
	Brown sand		5	500
	Coarse gravel and sand		25	525
Pierre formation.	Black shale		12	537
	Gray shale		41	578

WELL NO. 22.

It is probable that well No. 22 penetrates the "Cloverly" formation, as the 182 feet of sandstone mentioned in the record resembles that formation. The rocks dip 41°–55° E., so that 182 feet vertical depth would penetrate only about 60 feet of strata.

Log of well No. 22, NW. ¼ SW. ¼ sec. 6, T. 32 N., R. 73 W.

[Altitude of surface, 5,370 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Coarse gravel		11	11
	Gravel and clay		8	19
	Sandy clay		35	54
	Red and light-blue sandy clay		42	96
	Gray sandy clay		9	105
	Red and gray sandstone		14	119
	Reddish clay		12	131
Benton shale.	Hard black shale		49	180
	Black sandy shale with streaks		31	211
	Blue shale with streaks of sand		27	238
	Black sandy shale	Oil "showing"	8	246
	Sand rock		4	250
	Black shale	Oil "showing"	92	342
"Cloverly" and Morrison formations.	Sand rock	Oil "showing"	182	524
	Dark-blue shale		10	534
	Blue shale with streaks of sand		18	552
	Blue sandy shale		8	560
	Blue shale with streaks of sand rock		5	565
	Black shale		3	568
	Soft sand		3	571
	Brown shale		85	656
	Black sandy shale		37	693

WELL NO. 26.

It seems certain that in well No. 26 the "Cloverly" formation was reached at a depth of 282 feet, although Jamison [1] states that in part his Dakota was entered at 48 feet. To depth of 282 feet there is too much shale to justify referring the beds to the "Cloverly" formation. The two oil sands mentioned in the log are probably sandstone lentils in the lower part of the Benton. The well yields a small stream of flowing water which is used for stock.

[1] Jamison, C. E., The Douglas oil field and the Muddy Creek oil field, Wyoming: Wyoming Geol. Survey Bull. 3, ser. B, p. 27, 1912.

Log of well No. 26, SW. ¼ sec. 8, T. 32 N., R. 73 W.

[Altitude of surface, 5,400 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Wash and brown gumbo		48	48
Benton shale.	Oil sand	Dark lubricating oil	2	50
	Brown shale		20	70
	Oil sand		7	77
	Shale	Water at 80 feet	20	97
	Black gumbo		31	128
	Brown shale		110	238
	Black gumbo		7	245
	Coarse rock	Water at 254 feet	10	255
	Lead-colored gumbo		7	262
	Wash		10	272
	White gumbo		6	278
	Dark shale		4	282
"Cloverly" formation.	Wind cap rock	Water at 294 feet	2	284
	White water sand		18	302

WELL NO. 28.

As stated by Jamison, well No. 28 does not penetrate the "Cloverly" formation (in part his Dakota). This formation is probably from 400 to 600 feet below the bottom of the well. The 1-foot sandstone band at the bottom of the well is probably a sandstone lentil in the Benton shale.

Log of well No. 28, SW. ¼ SE. ¼ sec. 8, T. 32 N., R. 73 W.

[Altitude of surface, 5,360 feet.]

Probable formation.	Driller's description of the rock.	Thickness.	Depth
		Feet.	*Feet.*
White River formation and Benton shale.	Gravel and sand	65	65
	Green shale	62	127
	Gray shale	38	165
	Green oil sand	10	175
	Light-gray shale with a pink tint	40	215
	Brown clay	40	255
	Black shale	40	295
	Black sand	5	300
	Gray shale and sand	5	305
	Dark-gray shale and sand	6	311
	Dark clay	13	324
	Dakota sand	1	325

WELL NO. 29.

Well No. 29 was not visited by the writer, hence its location is taken from the map accompanying Jamison's report. The well is near the outcrop of the "Cloverly" formation and probably penetrates that formation to a depth of 60 feet.

Log of well No. 29, SE. ¼ sec. 8, T. 32 N., R. 73 W.

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation and Benton shale.	Wash		25	25
	Gray shale	Water at 55 feet	30	55
	Blue and gray shale	Good oil "showing"	53	108
	Brown sugary oil sand	Gas and oil; gas burned over the hole.	2	110
	Yellow shale	Good oil "showing" with some gas.	30	140
	Greenish sand		5	145
	Gray shale		15	160
	Brown gumbo		5	165
	Brown shale	"Showing" of oil and some gas.	135	300
	Purple and lilac gumbo		5	305
"Cloverly" formation.	Sandstone		60	365

WELL NO. 30.

Well No. 30 has a pump attached, which in the fall of 1912 was rigged up with a long gas-pipe handle for pumping by hand. By this means a near-by ranch procured oil for use in a heating stove which had been arranged for burning this kind of fuel. Mr. A. W. Phillips states that the oil from this well was pumped steadily by steam power for a long time for use as fuel by the contractors who built the La Prele dam, and that it produced over 40 barrels a day. This well yields a light oil having a paraffin base; its composition is given in the table (p. 25, No. 30).

Log of well No. 30, SW. ¼ SE. ¼ sec. 8, T. 32 N., R. 73 W.

[Altitude of surface, 5,340 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Clay		50	50
	Blue rock	Water	30	80
	Clay		105	185
	Green shale		70	255
Benton shale.	Black shale		45	300
	Black shale and paraffin	Oil at 325 feet	28	328

WELL NO. 33.

Well No. 33 does not penetrate the "Cloverly" formation. If the dip observed along the outcrop is continuous to the point where the well is located, the "Cloverly" would be about 1,000 feet below the surface, or about 400 feet below the bottom of the well. This statement is based on the assumption that the fault in sec. 9 does not extend as far west as this well. If, however, the fault is present in sec. 8 and the downthrow is on the north, as it appears to be farther east, then the "Cloverly" is deeper than is stated above.

Log of well No. 33, NW. ¼ SE. ¼ sec. 8, T. 32 N., R. 73 W.

[Altitude of surface, 5,280 (?) feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation and Benton shale.	Gravel wash and gray shale		74	74
	Brown shale	Water at 74 feet	50	124
	Gray shale		60	184
	Brown and gray shale		36	220
	Blue and brown shale	Water at 220 feet	50	270
	Brown dope; very slow drilling		26	296
	Gray rock, shell mixed with yellow shale, and a little sand; turned into a brown dope which stands up well.		50	346
	Benton shale; caves badly		10	356
	Paraffin		7	363
	Benton shale		42	405
	Gray shale	Very good oil "showing"	10	415
	Gray shale, black dope, and a little Benton shale.	Oil	8	423
	Benton shale		177	600
	Artesian water sand		1	601
	A pinch of Dakota oil sand	Water at 601 feet	1	602

WELL NO. 34.

Well No. 34, which has been left with the casing open, stands full of water. Apparently there is a small flow of water from the well. It is probable that bentonite or some similar clay is meant by the driller's term "paraffin" in the well log.

Log of well No. 34.

[Altitude of surface, 5,290 (?) feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Light clay		10	10
	Granite		5	15
	Light shale		45	60
	(?)		60	120
	Light clay	Water at 60 feet	33	153
	Clay and blue shale		142	295
	Red rock		15	310
	Yellow rock		35	345
Benton shale.	Black shale	Water at 665 feet	330	675
	Black sand	Water at 675 feet	27	702
	Black shale and paraffin		3	705
	Black shale		9	714
	Black sand		6	720
	Black shale and paraffin		11	731
	Gray shale and paraffin		141	872
	Soft gray sand		19	891
	Black and gray shale		9	900
	Gray shale		10	910
	Black shale and iron		15	925
	Paraffin	Water at 930 feet	5	930

WELL NO. 35.

Light oil fills the casing in well No. 35 to the level of the surface of the ground. The well also yields some water which flows up around the inner casing.

Log of well No. 35, NE. ¼ SE. ¼ sec. 8, T. 32 N., R. 73 W.[a]

[Altitude of surface, 5,300 (?) feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Water formation		10	10
	Brown lime formation	Water at 36 feet	70	80
	Gray shale		40	120
	Blue shale		70	190
	Blue gumbo		22	212
	Brown and green gumbo	Water at 217 feet	50	262
	Crystal formation		13	275
	Blue gumbo		10	285
	Pink and brown formation		25	310
	Mixed shales		22	332
	Shale		188	520
Benton shale.	Water sand	Water flowed over top of hole.	8	528
	Hard shell rock	Strong flow of gas	1	529
	Black sand		13	542
	Shale	Water at 550 feet	104	646
	Paraffin		5	651
	(?)	Water cased off at 667 feet; struck oil at 718 feet.	74	725

[a] This well log is identical with Jamison's No. 13, so far as it goes, but his log shows a maximum depth of 810 feet, whereas the log given above, which was procured from A. W. Phillips, states that the depth of this well is 725 feet.

WELL NO. 41.

Well No. 41 is about 1,000 feet south of No. 35 and contains oil of a similar character. It has tubing and jack attached for pumping. The oil comes from a sandstone in the bottom of the well, apparently in the Benton shale.

Log of well No. 41, SE. ¼ sec. 8, T. 32 N., R. 73 W.

[Altitude of surface, 5,320 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Surface formation		10	10
	Gray shale	Water at 85 feet	80	90
	Gumbo		50	140
	Gray shale	Water at 145 feet	10	150
	Brown gumbo		15	165
	Blue shale		10	175
	Gray shale		15	190
	Light shale		50	240
	Sand		5	245
	Gumbo		21	266
	Yellow shale		29	295
Benton shale.	Black shale	Gas at 312 feet	104	399
	(?)	Oil at 399 feet	2	401

WELL NO. 44.

Well No. 44 was drilled near the outcrop of the oil-saturated sandstone which was uncovered in digging the tunnel for an irrigation ditch, but only a small amount of oil was found. The casing was pulled and the well abandoned.

Log of well No. 44, SW. ¼ sec. 9, T. 32 N., R. 73 W.

[Altitude of surface, 5,300 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Surface formation		118	118
	Red shale		22	140
	Light shale		20	160
Benton shale.	Black shale		40	200
	Light shale		20	220
"Cloverly" formation.	Sand	Good "showing" of oil	2½	222½
	....do	Oil	7½	230
	White, fine sand		5	235
	....do	Water	6	241
	Coarse, gray sand		4	245
	Soft, light gray sand		7	252
	Light and red shale		5	257
	Darker shale		10	267
	Black shale		18	285
	Sand, with coarse pebbles		4	289
	Fine white sand		26	315
	White sand, coarse, soft		15	330
	Shale, black		12	342

WELL NO. 47.

Well No. 47, like most of the other wells in sec. 9, was drilled near the outcrop of the oil-saturated sandstone and found only a small amount of oil. The casing was pulled and the well abandoned.

Log of well No. 47, SE. ¼ sec. 9, T. 32 N., R. 73 W.

[Altitude of surface, 5,300 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Made land and sedimentary formation.		118	118
	Red rock		22	140
	Light shale		20	160
	Black shale		40	200
	Light shale		20	220
	Sand	"Showing" of oil	10	230
	Fine white sand	....do	11	241
	Gray soft sand	Water	4	245
	Light-gray soft sand		7	252
	Light and red shales		5	257
	Darker shale		10	267
	Black shale		18	285
	Sand, with coarse pebbles		4	289
	Fine white sand	Water	16	305
	Coarse white sand		15	320

WELL NO. 48.

Well No. 48 has tubing and pumping jack attached. Heavy oil like that from well No. 49 has been pumped from it. This well is about 200 feet south of No. 49 and its log is almost identical.

Log of well No. 48, SW. ¼ sec. 9, T. 32 N., R. 73 W.

[Altitude of surface, 5,290 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Light clay		65	65
	(?)	Water	10	75
	Green shales		248	323
	Mixed sand and gumbo		17	340
Benton shale.	Black shale		25	365
	(?)	Oil "showing"	5	370
	Black shale and paraffin		50	420
	Oil sand	Heavy oil	5	425

WELL NO. 49.

Well No. 49 has a pump with a gasoline engine attached. The oil is heavy and is the one from which sample No. 2 was collected. (See analysis, p. 71.) When drilling stopped the oil rose within 20 feet of the surface.

Log of well No. 49, SW. ¼ sec. 9, T. 32 N., R. 73 W.

[Altitude of surface, 5,300 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Clay	Water at 60 feet	60	60
	Green shale		267	327
	Red rock and green shale		8	335
	Yellow rock		5	340
	Gas sand		5	345
Benton shale.	Yellow rock		5	350
	Black shale		45	395
	Black shale and paraffin		40	435
	Oil sand	Good supply of heavy oil	5	440

WELL NO. 50.

Well No. 50, like Nos. 49, 48, 44, and 47, is near the outcrop of the oil-saturated sandstone. The well is cased and capped.

Log of well No. 50, NW. ¼ SE. ¼ sec. 9, T. 32 N., R. 73 W.

[Altitude of surface, 5,290 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Clay	Water	55	55
	Green shale and clay		263	318
	Red rock		8	326
	Gas sand		8	334
	Yellow rock and light shale		29	363
Benton shale.	Black shale		42	405
	Black shale and paraffin		45	450
	Oil sand		5	455
	Gray shale		13	468
	Black shale		7	475

WELL NO. 54.

Well No. 54 produces gas that has been piped to the nearest ranch. It is asserted by the ranchmen that there is sufficient to supply the ranch if the well were kept cleaned out, but at the time of the writer's visit the flow had nearly stopped.

Log of well No. 54, SW. ¼ NE. ¼ sec. 9, T. 32 N., R. 73 W.

[Altitude of surface, 5,250 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Dark-gray shale		55	55
	Light-green shale	Water at 55 feet	75	130
	Blue shale		30	160
	Light-brown shale		30	190
	Light-blue shale		60	250
	Brown and slate-colored shale		87	337
	Light-brown shale		33	370
	Slate-colored shale		35	405
	Gas sand	Gas	1	406

WELL NO. 55.

Well No. 55 is said to contain sufficient gas for ranch use, but it is not being utilized at the present time. The well was drilled in 1902, and since that time it has remained cased and capped.

Log of well No. 55, NW. ¼ NE. ¼ sec. 9, T. 32 N., R. 73 W.

[Altitude of surface, 5,200 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Blue, green, and light-colored shale	Water at 8, 48, and 375 feet	375	375
	Sandy	Water and gas	5	380
	Green and light-blue shale		32	412
	Red shale		39	451
	Green shale		3	454
	Sand, with green shale mixed	Gas	1	455
	Soft gray sand		2	457
	Shale and sand mixed		3	460
	Fine white sand		3	463
	Sand	Strong flow of gas	3	466

WELL NO. 57.

Well No. 57, according to Jamison's report, had so strong a gas pressure when the drill reached the depth of 468 feet that it threw sand and pebbles 70 feet into the air. The well is now cased and capped, but the gas is not being used.

Log of well No. 57, NE. ¼ NE. ¼ sec. 9, T. 32 N., R. 73 W.

[Altitude of surface, 5,210 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Shale	Water at 12 and 22 feet	308	308
	Coarse white sand		2	310
	Shale		98	408
	Pale pink shale		24	432
	Red shale; hole caved		26	458
	Green shale and gray sand		10	468
	(?)	Gas	2	470

WELL NO. 59.

Well No. 59 is one of three gas wells just northwest of Table Mountain. It is 515 feet deep and is probably entirely in the White River formation.

Log of well No. 59, NE. ¼ sec. 11, T. 32 N., R. 73 W.

[Altitude of surface, 5,220 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Brown soapstone		20	20
	Blue soapstone		38	58
	Gray shale		20	78
	Green shale		10	88
	Gray shale		22	110
	Sandy green shale	Water	10	120
	Blue shale		28	148
	Gray, mixed with blue shale		33	181
	Gray shale		67	248
	Brown, mixed with blue shale		25	273
	Gray shale		5	278
	Brown shale		61	339
	Gray shale		76	415
	Blue shale		32	447
	Red shale		35	482
	Gas sand	Water and oil	6	488
	Gray shale and paraffin mixed		4	492
	Red shale		20	512
	Gas sand	Gas	3	515

WELL NO. 60.

Well No. 60, like Nos. 59 and 61, is on the west flank of Table Mountain and is a producing gas well. Gas is piped,[1] as indicated on the map, to two ranches in the Brenning Basin, where it is used for domestic purposes. The gas pressure is reported by Jamison to be 145 pounds to the square inch.

[1] In 1913, after this paper was written, the pipe was taken up.

Log of well No. 60, NE. ¼ sec. 11, T. 32 N., R. 73 W.

[Altitude of surface, 5,230 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Shale formations; stray sand	Gas at 480 feet	480	480
	Red rock	Strong flow of gas	11	491
	Sand		7	498

WELL NO. 61.

The casing of well No. 61 is still in the well and is capped. Gas is reported.

Log of well No. 61, NW. ¼ NW. ¼ sec. 12, T. 32 N., R. 73 W.

[Altitude of surface, 5,220 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Surface dirt		50	50
	Blue shale		4	54
	Gray and brown shale		6	60
	Blue sand	Water at 60 feet	60	120
	Brown sandy shale		25	145
	Clay		15	160
	Green shale		40	200
	Light-gray shale		10	210
	Sand		3	213
	Light shale		58	271
	Red rock mixed with green shale		87	358
	Green shale		15	373
	Green and red shale		15	388
	Green shale		67	455
	Red rock		20	475
	Gray shale		5	480
	Red rock		8	488
	Gray rock		3	491
	Gas sand	Gas	2	493

WELL NO. 63.

Well No. 63 is on the northeast side of Table Mountain, in R. 72½, very near the west quarter corner of sec. 7, T. 32 N., R. 72 W., and is cased and capped. The well record indicates that water, oil, and gas were found, but apparently only a small amount of oil. Gas is reported to have been obtained from the bottom of the well.

Log of well No. 63, lot in sec. 12, T. 32 N., R. 72½ W.

[Altitude of surface, 5,316 feet.]

Probable formation.	Driller's description of the rock.	Content.	Thickness.	Depth.
			Feet.	*Feet.*
White River formation.	Greenish shale		97	97
	Brown shale and gumbo		78	175
	Bluish shale, with streaks of sand	Gas	100	275
	Chalky formation		10	285
	Shale formation	Oil and water	15	300
	Shale formations	Gas	365	665

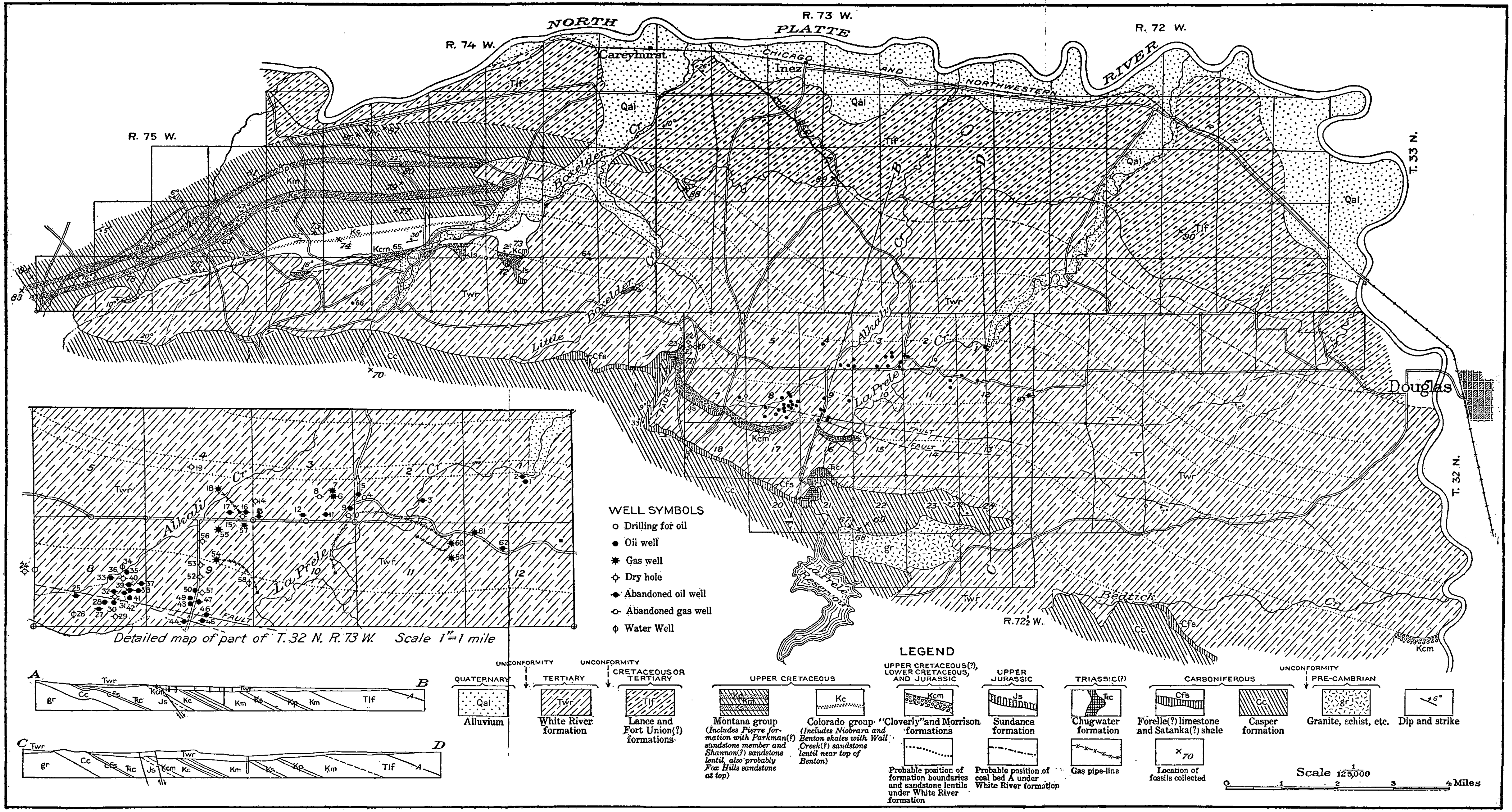
PRODUCTION.

The present production of oil in the Douglas field is small, but if the demand were sufficient the field could probably produce from the wells now open a hundred barrels a day for a short time. The gas supply is small, only three ranches using it in 1912. It seems probable, however, that the output could be increased so as to supply other ranches with light and heat, but the amount available would never be large unless new wells with greater flows of gas were found.

FUTURE DEVELOPMENT.

Although no one can say definitely that oil will or will not be found in a given area in advance of drilling, yet the writer is inclined to the opinion that future drilling in this field will find no great quantity of oil. It is said that drilling in 1913 is contemplated in the region north of Douglas. Here the highest known oil sand in this part of the State—the Shannon sandstone lentil—if present, should be reached at a depth of 4,000 to 5,000 feet. Drilling is also contemplated in the Labonte district, south of Douglas, but the writer is unfamiliar with this region.

The dips of the rocks near Glenrock suggest a favorable structure for the accumulation of oil, but this area has not been sufficiently studied to justify more than a mere mention at this time. The rocks at Glenrock dip toward the north, about 2½ miles southeast they dip toward the east, and about 3½ miles south of Glenrock they dip nearly south. These attitudes suggest a pitching anticline with an east-west axis about 1½ miles south of the town of Glenrock, but to reach the Shannon sandstone lentil here, if present, a thickness of about 2,700 feet of strata would have to be penetrated.



MAP OF THE DOUGLAS OIL AND GAS FIELD, CONVERSE COUNTY, WYO.

By V. H. Barnett.

THE SHOSHONE RIVER SECTION, WYOMING.

By D. F. Hewett.

INTRODUCTION.

Shoshone River rises among the ridges of the Absaroka Range in northwestern Wyoming and, except for a local diversion around McCulloch Peak, flows in a course approximately N. 60° E. to a point near the Montana line, where it empties into Bighorn River. (See fig. 2, p. 49.) Its course is approximately normal to the axis of the Bighorn Basin. On the west side of the basin the front of the Absaroka Mountains coincides approximately with the eastern limit of lava flows which overlie the pre-Eocene sedimentary rocks, but in the border belts on the east and west the river cuts through broad anticlinal folds, along the flanks of which the stratigraphic section is exposed in great detail. Thus on the west, along the east limb of the Rattlesnake-Cedar Mountain anticline, a complete section from the base of the Cambrian to the Eocene is visible, and though on the east, where Shoshone River cuts through the north end of Little Sheep Mountain, only the Cretaceous and Eocene formations are shown along the river, the complete Mesozoic section is brought to the surface near the center of the mountain.

With the view of using it as a guide in the study and mapping of a large area south of the river in which the geologic structure is favorable for the accumulation of oil and gas, the Mesozoic section along the river east of the Rattlesnake Mountain fold has been accurately measured and examined in greater detail than is customary in areal geologic work. Though the entire section from Cambrian to Eocene is exposed, the present examination has been confined to the Mesozoic and overlying Tertiary formations, for the reason that they probably contain all the sands which may carry oil and gas in the region under consideration. Furthermore, oil and gas have been found in two wells located on the axis of the narrow anticline shown on Plate V, and the sands from which they are derived outcrop prominently along the upper portion of the river.

The detailed examination of so continuous a stratigraphic section involving a great thickness of sedimentary rocks is not only rarely possible, but aside from the accuracy of measurement which it permits, it has the advantage of facilitating the more accurate delimitation of the formations. The section also shows in detail the sedimentary succession on the west side of the Bighorn Basin. The Mesozoic and Tertiary formations, exclusive of beds of Wasatch age, are approximately 15,000 feet thick along Shoshone River.

METHOD OF WORK.

In order to measure and study in detail the formations along the Shoshone Canyon, two operations were involved—first, the location, by means of a plane-table survey on a scale of 2,000 feet to an inch, of numerous points on prominent as well as critical lithologic members, between which the stratigraphic thickness does not exceed 1,000 feet; second, the detailed measurement by tape or by clinometer and pacing, as the exposures permitted, of the various lithologic units, the points previously established being used as a basis of control. It is obvious that detail is more desirable in those portions of the section which contain thin, clearly separable formations of distinct lithologic character than where the formations are thick and merge gradually with bounding formations of different character. Thus greater detail has been sought in the lower marine sandstones and shales than in the higher beds of fluviatile origin. Lack of time also prevented the same amount of study of the higher beds that was given to those of the lower part of the section.

FOSSILS.

On several occasions the section along the Shoshone has been examined in more or less detail by members of the Geological Survey,[1] and numerous collections of fossils have been made with the view of correlating the formations with those that are well known in south-central Montana and eastern Wyoming. In 1907 Fisher and Woodruff [2] measured the Mesozoic part of the section, and with Stanton, Knowlton, and Willard collected plants and invertebrate fossils from a number of horizons. It has been possible to identify most of these horizons, and with the permission of those who made the collections their lists of fossils are here presented with those made by the writer. Acknowledgment is also due to Mr. E. G. Woodruff for suggestions in the field and for reference to unpublished notes in the office.

[1] Woodruff, E. G., Coal fields of the southwest side of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 341, p. 202, 1909.

[2] Unpublished notes.

GEOLOGY.

STRATIGRAPHY.

OUTLINE.

The following table shows the character and relations of the formations from the Sundance (Upper Jurassic) to the Wasatch (Eocene):

Summary of Jurassic, Cretaceous, and Tertiary formations along Shoshone River.

System.	Series.	Formation.	Character.	Thickness (feet).
Tertiary.	Eocene.	Wasatch.	Buff and white sandstones, locally conglomeratic and feldspathic, alternating with greenish and red shales and clays.	(?)
		—Unconformity—		
		Fort Union.	White and buff massive sandstones with conglomerate zone at base. Upper portion more shaly. Contains flora and fresh-water fauna.	5,592
		Unconformity (?)		
Cretaceous or Tertiary.	?	Ilo.	Buff and yellow sandstones with minor sandy shale and clay. No coal beds; saurian bones and fresh-water invertebrate fossils.	1,790
Cretaceous.	Upper Cretaceous.	Meeteetse.	Argillaceous sandstone and sandy shale with numerous beds of brown carbonaceous shale and lenticular coal near top. Montana flora.	1,110
		Gebo.	Massive sandstone, buff near base and white near top, separated by thin beds of shale. One or more coal beds near base. A few plants and invertebrates of Montana types.	1,120
		Colorado.	Upper member: Dark-green to black shale, sandy near top; numerous marine fossils.	2,150
			Middle member: Buff sandstone locally conglomeratic, alternating with sandy shale and thin carbonaceous shale. One coal bed near top and several beds of bentonite.	494
			Lower member: Gray to black shale with several sandstones and numerous beds of bentonite throughout. Few marine fossils and fish scales.	1,026
	Lower Cretaceous.	"Cloverly."	Two sandstones separated by shale.	110
Jurassic or Cretaceous.	?	Morrison.	Maroon, gray, and brown shales with several sandstones. Saurian bones.	580
Jurassic.	Upper Jurassic.	Sundance.	Glauconitic green and gray shales, calcareous sandstone, and gypsum beds. Numerous marine and brackish-water fossils.	530

Total thickness, 14,502+ feet.

Plate V presents a plan of the survey of Shoshone River covering a strip 9 miles long and a vertical cross section showing an interpretation of the structure along a line approximately coinciding with the course of the river. It also shows, graphically, the stratigraphic section of the rocks from the Sundance formation (Upper Jurassic) to the Fort Union formation (Eocene) and an enlargement of the lower 2,700 feet of the section in order to show in greater detail the position and relations of the oil and gas bearing sands.

SUNDANCE FORMATION.

Beds containing Sundance (Upper Jurassic) fossils have been recognized at many localities in the Bighorn Basin and in eastern Wyoming. They present similar lithologic features and are characterized by abundant fossils, notably of the genera Gryphæa, Ostrea, and Pentacrinus. A section of the formation has been examined in detail by Fisher[1] along Trail Creek, 8 miles northwest of Cody and within 6 miles of the point of exposure along Shoshone River. Along Trail Creek a thickness of 322 feet was measured, but along the river, if the lower and upper limits of marine Jurassic fossils are taken as the base and top, respectively, the thickness of the formation is 530 feet, the greatest which has been measured in Wyoming. The beds are well exposed along the south bank of the river and may be examined closely. There is no appreciable difference in dip or evidence of erosional unconformity between the Sundance formation and the underlying red sandstone of the Chugwater formation (Triassic?). There was, in fact, a gradual transition from conditions of Chugwater sedimentation to those of the marine Sundance formation.

The distinguishing features of the Sundance formation are the numerous alternations of fossiliferous marine shales and gypsum beds near the base, its evenly bedded condition throughout, and the gradual increase in content of glauconite and quartz sand toward the upper sandstone which limits it. In the following section the details of the lower part of the formation are those of the section made by Fisher and Woodruff.

Section of Sundance formation on Shoshone River.

	Feet.
Shale, gray, sandy, and sandstone, lower half shaly, upper half firm and massive; fossil collection 4997	42
Sandstone, gray, massive, cross-bedded, with several poorly indurated layers and a number of thin limestone beds composed of Ostrea fragments; fossil collections 4988, 4996	60

[1] Fisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, p. 21, 1906.

	Feet.
Sandstone, gray, with numerous shale layers; fossil collections 4985, 4986	6
Shale, dark	15
Shale, green, highly fossiliferous near the base, becoming sandy above; the upper more sandy portions are uniformly glauconitic; fossil collection 4989	240
Shale, green, sandy, containing a number of fossiliferous layers	22
Shale, green, sandy, with several thin nodular limestones	16
Shale, red, sandy, traversed by numerous gypsum veinlets	48
Gypsum	12
Limestone, gray, fossiliferous, and greenish-gray shale in alternating beds	23
Limestone, gray, fossiliferous	2½
Clay, gray	1
Limestone, gray, fossiliferous	2
Limestone, gray, fossiliferous, and yellowish-gray clay, in alternating layers; fossil collection 4982	3½
Clay, dark	2
Limestone, gray, fossiliferous, composed largely of fossil fragments	5
Clay	3
Limestone, gray, fossiliferous, containing many fragments of fossils; fossil collection 4981	21½
Sandstone, gray, fossiliferous; fossil collection 4980	4½
Clay, gray, compact	1
	530

The following collections of fossils from the Sundance formation were made in 1907 by Stanton and Willard:

4997. Stanton:
- Trigonia sp.
- Astarte sp.
- Undetermined pelecypods.

4988. Willard:
- Rhynchonella sp.
- Ostrea sp.

4996. Stanton:
- Rhynchonella myrina H. and W.
- Ostrea strigilecula White.

4985. Willard:
- Rhynchonella.
- Camptonectes.

4986. Willard:
- Ostrea.
- Camptonectes.
- Modiola.

4989. Willard:
- Gryphæa calceola var. nebrascensis M. and H.
- Camptonectes pertenuistriatus M. and H.

4989. Willard—Continued.
- Gervillea sp.
- Arca (?) sp.
- Trigonia sp.
- Astarte meeki Stanton.
- Astarte sp.
- Pleuromya subcompressa Meek.
- Ammonite fragment.

4982. Willard:
- Ostrea strigilecula White.
- Obscure bivalves.

4981. Willard:
- Pentacrinus astericus M. and H.
- Camptonectes bellistriatus Meek.
- Trigonia.

4980. Willard:
- Lima sp.
- Trigonia americana M. and H.
- Trigonia sp.

MORRISON FORMATION.

The Morrison formation has been recognized at a number of localities throughout the Bighorn Basin by its characteristics and relations and in places by the presence in it of saurian bones. Measurements of its thickness have ranged from 130 to 382 feet.[1] The formation is well exposed along the north bank of Shoshone River, where its thickness has been determined to be 580 feet. At the base it is not clearly separable from the underlying Sundance formation, but the division is made at the top of the uppermost outcropping sandstone which contains marine Jurassic fossils. As no fossils other than saurian bones from the middle portion have been found in either this formation or the overlying "Cloverly," the upper limit is taken to be the base of the sandstone overlying the uppermost maroon clay. In describing the character of the overlying "Cloverly" formation in the vicinity of the Bighorn Mountains Darton [2] states that the base is usually marked by a conglomeratic sandstone and considers that this member limits the underlying Morrison. On this criterion several beds of maroon clay are included in the "Cloverly" formation, though beds of similar character occur throughout the Morrison. In the absence of a conglomerate at this horizon on Shoshone River it seems reasonable to consider that the uppermost red clay marks the limit of Morrison sedimentation.

There is a striking resemblance between the middle portion of the formation along Shoshone River and that in the region north of Thermopolis described by Darton.[2] Evidence of an unconformity between the Morrison and "Cloverly," noted by Fisher [3] in places has not been found on Shoshone River.

Besides the variegated color and alternations of several diverse types of material, a characteristic feature of the formation is the presence of gastroliths, or "stomach stones," which are found in intimate association with large saurian bones. In an area 20 feet in diameter on the cut bank where the beds are exposed on the north side of the river no less than 60 pounds of large bone fragments and 15 pounds of gastroliths were found. The gastroliths range from 2 to 5 inches in diameter and are faceted but highly polished. Most of them are chert, showing crinoid stems and Bryozoa, and one large pebble is hornstone, containing a few pyrite crystals, a rock not known to exist in place within 150 miles of this locality.

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[1] Fisher, C. A., op. cit., p. 25.
[2] Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, p. 50, 1906.
[3] Fisher, C. A., op. cit., p. 26.

Section of Morrison formation on Shoshone River.

	Feet.
Shale, maroon and gray, sandy	50
Sandstone, buff	6
Shale, gray, sandy	12
Sandstone, buff	4
Shale, gray, sandy	10
Sandstone, buff, cross-bedded	8
Clay, gray, sandy	50
Sandstone, buff, fine grained, evenly bedded, and ripple marked	6
Clay, maroon and yellow, sandy	44
Clay, dark brown to black, containing saurian vertebræ, limb bones, and gastroliths	20
Sand, gray, argillaceous, only locally indurated, containing wood silicified in place, as well as rounded pebbles of similar material; carbonized plant remains and small calcareous concretions	50
Clay, maroon, sandy	55
Sandstone, white, homogeneous, only locally indurated	25
Clay, prevailingly gray and olive-colored, but with three broad maroon bands, sandy	100
Shale, green, sandy, transitional to upper sandstone of the Sundance formation	140
	580

C. W. Gilmore reports that bones collected from the 20 feet of clay near the middle of the formation represent "the vertebra of a carnivorous dinosaur, not otherwise determinable."

"CLOVERLY" FORMATION.

The recognition of the "Cloverly" formation is based wholly on its lithologic character and relation to the overlying marine shale and the underlying Morrison formation. The name has been applied by Darton [1] to a group of beds which lie beneath the Colorado formation on the west side of the Bighorn Mountains and which he believed to include the equivalent of the Dakota sandstone, together with beds of Lower Cretaceous age. Fisher [2] has reported a collection of plants from shale overlying a coal bed below the base of the Colorado formation in the eastern part of the Bighorn Basin, which were determined to be of Kootenai (Lower Cretaceous) age, and on the basis of this determination he regards the "Cloverly" as the equivalent of the Kootenai of the Montana region. No fossils have been found along the west side of the basin, nor is there evidence of the presence of a coal bed with which the leaves are associated.

[1] Darton, N. H., op. cit., p. 53.

[2] Fisher, C. A., Southern extension of the Kootenai and Montana coal-bearing formations in northern Montana: Econ. Geology, vol. 3, p. 84, 1908.

On account of the nearly vertical walls of the canyon of Shoshone River these beds, although well exposed, can not be examined in detail.

The sandstones are fine grained and the grains are angular and fairly uniform in size, ranging from 0.1 to 0.25 millimeter in diameter. They are firmly held by a cement composed largely of carbonate of iron. No conglomerate beds such as have been recognized elsewhere in the basin were found in the section.

Section of "Cloverly" formation on Shoshone River.

	Feet.
Sandstone, buff, indurated, characteristically thin bedded and ripple marked. The beds range from half an inch to 20 inches in thickness and are composed of angular and subangular grains of quartz, with traces of muscovite near the top	60
Shale, gray, sandy	25
Sandstone, buff, massive	25
	110

COLORADO FORMATION.

GENERAL CHARACTER.

The entire Colorado formation is exposed in exceptional detail along Shoshone River and is separable lithologically into three members—the lowest, 1,026 feet thick, composed largely of shale; the middle, 494 feet thick, predominantly shaly but containing a number of massive sandstones from 3 to 40 feet thick; and the uppermost, 2,150 feet thick, principally shale. The lower two members contain but a few fossils, which do not serve to correlate them accurately with portions of the formation observed in near-by regions. The lower part of the upper member is highly fossiliferous. Most of the sections presented herewith are those exposed on the north side of the river, though a portion of the formation near the base has been examined on the south side. There is no evidence of unconformable relations such as have been inferred by Washburne [1] on the east side of the basin.

The section is interesting as containing the oil sands which have been struck in the well of the Shoshone Oil Co., the log of which is given on page 65. The sandstone referred to by Washburne as the source of gas in wells on the east side of the basin is undoubtedly the equivalent of the 20-foot sandstone near the base of the lower shale member on Shoshone River, which has also yielded oil in the Shoshone Oil Co.'s well. There is a close resemblance between the section given by Washburne [1] and that on Shoshone River.

[1] Washburne, C. W., Gas fields of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, p. 350, 1908.

LOWER MEMBER.

The most unusual feature of the lower member is the persistent occurrence of bentonite, a yellow unctuous clay, in beds from 1 inch to 4 feet thick. Near the base of the member there are numerous thin beds of bentonite, the 392-foot shale of the section below containing no less than 35 beds, whereas the upper portion contains fewer though much thicker beds. Bentonite is known to occur in many localities in Wyoming where the Colorado shale is well exposed,[1] but the number of beds in the Shoshone River section greatly exceeds that reported elsewhere. It appears to be at least possible that more beds of bentonite than have been reported exist in the Colorado shale in other parts of Wyoming, but that the conditions of exposure do not permit their recognition. The shale of this member is gray to blue-black, dense, fine grained, and near the base carbonaceous.

Section of the lower member of the Colorado formation on Shoshone River.

	Feet.
1. Shale, sandy	32
2. Shale, blue-gray, with fish scales	56
3. Sandstone, buff	4
4. Bentonite	4
5. Shale, gray, with fish scales and vertebræ	45
6. Bentonite	4
7. Shale, gray, with fish scales	151
8. Sandstone, buff, thin bedded	80
9. Shale, dark, dense	50
10. Sandstone	3
11. Shale, bluish black, containing several thin gray sandstones and numerous beds of bentonite from 1 inch to 4 feet thick	392
12. Sandstone, buff, massive; the lower portion cross-bedded and containing numerous crocodile teeth, several caudal vertebræ of dinosaurs, and a turtle, also many pieces of carbonized plant material; fossil collection 123	20
13. Shale, dark brown to black, containing thin beds of bentonite near the top	185
	1,026

Fossil collection No. 123 contained "caudal vertebræ of dinosaur; teeth of crocodile," according to C. W. Gilmore. O. P. Hay reports that the turtle "represents an undescribed species probably belonging to the genus Gyremys. This genus is known from a single specimen, *G. spectabilis* Hay, believed to be from the Judith River formation of Montana."

MIDDLE MEMBER.

The middle member is extraordinarily well exposed and accessible. The shale in the member is gray, sandy, and only locally carbonaceous. The sandstones are gray and buff and well indurated, and sev-

[1] Fisher, C. A., The bentonite deposits of Wyoming: U. S. Geol. Survey Bull. 260, p. 559, 1904.

eral of them contain persistent zones of chert pebbles, a feature which has been recognized elsewhere in the Bighorn Basin. Though the middle member contains several thick beds of bentonite, it lacks the great number of thin beds noted in the lower member.

Section of the middle member of the Colorado formation on Shoshone River.

	Feet.
1. Sandstone, buff, separated into three benches by thin brown shale bands; upper and lower benches contain chert pebbles, the largest half an inch in diameter	24
2. Sandstone, buff to gray, shaly	60
3. Shale, brown	1
4. Bentonite	8
5. Shale, brown	5
6. Sandstone, buff	6
7. Bentonite	6
8. Shale, brown, with 4 inches of coal	3
9. Sand, brown, shaly	8
10. Shale, brown, with two thin coal beds	2
11. Shale, dark	13
12. Sandstone, buff	3
13. Shale, sandy	30
14. Sandstone, buff	6
15. Shale, sandy	55
16. Sandstone, drab, separable into four massive benches by thin shale layers; second bench from the top contains black chert pebbles three-fourths of an inch in diameter	40
17. Shale, sandy	32
18. Sandstone, buff, thin bedded	18
19. Shale, sandy	22
20. Sandstone, buff, thin bedded	12
21. Shale	16
22. Sandstone, buff	8
23. Shale	16
24. Sandstone, buff	40
25. Shale	24
26. Sandstone, buff, thin bedded, containing nonpersistent zones of chert pebbles as much as 3 inches thick near the top and a highly persistent zone 6 inches thick near the middle; the pebbles range from three-fourths of an inch to 2 inches in diameter; fragments of bone and bivalve shells are common	36
	494

UPPER MEMBER.

The uppermost sandstone of the middle member is overlain by a great thickness of shale which, though increasingly sandy near the upper limit, does not contain any lithologic units clearly separable from the shale. The thickness of this member along Shoshone River is 2,150 feet, the upper limit being the first massive sandstone of the overlying Gebo formation. The beds may be most satisfactorily examined on the south side of the river east of the anticline on which the Shoshone Oil Co.'s well is situated.

The lower portion of the member contains many concretions, most of which contain numerous fossils. These definitely establish the age of the beds as upper Colorado.[1]

Though there are no separable lithologic units in this shale member, close examination shows that several diverse types are present. The basal 200 feet is predominantly dark blue-gray to black in color, fine grained, and free from sand. This portion contains relatively few fossils. The next 300 feet is olive-gray to pale green, is locally sandy, and contains the concretions from which most of the fossils are derived. Its color is due to a disseminated green mineral, which is probably glauconite. Above this zone the member contains an increasing proportion of quartz sand, and the 400 feet underlying the basal massive sandstone of the Gebo formation is essentially a succession of thin argillaceous sandstones. This portion is buff in color, evenly bedded, and locally ripple-marked. It has thus far only yielded a few gastropods too poorly preserved to permit identification.

The following collections of fossils from the upper member of the Colorado formation were made by Woodruff and Willard and by the writer:

4960. Woodruff:
- Inoceramus exogyroides M. and H.
- Inoceramus undabundus M. and H.
- Inoceramus acuteplicatus Stanton.
- Inoceramus sp.
- Legumen sp.
- Pholadomya papyracea M. and H.
- Baculites asper Morton (?)
- Baculites sp.
- Scaphites ventricosus M. and H.
- Ancyloceras (?) sp.
- Mortoniceras sp. related to M. shoshonense M. and H.

4991. Willard:
- Anomia sp.
- Avicula sp. cf. A. linguiformis E. and S.
- Inoceramus acuteplicatus Stanton.
- Inoceramus sp.
- Crassatellites n. sp.
- Corbula sp.
- Turritella n. sp.
- Baculites asper Morton?
- Baculites sp.
- Scaphites ventricosus M. and H.
- Mortoniceras sp.

5032. Willard:
- Avicula sp.
- Inoceramus umbonatus M. and H.
- Inoceramus acuteplicatus Stanton.
- Crassatellites n. sp.
- Corbula sp.
- Dentalium sp.
- Turritella sp.
- Gyrodes conradi M. and H.
- Fusus (?) sp.
- Baculites asper Morton.
- Scaphites ventricosus M. and H.

7369. Hewett:
- Anomia sp.
- Avicula sp. cf. A. linguiformis E. and S.
- Nemodon? sp.
- Veniella sp.
- Pholadomya papyracea M. and H.
- Corbula sp.
- Dentalium sp.
- Volutoderma sp.
- Cinulia sp.
- Baculites sp.
- Scaphites ventricosus M. and H.
- Mortoniceras shoshonense Meek.

[1] In the report by Fisher (U. S. Geol. Survey Prof. Paper 53) these beds, on the basis of meager fossil collections, were regarded as being equivalent to the Pierre of eastern Wyoming and Montana. Their age appears now to be established as Colorado.

GEBO FORMATION.

Overlying the thin-bedded shaly sandstones of the upper member of the Colorado is a mass of buff to cream-colored sandstone, in beds ranging from 18 to 65 feet in thickness, with thin intercalated shales, which near the base contain coal. On account of the indurated condition of the sandstone the river flows in a narrow gorge for the greater portion of the section and they can not be examined in detail. In the region south of the river, however, these beds constitute a well-defined lithologic unit and wherever they outcrop form high rugged ridges. The name is derived from the town of Gebo, near Thermopolis, in the south end of the Bighorn Basin, near which extensive mining operations have been conducted on a coal bed near the base of the formation.

The thickness assigned to the formation along Shoshone River is 1,120 feet, the basal and top members being assumed as the lowest massive sandstone above the upper member of the Colorado and the highest indurated sandstone below the Cody coal bed. This thickness compares with measurements of 1,250 to 1,430 feet, made in the region south of the river. The formation has yielded a meager flora and a few invertebrate fossils along the river, on the basis of which the lower portion is correlated with the beds referred to the Eagle, containing the coals near Bridger, Mont. This correlation is confirmed by the field work of Fisher, Washburne, and Woodruff, who have traversed and mapped the coal beds of the formation almost continuously from south-central Montana into Wyoming and around the Bighorn Basin. The formation contains a characteristic marine fauna in the upper Missouri River region[1] and in southern Montana,[2] but no invertebrate fossils have yet been found in the basal portion of the formation on Shoshone River. A few poorly preserved mollusks were collected from the sandstone overlying the lowest coal, 85 feet above the base of the formation at Thompson's coal mine, 15 miles south of Cody, but they are not diagnostic species.

Throughout central and southern Montana the thickness of the Eagle sandstone ranges from 200 to 370 feet. In the region north of Shoshone River, where the Eagle has been more carefully studied, it is overlain by the Claggett formation, from 400 to 760 feet thick. In the type locality in central Montana the Claggett formation is predominantly shale which yields a characteristic marine fauna, but, as shown by the sections given by Fisher,[3] in its southern extension the proportion of sandstone increases, and at Elk Basin, on the Montana-Wyoming line, the section shows only a minor proportion of

[1] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S Geol. Survey Bull. 257, p. 12, 1905.

[2] Unpublished notes of T. W. Stanton.

[3] Fisher, C. A., Southern extension of the Kootenai and Montana coal-bearing formations in northern Montana: Econ. Geol., vol. 3, p. 87, 1908.

shale. Though the beds yield a characteristic fauna as far south as Bridger, Mont.,[1] none of the fossils have thus far been found on Shoshone River nor in the region south of it. The conclusion appears justifiable that the upper sandstones of the Gebo formation correspond to the Claggett formation of Montana, and therefore that the Gebo formation, having a thickness of 1,120 feet on the river, is essentially the equivalent of both the Eagle and Claggett formations.

Section of Gebo formation on Shoshone River.

	Feet.
Sandstone, buff, massive	18
Shale, drab to brown; fossil collection 17, Knowlton (?)[2]	50
Sandstone, buff, massive	20
Sandstone, locally massive and indurated, with few beds of gray to brown shale; fossil collection 4972, and 38, Woodruff	720
Sandstone, buff, massive	40
Clay, gray to brown, homogeneous, sandy	20
Sandstone, buff, thin bedded	55
Shale, carbonaceous, with thin coal bed	20
Sandstone, thin, and shale	50
Shale, dark, with two thin coal beds	32
Sandstone, buff, massive	28
Shale, sandy	2
Sandstone, massive, cavernous outcrop	65
	1,120

The following collections of fossils from the Gebo formation were made by Woodruff and Knowlton in 1907:

4972. Woodruff:
- Unio sp.
- Sphærium sp.
- Corbula subtrigonālis M. and H.
- Goniobasis invenusta M. and H.
- Viviparus sp. related to V. conradi M. and H.

Comment by T. W. Stanton: "Judith River rather than Claggett."

38. Woodruff:
- Sequoia brevifolia.
- Protophyllum n. sp.
- Ficus (?) sp.
- Juglans (?) sp.

Comment by F. H. Knowlton: "I do not know this flora. It is not like what has come heretofore from the Eagle, though it may be an Eagle flora. The Protophyllum is of the type of certain species found in the Dakota, while the Sequoia is ordinarily an upper Montana form."

17. Knowlton:
- Platanus (?) wardii Kn.
- Ficus sp.

Comment by F. H. Knowlton: "If the above species is correctly determined, the age of this should be Eagle, but it is insufficient to be very positive about."

[1] Unpublished notes of T. W. Stanton.

[2] The source of this collection can not be indicated with assurance.

MEETEETSE FORMATION.

The name Meeteetse is applied to a group of beds 1,110 feet thick which overlie the Gebo formation and which, being poorly exposed along the river, have been more thoroughly studied in the region south of it. From their lithologic character and relations in that region these beds have been recognized as a persistent formation, which is named from the town of Meeteetse, on Greybull River, the largest town in the southwestern portion of the basin. No fossils have been found in the formation along the river, but in the region south of it no less than 19 species of plants have been found. This flora is distinctly that of the Montana group, six species occurring in the upper part of the Mesaverde formation at Point of Rocks, Wyo., and five in the Judith River formation on Willow Creek, Mont. Most of the collections have been designated "Judith River" by F. H. Knowlton, and the beds are regarded by him as equivalent to the Judith River formation or Belly River beds of Canadian geologists. One collection containing five species of leaves, obtained 130 feet above the base of the formation, 15 miles south of the river, is reported by F. H. Knowlton to indicate "the approximate position of the Mesaverde." No vertebrate or invertebrate fossils have yet been found in the formation.

The conspicuous features of the formation are the presence of a number of beds of carbonaceous shale and coal and the general absence of induration of the beds. Along Shoshone River and also throughout the greater portion of the region south from the river to Owl Creek carbonaceous shale and coal beds are largely confined to the upper half of the formation, and though on the river there is but one bed of coal more than 14 inches thick—that which has been mined by the Cody Coal Co.—in the neighborhood of Meeteetse some sections contain as many as five beds. The beds are, however, highly lenticular and the coal is poor in quality compared to the coals in the underlying Gebo formation and the higher Fort Union formation. Somber colors prevail throughout the formation, the greater portion of the beds being gray to olive colored.

The material constituting the formation is characteristically poorly assorted; the sandstone contains much clay and the shale is sandy, features which partly account for the absence of induration. Mica is common throughout the formation, and some beds near the middle contain a large proportion of fresh biotite. Silicified wood is not common on the river, but is abundant in the lower 600 feet of the formation, where the beds are exposed in bad lands. Trunks of trees as much as 28 inches in diameter and 10 feet long, as well as roots silicified in place, have been found. The upper limit is the base of a bed of white, poorly indurated sandstone which is persistent throughout the west side of the Bighorn Basin.

Section of Meeteetse formation on Shoshone River.

	Ft.	In.
Shale, brown, carbonaceous	3	
Shale, gray	6	
Shale, carbonaceous	2	
Shale, gray	8	
Shale, carbonaceous	3	
Sand, olive-colored, argillaceous, with zones of sandy clay	210	
Shale, gray, sandy, with thin beds of carbonaceous shale	60	
Shale, carbonaceous	3	6
Sand, olive-colored, argillaceous	60	
Coal, Cody {Coal, 30 inches; Shale, 1 inch; Coal, 23 inches}	4	6
Sandstone, buff and pale olive-gray, argillaceous	750	
	1,110	

ILO FORMATION.

The Ilo formation presents poorer exposures along Shoshone River than any of the Upper Cretaceous formations. Its character is best displayed in the region south of the river, where several collections of invertebrate fossils have been made. Sandstone is the most abundant constituent, but the beds are so lacking in induration that except in small areas of bad lands where portions of the formation are shown there are few outcrops and it has not been possible to examine a complete section. The best exposures on the west side of the Bighorn Basin are in the open valley northwest of Ilo, a settlement 50 miles southeast of Cody, from which the name of the formation is derived. Here a thickness of 810 feet has been measured, compared to 850 feet 2 miles west of Meeteetse. As no fossil collections have been obtained on the river from the zone approximately 1,300 feet thick between the beds in which fossils were found by Woodruff (4959) and Willard (365), the upper limit of the Ilo formation has not been established. There is some reason, however, for believing that the lowest conglomerate zone in the Fort Union formation is approximately the equivalent of a persistent zone 400 feet above the base of the Fort Union throughout the region between Greybull River and Owl Creek, where data bearing on the relations between the Ilo and Fort Union are abundant. On Shoshone River, therefore, the top of the Ilo formation is provisionally assumed to be 400 feet below the lowest conglomerate of the Fort Union formation. The formation is regarded as approximately equivalent to the Lance formation in the eastern part of the State.

The Ilo formation consists of several groups of beds of massive yellow sandstone which range from 20 to 60 feet in thickness. Unindurated clay and argillaceous sand alternate with the sandstone, and zones 200 to 600 feet from the base contain invertebrate and vertebrate fossils which serve to establish the age of the formation. Thin beds of carbonaceous shale occur near the bottom, but are not persistent, and coal is conspicuously absent. The materials are more perfectly assorted than those of the Meeteetse formation, but along Shoshone River there are few well-defined lithologic units capable of separation from the associated materials.

Section of Ilo formation on Shoshone River.

	Feet.
Sandstone with zones of conglomerate of the Fort Union formation.	
Sandstones, buff and olive-colored, unconsolidated, with minor zones of sandy clay; fossil collections 4976, 4990, 4959	1,555
Shale, carbonaceous	6
Sandstone, olive-colored, argillaceous	160
Shale, carbonaceous	4
Clay, gray, sandy	25
Sandstone, white, unindurated	40
	1,790

The following collections of fossils from the Ilo formation were made in 1907 by Woodruff and Willard:

4976. Woodruff:
  Sphærium sp.
  Campeloma multilineata M. and H.
  Physa sp.
    Comment by T. W. Stanton: "Horizon probably 'Ceratops beds.'"

4990. Willard. 1,125 feet east of Cody coal mine;
  Sphærium sp.
  Goniobasis tenuicarinata M. and H.
  Physa sp.
  Columna sp.
  Hydrobia (?) sp.
    Comment by T. W. Stanton: "Horizon probably 'Ceratops beds.'"

4959. Woodruff. 900 feet stratigraphically above Cody coal mine:
  Unio sp. related to U. priscus M. and H.
  Sphærium sp.
  Goniobasis (?) sp.
  Viviparus sp.
  Campeloma multilineata M. and H. (?)
    Comment by T. W. Stanton: "Horizon not closely fixed by these fossils, but it is believed to be about that of the 'Ceratops beds.'"

FORT UNION FORMATION.

From the point where Sage Creek enters Shoshone River from the south to the bend where the river turns northward around McCulloch Peak, a distance of 12,000 feet, a group of beds are exposed which have thus far yielded only a Fort Union flora and fauna. On account of the great thickness of this formation, 5,400 feet, and the minor importance of the stratigraphy at this horizon, it has not been deemed advisable to measure the section in great detail. The point at which these beds are overlain by those of Wasatch age lies east of the limit of this survey.

It is to be regretted that the valley of Sage Creek meets the river at a point near the base of this formation, for this fact, together with the poor exposures throughout the upper portion of the Ilo formation, prevents detailed examination of the relations of the two formations.

In degree of consolidation and lithologic character the beds of the Fort Union stand in contrast to those of the underlying Ilo and Meeteetse formations. Though they include many zones of relatively unconsolidated material, the beds of the lower portion of the Fort Union are compact and resistant and in the region south of Shoshone River form persistent high ridges. Beds of conglomerate occur at several horizons and are interesting as indicating the conditions of sedimentation as well as the lithologic types present. The lowest group of conglomerates contains six zones from 5 to 20 feet thick in a stratigraphic distance of about 250 feet. Each of these zones is composed of smaller zones or beds of conglomerate, which range from 2 to 10 feet in thickness. The dip section is well exposed and shows the single beds to be relatively persistent in the direction of the dip—northeast—whereas in the strike section, which is not so well shown, the separate beds are not persistent, but lenticular and characteristically anastomosing. Though definite conclusions can scarcely be based on this single exposure, these features suggest that the pebbles were deposited by streams flowing from the west or southwest toward the east or northeast. The pebbles are mostly subangular to rounded. The largest pebbles are indurated fine sandstones about 5 inches in diameter. Most of the pebbles are gray to black chert, from half an inch to 2 inches in diameter. There are a few pebbles of red and gray quartzite; limestone pebbles are rare, and pebbles of vein quartz and igneous rocks are conspicuously absent. A few of the chert pebbles contain fossils which can be referred broadly to the Carboniferous, but from the same zone of conglomerates within 10 miles south of the river a collection of chert pebbles containing no less than 11 species has been made. The age of these fossils ranges from Pennsylvanian to probably Permian (Phosphoria fauna), and it is evident that rocks of this age that were being eroded were the source of a part of the Fort Union sediments. It appears highly probable that the pebbles of silicified wood were derived from the Meeteetse formation. If this is true it is a factor in proving that local unconformities exist between the Fort Union formation and the underlying beds.

The higher conglomerate beds, such as occur in the 50-foot sandstone near the middle of the subjoined section, are thinner and contain lithologic types not found lower in the formation. Quartzites are more abundant than chert, and there are fair proportions of quartz schist and pink granite pebbles not represented in the lower beds. At one place a well-rounded pebble of coal 3 inches long was found.

The presence of red clay in the upper part of the Fort Union formation and the small amount of mica throughout the formation serve further to distinguish these beds from the Ilo and Meeteetse formations. There is no coal in the Shoshone River section of the Fort Union, but a bed is mined near Meeteetse at a horizon which corresponds closely with that of the lower conglomerate on the river.

Section of Fort Union formation on Shoshone River.

	Feet.
Sandstone, buff, massive	20
Clay, gray, and argillaceous sand, with thin zones of carbonaceous shale	185
Shales, maroon and gray, sandy	150
Clay, red	8
Clay, gray	6
Clay, red	6
Clay, gray	6
Clay, red (mouth of creek from south)	8
Clay, gray	8
Sandstone, buff, massive	15
Sand, drab, argillaceous	166
Clay, red	3
Clay, gray	1
Clay, red	2
Sand, gray, argillaceous	40
Sandstone, massive	8
Sand, gray to olive-gray, with conglomeratic layers	50
Sand, argillaceous	30
Sandstone, massive	40
Sand, argillaceous	30
Sand, buff to olive-gray, argillaceous; fossil collection 4994	558
Clay, red	3
Clay, gray	8
Clay, red	3
Sandstone, massive	24
Shale, gray, sandy	8
Sandstone, massive, conglomeratic	16
Sand, argillaceous, and unconsolidated clay, with thin carbonaceous shale; fossil collections Woodruff 40, Knowlton 16	1,760
Shales, gray and olive-gray, sandy, and sand with carbonaceous shale; fossil collection 4973	440
Sand, argillaceous, and clay	680
Sandstones, gray and buff, alternating with zones of unconsolidated sand	410
Sandstones, gray and buff, containing numerous zones of conglomerate in the lower 200 feet; fossil collection 366 Willard	500
Sandstone, buff; fossil collection 365 Willard	400
Mouth of Sage Creek.	
	5,592

The following collections of fossils from the Fort Union formation were made by Willard, Woodruff, and Knowlton in 1907:

366. Willard:
    Populus sp. (?)
    Fragments of dicotyledons.
        Comment by F. H. Knowlton: "Horizon probably Fort Union."
365. Willard:
    Platanus raynoldsii Newb.
    Platanus haydenii Newb.
    Platanus nobilis (?) Newb.
        Comment by F. H. Knowlton: "Horizon Fort Union."
4973. Woodruff:
    Viviparus trochiformis M. and H.
    Goniobasis tenuicarinata M. and H.
        Comment by T. W. Stanton: "Horizon Fort Union."
16. Knowlton:
    Taxodium occidentale Newb.
    Populus sp. probably P. speciosa Ward.
    Populus arctica Heer of Lesq.
    Hicoria antiquorum (Newb.) Kn.
    Celastrinites sp. cf. C. grewiopsis Ward.
    Juglans, probably new.
        Comment by F. H. Knowlton: "Horizon Fort Union."
40. Woodruff:
    Sequoia langsdorfii (Brgt.) Heer.
    Sapindus grandifolius Ward.
    Populus glandulifera? Heer.
    Carpites sp. (Palmocarpon?).
    Juglans sp.
    Platanus nobilis (?) Newb.
        Comment by F. H. Knowlton: "Horizon Fort Union."
4994. Woodruff:
    Helix sp.
    Physa sp.
    Goniobasis tenuicarinata M. and H.
    Viviparus trochiformis M. and H.
        Comment by T. W. Stanton: "Horizon Fort Union."

CORRELATIONS OF THE FORMATIONS.

The Sundance formation has furnished a sufficient number of marine fossils to permit its correlation beyond any doubt with well-known sections throughout eastern and northern Wyoming and southern Montana.

Though the presence of saurian bones appears to establish the existence of the Morrison formation, it can not be stated with assurance that a part of the thickness here assigned to it does not represent the Kootenai formation, nor that the beds assigned to the "Cloverly" in this section are not also a part of the same formation.

The great thickness of the Colorado formation, 3,670 feet, compares with measurements of 2,775 feet in the Electric coal field, Mont.,[1] and 3,700 feet near Livingston, Mont.,[2] where faunas similar to that on Shoshone River have been obtained. In comparing the Shoshone River section of the Colorado with those in eastern Wyoming,[3] it is noted that though there is a lithologic resemblance the eastern Wyoming sections contain a Niobrara fauna that is absent in the Bighorn Basin. In southwestern Wyoming the combined Colorado and Montana sections are from 9,000 to 11,000 feet thick and are capable of division into three formations relatively distinct lithologically, as well as faunally, much resembling the three members of the Colorado recognized on Shoshone River. The coal near the top of the middle member would therefore occupy a stratigraphic position similar to the beds of the Kemmerer coal group in the Frontier formation[4] in Uinta and Lincoln counties, Wyo. Only two of the marine fossils of the upper member on Shoshone River are present in the southwestern Wyoming section. The Pierre shale of Fisher's report on the Bighorn Basin[5] and of Darton's report on the Bighorn Mountains[6] is the upper shale member of the Colorado formation.

The most interesting feature of the Shoshone River section is the apparent absence of marine beds above the sandstone overlying the lowest coal of the Gebo formation. No fossils have been found at this horizon on Shoshone River, but a small collection was obtained from the roof of Thompson's coal mine, 15 miles south of Cody. For correlating the formations above this horizon with those of near-by regions dependence must be placed on vertebrate and fresh-water invertebrate fossils and plant remains, and it is to be regretted that good collections have not been found near well-defined and persistent lithologic units, though small collections have been obtained. In the absence of more complete collections, it is at least possible that the Colorado formation should include the lowest two sandstones of the Gebo formation.

The marine faunas of the Eagle and Claggett formations[7] of central Montana have not been found south of the Montana-Wyoming line, though Claggett fossils have been found near Bridger, Mont. Commenting on collections of fossils made by himself and others along Shoshone River and northward into Montana, Stanton writes:[8]

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[1] Calvert, W. R., The Electric coal field, Park County, Mont.: U. S. Geol. Survey Bull. 471, p. 413, 1912.

[2] Calvert, W. R., The Livingston and Trail Creek coal fields, Mont.: U. S. Geol. Survey Bull. 471, p. 387, 1912.

[3] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, p. 45, 1911.

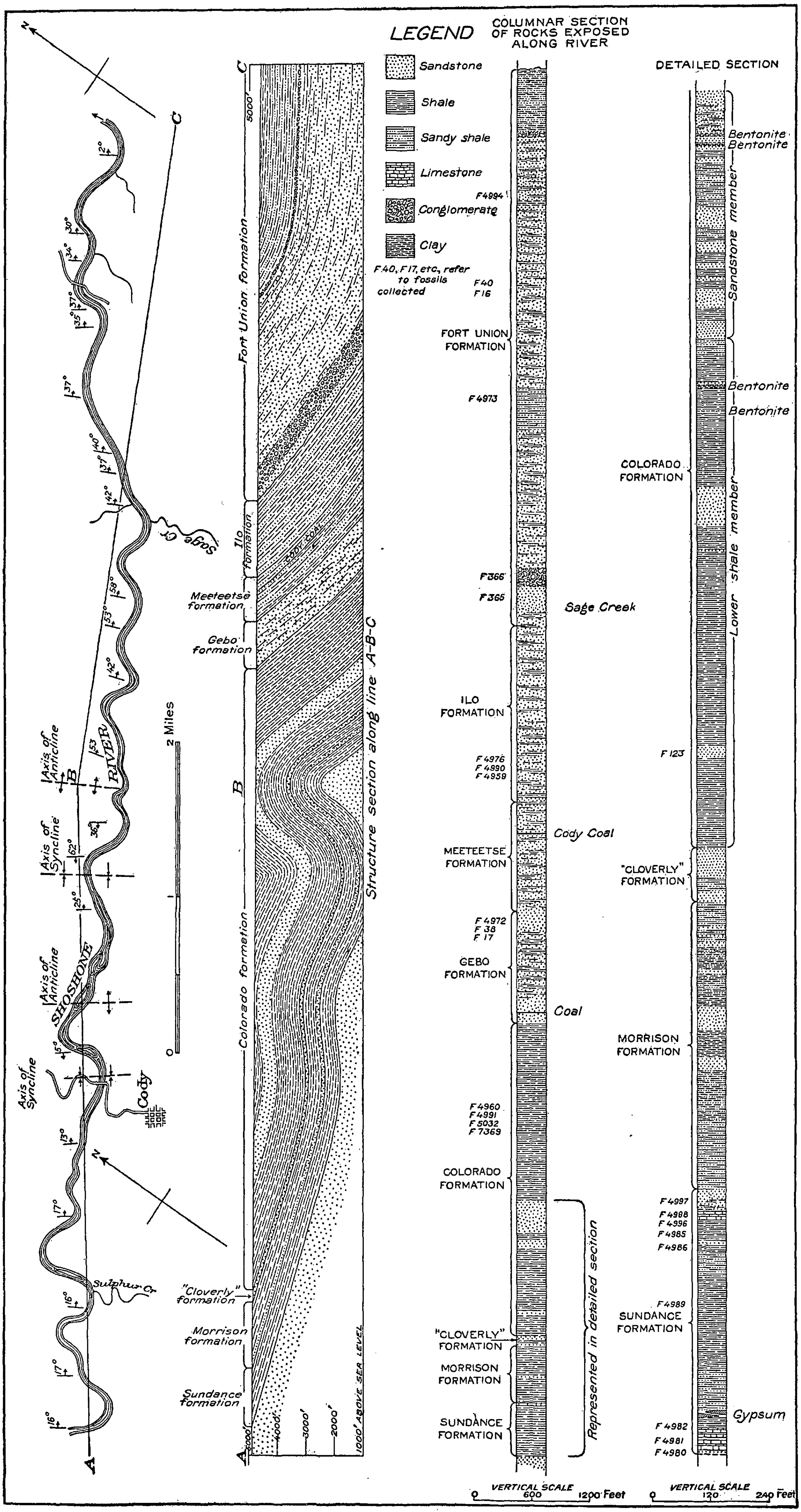
[4] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, p. 115, 1907.

[5] Fisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, p. 30, 1906.

[6] Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, p. 58, 1906.

[7] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, pp. 12, 13, 1905.

[8] Letter accompanying report on fossils to E. G. Woodruff, February, 1908.



STRUCTURE AND COLUMNAR SECTIONS OF ROCKS EXPOSED ALONG SHOSHONE RIVER NEAR CODY, WYO.

The Eagle, Claggett, and Bearpaw formations ought all to have marine faunas, but none such have been found in the Shoshone River section. Their absence indicates that possibly here and farther south in Bighorn Basin land conditions may have begun earlier than elsewhere and may have continued with little or no interruption to the end of the Cretaceous. Of course, it is recognized that there was more or less break in marine conditions during the deposition of the Eagle, even where that formation is mostly marine. This is indicated by the occurrence in it of land plants and vertebrates and of coal beds.

Further study appears to confirm this interpretation. The sandstone formation overlying the Colorado shale 750 to 900 feet thick in the Livingston coal field [1] and 1,000 feet thick in the Electric coal field [2] is undoubtedly the equivalent of the Gebo formation.

In view of the fact that the recognition of the Meeteetse and Ilo formations is based largely on data collected in field work in the Oregon Basin, Meeteetse, and Ilo quadrangles, south of Shoshone River, it is deemed advisable to present the discussion of their relations in the report on those areas.[3]

The incomplete section of the Fort Union formation, 5,592 feet thick, compares with a measurement of 8,500 feet by Woodruff in the Red Lodge coal field,[4] though there is no indication of coal beds in the Shoshone River section similar to the coal beds which occur in the upper portion of the Red Lodge section. Coal beds are present near the base of the Fort Union, however, near Meeteetse and Ilo, Wyo., a fact which, taken with other lithologic features, is proof of the great differences in the conditions of deposition existing in adjacent regions at the same relative epoch.

STRUCTURE.

The structure of the northern portion of the Bighorn Basin has been described by Eldridge [5] and Fisher [6] and has been illustrated by cross sections and a structural contour map. Rattlesnake and Cedar mountains, lying 3 miles west of the limits of the present survey, are portions of a broad asymmetric anticline through which Shoshone River has cut a deep narrow gorge. The section presented on Plate V shows two minor anticlines on the east flank of this major structural feature. On the west side of Rattlesnake Mountain the Madison limestone dips 55° SW., whereas on the east at the same level this formation dips 16° NE. From this point eastward to the out-

[1] Calvert, W. R., The Livingston and Trail Creek coal fields, Mont.: U. S. Geol. Survey Bull. 471, p. 387, 1912.

[2] Calvert, W. R., The Electric coal field, Park County, Mont.: U. S. Geol. Survey Bull. 471, p. 410, 1912.

[3] Hewett, D. F., Geology and coal resources of the Oregon Basin and Meeteetse quadrangles, Wyo.: U. S. Geol. Survey Bull. — (in preparation).

[4] Woodruff, E. G., The Red Lodge coal field, Mont.: U. S. Geol. Survey Bull. 341, p. 94, 1909.

[5] Eldridge, G. H., A geological reconnaissance in northwest Wyoming: U. S. Geol. Survey Bull. 119, 72 pp., 1894.

[6] Fisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, p. 30, 1906.

crop of the middle member of the Colorado the dip varies from 16° to 17°, and then decreases until the axis of the syncline opposite the town of Cody is reached. Proceeding eastward, surface observations being made on beds of the upper shale of the Colorado, the strata rise over a low anticline and again descend at 22° to a second synclinal axis. There is then a broad belt within which exposures are poor. The first good exposures are in upper shale of the Colorado, dipping 62° SW., and a short distance east the axis of a narrow anticline is crossed. From this point northeast to the mouth of Sage Creek the dip varies from 42° to 58°, and then after remaining relatively uniform at 37° for 1½ miles decreases abruptly to 3°, an inclination which is maintained beyond the limits of the survey.

The areal extent of the anticlines exposed along Shoshone River has not been determined. Together with the Rattlesnake-Cedar Mountain anticline they form a portion of a belt of folded rocks which extends around the entire border of the basin. Throughout this belt the anticlines are from 8 to 15 miles long and from 3 to 6 miles wide and therefore may be regarded as elongated domes. Their axes, though essentially parallel, are successively offset and an anticlinal axis is commonly succeeded along the strike by a synclinal axis. As far as this examination has been carried the broad western anticline, which may be referred to as the Cody anticline, appears to be a minor structural feature, whereas the eastern or Shoshone anticline is a more extensive fold probably 5 or 6 miles long, and Shoshone River exposes a section across the extreme south end. The highest point of the fold probably lies several miles north of the river.

OIL AND GAS.

WELL OF THE SHOSHONE OIL CO.

One of the objects of the detailed measurement of the Shoshone River section was to ascertain the position and character of the sands from which oil and gas have been derived in the well of the Shoshone Oil Co., situated 1,700 feet north of the river, 3 miles east of Cody. This well is located approximately on the axis of the Shoshone anticline within 3 miles of its southern limit, at the point *B* on Plate V. Information concerning this well has been placed at the writer's disposal by Mr. C. L. Sheedy, at present in charge of operations for the company. A detailed record of the well was not kept during drilling operations and the following log represents notations made by one of the employees:

Log of Shoshone Oil Co.'s well No. 1.

	Feet.
Terrace bowlders	20
Muddy sands	10
Shales, little water	90
Mud, trace of oil	50
Slate	50
White sand, trace of oil	3
Dark shaly sands	77
Shaly sands and slate	60
Slate	225
Dark sandstone, No. 1 oil sand, trace of gas	10
Light sandstone	5
Slates with some thin sandstones	260
Dense sandy shales yielded a little oil	5
Slates	163
Sandstone, No. 2 oil sand; good gas flow at 1,262 feet	234
	1,262

This well was dry except for the small flows encountered above 300 feet. Drilling began November, 1909, and with relatively little interruption continued to 1,000 feet. It started again March, 1911, and was carried to a depth of 1,285 feet by June, 1911. A standard rig was used. Much trouble was experienced from the caving of the shales and swelling of bentonite, and the well was finally cased with 10-inch casing to 260 feet, 8-inch from 260 to 410 feet, and 6¼-inch from 410 to 1,028 feet. During the winter of 1911–12 this well was drilled to a depth of 1,700 feet, where a second gas sand was encountered, which corresponds closely with the 50-foot sandstone in the section of the Morrison formation on page 95. No attempt was ever made to pump from any of the oil sands. No record of production has been kept; it probably did not exceed 200 barrels. All the oil produced was stored and sold locally for lubricating.

OIL SANDS.

By comparison of the log of the well with the stratigraphic section of the lower two members of the Colorado, the "Cloverly" and the Morrison formations, exposed along the river and presented herewith, it has been possible to ascertain the beds which have yielded oil and gas. The top of the well approximately coincides with the top of bed 16 of the section of the middle member of the Colorado on page 98. If this basis is assumed for correlation, the first traces of oil, from 120 to 170 feet, appear to have come from one or more of beds 22, 23, and 24, but the exact sand can not be identified. The sand at 220 feet which yielded a trace of oil is probably a portion of the conglomeratic sandstone No. 26. The first sand which yielded more than a trace of oil, at 585 feet (see analysis No. 1 below), corresponds with bed 8 of the section of the lower member of the Colorado on page 97; this bed, though reported to be but 15 feet thick in the well, is 80 feet thick on the river. The shale bed which yielded a little oil at 860 feet lies in the bentonite-bearing shale, but can not be identified. The sandstone at 1,028 feet, from which of the total yield of this well to date the greatest amount of oil was derived, corresponds closely to bed 12 of the section of the lower member of the Colorado. The analysis of oil from this sand is given under No. 2 in the table. This sandstone lies between thick beds of carbonaceous shale and is that in which saurian bones, crocodile teeth, and a turtle were found. It underlies the shale bearing numerous fish scales and vertebræ which is probably the equivalent of the Mowry shale member of eastern Wyoming. The sandstone at the bottom of the hole, 1,285 feet, which yielded a good flow of gas, is the upper sandstone of the "Cloverly" formation. The oil from two of the oil sands, at 585 and 1,028 feet, rose in the well and flowed when the sands were struck, but soon ceased, and the sands were later cased off in order to drill deeper.

To summarize, it is interesting to note that though oil has been derived from several sandstones in the lower portion of the Colorado formation, the sandstone which has yielded the greatest flow in this well is in or near the position of the Mowry shale member, depending on the limits assigned to it in this section. The sandstones of the lower portion of the Colorado formation yield oil in the Garland,[1] Spring Valley,[2] Labarge,[3] Lander,[4] and Salt Creek[5] fields in Wyoming where structural and other conditions are favorable. In the first three of these fields the sandstones are in or near the position of the Mowry shale member. In the Shoshone anticline the oil has been found along the axis, and, though it can not be stated that pools do not occur at points on the flanks, it appears that structural conditions have been predominant in determining the location of the oil.

Prior to the drilling of the well of the Shoshone Oil Co., another operator drilled a well to a depth of 850 feet near Shoshone River (No. 2 on Pl. V). The log of this well could not be obtained. It was cased but never capped, and oil, water, and gas now issue in small amounts from the mouth.

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[1] Washburne, C. W., Gas fields of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, p. 355, 1908.

[2] Veatch, A. C., Coal and oil in southern Uinta County, Wyo.: U. S. Geol. Survey Bull. 285, p. 349, 1906.

[3] Schultz, A. R., The Labarge oil field, central Uinta County, Wyo.: U. S. Geol. Survey Bull. 340, p. 369, 1908.

[4] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, p. 27, 1911.

[5] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, p. 71, 1911.

THE OIL.

Analyses of two samples of oil from the wells of the Shoshone Oil Co. are given below. These analyses were made in the laboratory of the United States Geological Survey, under the direction of David T. Day.

Analyses of samples of oil from wells of Shoshone Oil Co.

	1	2
Color	Dark green.	Green.
Specific gravity	0.8454	0.8335
Gravity ° B.	35.60	37.98
Begins to boil at ° C.	190	160
Boiling between 150° and 300° C. per cent.	37	48
Specific gravity of above fraction	0.8169	0.8009
Residue per cent.	59.6	52.4
Specific gravity of residue	0.9278	0.8696
Total per cent.	96.6	100.4
Paraffin do.	7.6	8
Water	Present.	0

1. 585 feet; middle sandstone member of Colorado formation.
2. 1,028 feet; lower shale member of Colorado formation.

Neither of these samples represents the oil as it came from the well. Sample 1 had been kept for some time in an open can and later in a bottle. Sample 2 was taken from an open tank. Neither of these oils is well adapted for lubricating in the raw state but would on distillation, as shown by the fraction distilling between 150° and 300° C., yield a good proportion of illuminating oil and a residue well adapted for lubrication. Sample 2 resembles the oil derived from the Wall Creek sandstone lentil of the Benton shale (lower Colorado) in the Salt Creek field,[1] and the oil from a sandstone in the Mowry shale member of the Mancos shale (lower Colorado) at the Plunkett well in the Lander field.[2] Oils of similar character, thought to have come from a sandstone in the Benton shale or "Cloverly" formation, have been found in wells in the Douglas oil field in central Wyoming (pp. 68–88). It is worthy of note that samples of oils from approximately the same geologic horizon in four fields in Wyoming should be of similar character.

[1] Wegemann, C. H., The Salt Creek oil field, Wyo.: U. S. Geol. Survey Bull. 452, p. 80, 1911.
[2] Woodruff, E. G., The Lander oil field, Wyo.: U. S. Geol. Survey Bull. 452, p. 29, 1911.

OIL AND GAS NEAR GREEN RIVER, GRAND COUNTY, UTAH.

By Charles T. Lupton.

INTRODUCTION.

FIELD WORK.

This paper is based on field work done in November and December, 1912, by M. W. Ball, R. V. A. Mills, and the writer. The area discussed contains about 300 square miles and lies just southeast of the town of Green River, in Grand County, Utah. It is included in Tps. 21, 22, 23, and 24 S., Rs. 16, 17, 18, 19, and 20 E., Salt Lake meridian. (See fig. 4.) Practically all the drilling in this area has been done along and adjacent to the fault zone that crosses the field in a northwest-southeast direction.

The object of the examination was to determine if this area, in which considerable drilling for oil and gas had been done and in which some development work is still going on, contains any reservoirs of oil or gas. The result of the investigation shows that in the area examined in detail there are no anticlines or domes in which large quantities of oil or gas might be expected to collect. It is true that traces of oil and small pockets of gas have been encountered in some of the wells but only in sufficient quantities to afford slight encouragement.

The greater part of the area examined in detail (see Pl. VI, p. 132) was mapped by means of plane table and telescopic alidade, a system of triangulation having been developed from a base line (*A–B*) measured in secs. 26 and 27, T. 22 S., R. 17 E. Practically all of the more nearly level part of the field situated east of the range line separating Rs. 17 and 18 E. and lying north and northeast of the road connecting Green River with Brink Spring was mapped by following section lines and recording observations on the plats.

A flying level line was run from Green River along the Green River-Moab road to the top of the divide in sec. 3, T. 23 S., R. 18 E., separating the drainage system of Salt Wash from that of Tenmile Wash, and another from this road in sec. 25, T. 22 S., R. 17 E., to Levi well

No. 2, in the NE. ¼ NW. ¼ sec. 35 of the same township. During the development of the triangulation system the altitudes of practically all points occupied and many others were determined by means of vertical angles and distances between points. The figures given on the map are not precise but are intended to show relative instead of exact altitudes. It is believed, however, that the altitudes shown

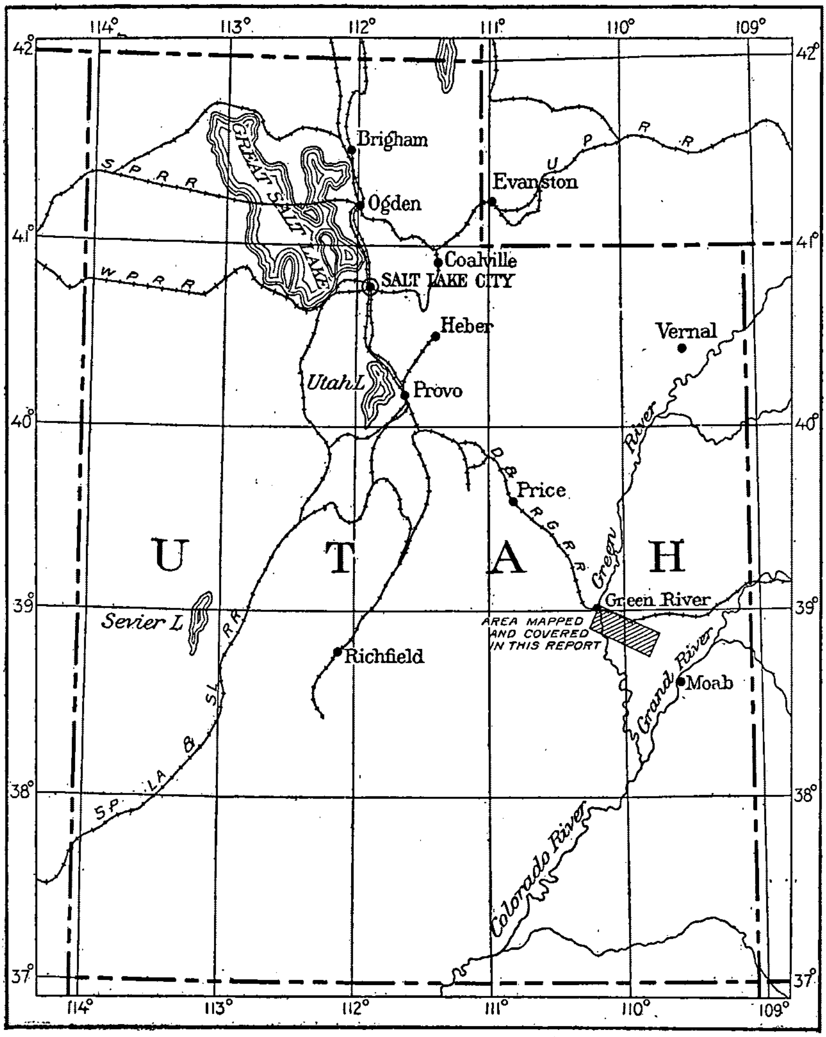


FIGURE 4.—Index map of Utah, showing location of area in Grand County examined in detail.

are within a very few feet of the exact elevations above sea. In the greater part of the area mapped by line riding, altitudes were ascertained approximately by means of the aneroid barometer.

In addition to the detailed work above described, a reconnaissance was made from Green River to Hanksville across the Green River Desert. No detailed mapping was done on this trip, but the stratigraphy and structure were studied in a general way. A brief discussion of the observations made at that time, with their bearing on the possible presence of reservoirs for oil or gas, is given under "Conclusions."

The writer desires to acknowledge the courtesy of the managers of the British-American Petroleum Co., who gave the geologic party every means of assistance at their command. Messrs. Frank Cook, William Dixon, Nat Levi, H. H. McFann, George Muller, Charles P. Tasker, and Robert Woodruff, of Green River; W. G. Clark, Knox Patterson, A. M. Rogers, of Moab, and others gave information which has made the historical part of this report possible. Millard and Arthur Massey rendered valuable service as camp assistants.

HISTORY OF DEVELOPMENT OF THE FIELD.

Prospecting for oil in this general region has been carried on at intervals for over 20 years. The presence of asphaltum-saturated sandstone and petroleum seeps at various places in and adjacent to the field suggested to the minds of the more optimistic prospectors the existence of an oil reservoir of commercial importance.

A well situated a short distance south of Elgin, in Grand County, in the SW. ¼ SE. ¼ sec. 15, T. 21 S., R. 16 E., was drilled about 1891 by Bamberger & Millis with an American or Parker rig. The upper 100 feet of this well is in the Mancos shale and the remainder in the Dakota sandstone and McElmo formation. No oil was encountered in the drilling, but a little carbonic acid gas escaped at one or more horizons in the well. A little water, which probably contains some lime, issues from the well and has built up a small deposit around its mouth. As this well furnished no encouragement for further prospecting, no additional efforts to discover oil or gas in this locality were made for 10 years.

About 1900 the increasing demand for petroleum and its products and the discovery of other seeps of asphalt or oil in the region encouraged prospectors again to test the field. In sec. 5, T. 22 S., R. 15 E., in Emery County, just west of the road connecting the Tomlinson ranch, on San Rafael River, with Green River, the California-Utah Oil Co. in 1899 drilled a well by means of a 72-foot standard rig to a depth of 1,600 feet. The upper 800 feet of the hole is in the Mancos shale and the remainder in the Dakota sandstone and the McElmo formation. At a depth of 500 feet, probably near the base of the Ferron sandstone member, water was encountered. Gas, which when ignited blazed 30 feet up in the derrick, was struck at a depth of 1,100 feet. A trace of oil was noted at the same depth by the "rainbow" colors on the surface of the water, which was very alkaline. At 1,600 feet a sand was encountered which, by the "paper test,"[1] showed a trace of oil. The showing was so poor, however, that drilling was discontinued.

In 1899 and 1900 a well was drilled by P. D. Jones, of Duluth, Minn., to a depth of 1,800 feet, in sec. 13, T. 22 S., R. 22 E., at a place about 2 miles south of White House, a flag station on the Denver & Rio Grande Railroad. Work at this locality extended over a period of 1½ years, owing to the fact that three strings of tools were lost. Two of these are in one hole and the other in another hole 20 feet away. The upper 800 feet of the latter well is in the Mancos shale and the lower 1,000 feet in the Dakota sandstone and McElmo formation. No trace of oil or gas, but much bad water, was encountered. At 1,600 feet water carrying copper in solution is reported to have been struck.

Another well was drilled in 1899 in sec. 15 or sec. 16, T. 20 S., R. 14 E., about 3½ miles southwest of Desert, a flag station on the Denver & Rio Grande Railroad about 13 miles northwest of Green River. The well, it is reported, was drilled by a man named Burns, with a standard rig, to a depth of 1,490 feet. At 1,100 feet a "showing" of oil was encountered and it is reported that about 1 gallon of oil was taken from the receiving tank. Excellent artesian water, which flowed over the top of the casing, was struck at 1,200 feet. The water was cased off at 1,290 feet, but 50 feet deeper another flow was encountered. So much water was present in the well at 1,490 feet that drilling was discontinued. At the present time a strong flow of artesian water issues from the well. It is estimated that the upper 1,100 feet of this well is in the Mancos shale and the lower 390 feet in the Dakota sandstone and McElmo formation.

About 1910, owing to the finding of hitherto unknown oil seeps and rocks saturated with asphaltum and oil at several localities, and also to the increased price of petroleum and its products, interest was again aroused in this field and active prospecting has continued to the present time. During the last three years several wells have been drilled and at present drilling operations are being continued at three localities.

Levi well No. 1, drilled with a Keystone rig No. 5, by the British-American Petroleum Co., is in sec. 25, T. 23 S., R. 18 E. Drilling was begun April 1, 1912, and was discontinued about July 1 of the same year at a depth of 530 feet. A fairly strong flow of water was struck at 350 feet and a little gas with a small quantity of oil is reported to have been encountered near the bottom of the hole. This well is wholly in the McElmo formation. Levi well No. 2, in the NE. ¼ NW. ¼ sec. 35, T. 22 S., R. 17 E., was drilled with a standard rig by the

[1] The "paper test" is applied by putting dry sand on paper and allowing it to remain there for some time. If the sand contains even a slight amount of oil the paper will be stained.

same company to a depth of 1,500 feet. No oil or gas is reported to have been encountered in this hole, which is now clogged owing to the "shooting" of the well in an attempt to loosen the casing, which could not be pulled. The same company, using a Keystone rig, drilled a hole in the SE. ¼ SE. ¼ sec. 26 of this township, to a depth of 425 feet, in an attempt to reach a thin sandstone which, on the face of a cliff 1,700 feet southwest of the well, is partly saturated with petroleum. The horizon of this sandstone should have been encountered at a depth of 140 feet, but as no petroleum-saturated sandstone was struck at on near this depth, it is believed that the bed is lenticular under cover, as it certainly is along the outcrop.

The Klondike well, drilled by the Moab Oil Co. of Utah to a depth of about 700 feet by means of a Keystone rig, is located in the NW. ¼ SW. ¼ sec. 26, T. 23 S., R. 19 E. Three pockets of gas were struck in the well but no water nor oil. The first pocket was encountered at a depth of 75 feet and furnished sufficient gas to light the cook tent and for cooking purposes until it was cased off. The gas, escaping through a ¾-inch pipe, burned with a flame 1½ to 2 feet long. The second flow of gas, much stronger than the first, was struck at 265 feet and lasted undiminished until it was cased off. The third flow, which was the weakest of the three, was encountered 500 feet below the surface and lasted about three weeks, when it was cased off. It is believed that the entire well is in the Mancos shale and that the underlying Dakota sandstone was not penetrated. If it had been reached a flow of water would probably have been encountered.

The Queen or Hagan well, in the SE. ¼ SE. ¼ sec. 18, T. 23 S., R. 19 E., was drilled by means of a Keystone rig to a depth of 920 feet. The upper 410 feet of this well is believed to be in the Mancos shale, the remainder being in the Dakota sandstone and McElmo formation. At a depth of 425 feet fresh water was found in a white sand (probably Dakota), and at 600 feet salt water was encountered. Salt water was again encountered at 870 feet and a "showing" of oil at 910 feet. Drilling was discontinued at 920 feet, the casing pulled, and the well abandoned.

The Collins well, in the NW. ¼ NE. ¼ sec. 20, T. 21 S., R. 17 E., was drilled by the Crescent Oil Co. with a National rig to a depth of 2,100 feet. Drilling began September 12, 1912, and was discontinued about March, 1913, on account of a strong flow of salt water that issued from the top of the well and could not be cased off without considerable difficulty. The well penetrated 850 feet of Mancos shale and then passed through the Dakota sandstone and McElmo formation and 100 to 150 feet into the La Plata sandstone, which, being coarse grained, is an excellent carrier of water. Gas was obtained in white sand (probably Dakota) at 850 feet and again in similar material at

976 feet. Gas associated with salt water was encountered at 1,840 feet and dry gas at 1,980 feet. Rainbow colors on the water accompanied each flow of gas. The same company is reported to have moved its rig about 1½ miles southeast and has begun another well near Solitude, approximately in the NE. ¼ NE. ¼ sec 28 of the same township. It is reported that at 70 feet in this well a good flow of water was encountered and that at 350 feet a pocket of gas was struck which burned for a short time a flame 8 to 10 feet in length.

Oil seeps and rocks saturated with oil and asphaltum are present at several localities in the region. Three of these were visited by the writer and are described briefly below. The most prominent seep known to the writer in the area mapped in detail is near the north boundary of the NE. ¼ sec. 2, T. 22 S., R. 16 E., and is known locally as "Goin's seep." It is situated in a narrow zone of rocks which have been disturbed by a fault whose displacement at this locality is about 450 feet, with downthrow on the south side. Several prospect pits for collecting the oil have been dug where the rocks seem to be most nearly saturated, but at the time the writer was in the field there was not sufficient oil in any of the pits to enable him to collect a sample, though the presence of films of oil on the surface of the water in one or two of the pits, as indicated by the rainbow colors was noted. Sandstone partly saturated with petroleum outcrops on a southwestward-facing cliff in the NE. ¼ sec. 35, T. 22 S., R. 17 E. This is the lenticular sandstone that the British-American Petroleum Co. attempted to reach by means of the 425-foot hole. A small lentil of sandstone in the SW. ¼ NW. ¼ sec. 35, T. 22 S., R. 16 E., is partly saturated with petroleum.

Two wells are now being drilled on the west side of Green River outside of the area examined in detail. One of these, located near the center of sec. 29, T. 26 S., R. 14 E., just southwest of "Flattops," is being drilled by the Des Moines Oil Co. At present the drill has penetrated to a depth of 2,140 feet, the upper 600 feet of which is in the McElmo formation, the part from 600 to 1,325 feet in the La Plata sandstone, and the part below 1,325 feet probably all in what has been referred to by Gilbert[1] in the Henry Mountain section as the Vermilion Cliff group. At a depth of about 310 feet a strong flow of good water was encountered which has reduced the expense of drilling considerably, as previous to this time water for all purposes had to be hauled about 10 miles. About 150 feet lower another good flow of water was struck; in fact, from about 310 feet down fresh water was encountered at several horizons. This locality was visited on a reconnaissance trip in November, 1912. From observa-

[1] Gilbert, G. K., Geology of the Henry Mountains: U. S. Geog. and Geol. Survey Rocky Mtn. Region, pp. 6–7, 1877.

tions made at that time it seems probable that the well is situated just north of the axis of a broad, nearly flat east-west anticline which connects the San Rafael Swell on the west with another reported anticline occupying a position near the junction of Grand and Green rivers.

About 10 or 12 miles southwest of the Des Moines Oil Co.'s well, above discussed, in the NE. ¼ sec. 9, T. 27 S., R. 12 E., another well is being drilled by the Mount Vernon Oil Co. This locality was not visited by the writer, as development work had not begun at the close of the field season. It is reported that at first a 600-foot hole was drilled for water and that another a few feet distant is now being drilled for oil. The drill penetrated to a depth of 820 feet in the early part of June. An 84-foot standard rig is used by this company and undoubtedly a thorough test for oil and gas will be made.

TOPOGRAPHY.

The country in the vicinity of Green River, shown in Plate VI (p. 132), lies at the base and south of the Book Cliffs, which form a continuous precipitous escarpment 1,500 to 2,000 feet high, extending from western Colorado as far west as the Wasatch Plateau. Part of the region in Utah lying south of this escarpment and east of the San Rafael Swell constitutes the Green River Desert, of which the area under discussion forms a part. There are excellent exposures of the strata in this region, for the wind and water remove the rock as rapidly as it is disintegrated. Except in a very few places the strata outcrop in nearly vertical scarps that range from a few feet up to 300 or 400 feet in height, wherever hard strata protect the softer underlying rocks. The surface between the escarpments, where the rocks are homogeneous, like the Mancos shale, is a comparatively smooth plain cut into badlands near the stream courses. The plains type of topography predominates north of the road extending southeastward from Green River to Brink Spring, in the SE. ¼ sec. 10, T. 24 S., R. 19 E., whereas the more rugged topography characterizes that part of the area south of the road above mentioned and east of Green River. Dip slopes, usually of small extent, are numerous in the rugged part of the field.

Green River, the only perennial stream, flows along the west side of the field in a canyon whose walls range from a few feet up to 200 or 300 feet in height. Little Grand, Salt, Red, and White washes also have cut canyon-like valleys. Badland topography occurs in many places adjacent to the streams. Salt Wash flows for the greater part of its course on a down-faulted block of McElmo rocks, which forms a conspicuous break in the rugged topography in T. 22 S., Rs. 16 and 17 E., and T. 23 S., R. 17 E.

The relief of the surface in this field is approximately 1,000 feet, the lowest point being on Green River in sec. 31, T. 23 S., R. 17 E., which is approximately 3,990 feet above sea level, and the highest point being in the NE. ¼ NW. ¼ sec. 19, T. 23 S., R. 18 E., where the altitude is about 4,990 feet.

WATER SUPPLY.

The climate is semiarid, as shown by the mean annual rainfall, which in the vicinity of the town of Green River is about 6½ inches. The most important water supply in the field is Green River, which forms the western boundary of the area and carries a plentiful amount of water the year round. Plans have been made to divert some of the water from the river to irrigate large tracts of land on each side of it, in addition to that already under irrigation. Little Grand, Salt, Red, and White washes, which are the principal tributaries, joining Green River from the east, are intermittent streams throughout the greater parts of their courses. In the vicinity of springs, however, the water flows on the surface for some distance, and then sinks into the sand to reappear as other springs or seeps farther down the valley.

In the NE. ¼ SW. ¼ sec. 27, T. 22 S., R. 17 E., about a mile northwest of Levi well No. 2, there is a fairly strong spring which, on account of its slightly saline and alkaline character, is known locally as Salt Spring. In the bed of Little Grand Wash, in sec. 8 of the same township, there is another fairly good spring. A spring of good water in the SE. ¼ NE. ¼ sec. 17, T. 22 S., R. 18 E., on a northern tributary of Little Grand Creek just west of the traction road connecting Floy or Little Grand with some manganese claims near the river, constitutes the only water supply in the township. In the S. ½ sec. 25, T. 22 S., R. 16 E., two or three salt springs furnish sufficient water to make the lower course of Salt Wash a perennial stream. Brink Spring, situated on a fault in the SE. ¼ sec. 10, T. 24 S., R. 19 E., has a strong flow of excellent water. Four to five miles slightly south of east from Brink Spring there are two good springs. One of these is in a stream bed just north of the Court House Cattle Co's ranch and the other at Court House stage station, about a mile farther northeast. A water hole of considerable size is situated in the SW. ¼ sec. 15, T. 23 S., R. 18 E.

At several places where the massive sandstone beds in the lower part of the McElmo formation outcrop in almost flat surfaces, holes, formed principally by wind erosion, collect rain water and retain it for relatively long periods of time, thus affording excellent temporary local supplies of water.

The wells drilled in the field to date, with the exception of the Klondike well in the NW. ¼ SW. ¼ sec. 26, T. 23 S., R. 19 E., have all encountered some water. Artesian water was struck in the well southwest of Desert station, in T. 20 S., R. 14 E., and in the Elgin well, in the SW. ¼ SE. ¼ sec. 15, T. 21 S., R. 16 E., as noted in the description of these wells under "History of development of the field," the former furnishing fresh and the latter salt water.

LAND SURVEYS.

The land surveys in parts of this field are remarkably good. Where section lines were followed in mapping practically all the corners were found, but where the triangulation method of mapping was employed only a sufficient number of corners were located to check the triangulation work. For this reason little can be said regarding the surveys in that part of the field where the triangulation method was used. From retracements of exteriors made in the more recent work for the General Land Office it is believed that the chaining in the earlier work was long, so that the old lines are slightly longer than is indicated on the original township plats.

STRATIGRAPHY.

GENERAL SECTION.

The rocks exposed in the Green River field belong to the Cretaceous and Jurassic systems. The Mancos shale and Dakota sandstone represent the former, and the La Plata sandstone and probably the McElmo formation represent the latter, although it is not yet definitely determined whether the McElmo is Jurassic or Cretaceous. Rocks of Cretaceous age in this field were mapped in a reconnaissance way by Richardson[1] in 1906. The underlying formation which, in the present report, is mapped as McElmo, was considered by Richardson[2] to be equivalent in part to the Morrison formation.

The following summary gives a general description of the rocks exposed in the Green River field:

[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colorado, and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, Pl. I, 1908.

[2] Idem, Pl. III, p. 14.

General section of rocks outcropping in the Green River field, Utah.

System.	Formation.	Member.	Description of strata.	Thickness (feet).	Economic value.
Cretaceous.	Mancos shale.		Yellow to bluish drab sandy shale; the upper part is very sandy and contains beds and lenses of sandstone; the middle and lower parts are mainly shale.	About 2,500 (after Richardson).	
		Ferron sandstone member.	This sandstone contains in places concretions which are fossiliferous. It forms a hogback through the field.	50-100.	Possibly this sandstone is a reservoir for the gas that has been obtained in some of the wells.
			Bluish drab sandy shale; sandy material is most plentiful near the base and top of this part of the formation.	About 400.	
	Dakota sandstone.		Yellowish-gray sandstone with thin beds of shale alternating. Sandstones, coarse, soft, and in places very conglomeratic.	0-40.	Contains a little coal in places, but none was observed in this field.
			Unconformity.		
Jurassic (?).	McElmo formation.		Gray conglomerate, variegated sandy shale, and clay, and a few feet of limestone about 175 feet from the top. Some of the sandstone is quartzitic.	325-350.	A few lenses of sandstone contain pockets of gas. Other lenses are partly saturated with petroleum.
		Salt Wash sandstone member.	Gray conglomeratic sandstone which outcrops in cliffs. The sandstone in places is lenticular, soft, and friable.	150-175.	Water-bearing in places. Probably contains a little gas and a trace of oil.
			Red sandstone, thin-bedded above and massive below.	About 700.	Gypsum and manganese in the upper part.
Jurassic.	La Plata sandstone.		Very cross-bedded coarse gray sandstone.	Estimated 700.	Water-bearing in many places.

JURASSIC SYSTEM.

LA PLATA SANDSTONE.

The La Plata sandstone consists of a cross-bedded coarse-grained, very massive gray sandstone, the base of which was not observed in the Green River field. It is believed, however, that the thickness of the formation in this locality is about the same as in the vicinity of the San Rafael Swell, where it is 700 or 800 feet. In places this sandstone is stained from the overlying red sandstone and sandy shale of the McElmo formation. The La Plata sandstone, first described by Cross[1] as "seldom more than 100 feet" in thickness at the type locality, is much thicker in this field, as noted above. This sandstone, being coarse grained and massive, is an excellent reservoir for water, and, as stated under "History of development of the field," it is believed that the salt water encountered in the Collins well, in sec. 20, T. 21 S., R. 17 E., is derived from its upper part.

JURASSIC (?) SYSTEM.

M'ELMO FORMATION.

General occurrence and character.—Overlying the La Plata sandstone with apparent conformity is the McElmo formation, which, according to Cross,[1] should include all the rocks between the Dakota sandstone above and the La Plata sandstone below. At the west side of the San Rafael Swell, east of Emery, marine fossils of Jurassic age were collected about 15 feet above what was taken to be the base of the McElmo formation, but this bed may belong with the underlying formation. Bones were also noted in a conglomerate about 500 feet below the top of the formation in the same area. On account of lack of time little attention was given during the field examination to the collecting of fossils. A detailed section of the greater part of the formation was measured in the NW. ¼ sec. 19, T. 23 S., R. 18 E., and is given on page 126.

[1] Cross, Whitman, Description of the Telluride quadrangle, Colorado: U. S. Geol. Survey Geol. Atlas, Telluride folio (No. 57), p. 3, 1909.

Section of part of McElmo formation measured in the NW. ¼ sec. 19, T. 23 S., R. 18 E. Salt Lake meridian, Utah.

		Ft.	in.
Sandstone, gray; weathers brown; contains clay-ball concretions in places		8	
Clay, bluish gray; contains a little limestone about 5 feet below top		28	6
Clay, brick-red, gray, and purplish, sandy; contains several thin beds of gray to white sandstone		116	
Sandstone, gray; weathers brown; indurated at base, conglomeratic and quartzitic in places, lenticular		5	
Clay, brick-red, sandy		52	
Sandstone, brick-red, massive		14	
Clay, brick-red, sandy		12	
Salt Wash sandstone member:	Ft.		
Sandstone, gray, conglomeratic; contains some interbedded gray sandy shale	58		
Sandstone, reddish, calcareous	17		
Sandstone, gray to white, soft, cross-bedded in places	10		
Sandstone, red and gray, soft, calcareous	42		
Sandstone, gray to white, soft, massive; contains a little argillaceous material	37		
		164	
Sandstone, grayish brown, interbedded with gray and reddish calcareous and argillaceous sandstone		27	
Sandstone, white; weathers reddish brown		12	
Sandstone, red with streaks of green, calcareous		20	
Sandstone, grayish brown, with calcareous layers		50	
Sandstone, brown		2	
Sandstone, calcareous		5	
Sandstone, grayish brown, medium bedded		4	
Sandstone, red below and gray above, very calcareous; contains many small nodules		40	
Sandstone, brick-red, thin and medium bedded. This sandstone is believed to be calcareous. It bears manganese ore in the upper part		128	
Sandstone, red, massive		400±	
		1,087	6

A section of the upper part of the McElmo formation measured in secs. 26, 34, and 35, T. 22 S., R. 17 E., near Levi well No. 2, shows that the formation is about 100 feet thicker than is indicated by the section given above. Most of the part omitted from the above section consists of alternating beds of sandstone and sandy shale of various colors capped by a conglomeratic quartzitic sandstone about 20 feet thick. The east end of the base line (*B*, Pl. VI), in the SE. ¼ SW. ¼ sec. 26, just north of Levi well No. 2, is on this sandstone.

The upper part of this formation was regarded by Richardson [1] as probably equivalent to the Morrison formation, as a number of

[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colorado, and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, p. 14, Pl. III, 1909.

dinosaur bones were found in that part of the formation near Grand Junction, Colo.,[1] some distance east of the area under discussion. These rocks in the Green River field are similar lithologically to the Morrison formation at its type locality and to the same formation in Wyoming, where the writer has had opportunity to observe it. The McElmo formation, described first by Cross,[2] is 400 to 500 feet thinner at the type locality than in the area under discussion. The upper 350 feet of the McElmo formation in the Green River field consists of variegated sandstone, sandy shale, shale, limestone, and about 150 feet of conglomeratic sandstone beds (Salt Wash sandstone member), which occur principally near the base of this portion of the section. The middle part of the formation consists of 300 to 400 feet of red, mainly thin-bedded sandstone and sandy shale which, in its upper part, contains in places considerable gypsum. As much as 60 feet of gypsum was measured at one place. At places where the gypsum is not present manganese in the form of pyrolusite may be found at about the same horizon—in fact, the Colorado Fuel & Iron Co. mined considerable of this mineral in the southern part of the area under discussion and hauled it to the railroad to be shipped east. At present, however, mining operations have been discontinued. The lower 400 feet or more of the formation is made up of massive red sandstone. At several horizons in the formation there are lentils of sandstone that in places are partly saturated with petroleum. Two of these outcrop at the surface in this field and have been described above under "History of development of the field." Some gas has also been encountered in the wells in this formation.

Salt Wash sandstone member.—A gray coarse-grained sandstone, conglomeratic in places, occurs in the Green River field about 350 feet below the top of the McElmo formation. It probably corresponds to the lower conglomerate of the "Henrys Fork group" of Powell's section [3] on the north flank of the Uinta Mountains and of Gilbert's section [4] in the Henry Mountains. This sandstone was used as a datum plane on which altitudes were determined, and is shown on the map by hachures in the unpatterned area. The writer proposes the name Salt Wash sandstone member of the McElmo formation for this sandstone.

[1] Riggs, E. S., The dinosaur beds of the Grand River valley, Colorado: Field Columbian Mus. Geol. Ser., vol. 1, 1901.

[2] Loc. cit.

[3] Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains and a region of the country adjacent thereto: U. S. Geol. and Geog. Survey Terr., 2d div., p. 157, 1876.

[4] Gilbert, G. K., Geology of the Henry Mountains: U. S. Geog. and Geol. Survey Rocky Mtn. Region, p. 4, 1877.

CRETACEOUS SYSTEM.

DAKOTA SANDSTONE.

The Dakota sandstone unconformably overlies the McElmo formation and in this region is variable in thickness. Richardson,[1] who examined this and adjacent formations from Grand River, Colo., to Sunnyside, Utah, found it to be cut out entirely in the vicinity of Elgin, though reaching a maximum of 200 feet in other places. In the Green River field it consists of 40 feet or less of yellowish-gray to white coarse-grained sandstone which in places is conglomeratic. Thin beds of coal have been found in this sandstone in the vicinity of Fruita and Grand Junction, Colo., and along the east side of Castle Valley to the west, but no carbonaceous material was observed in the Green River field.

The Dakota sandstone is a water bearer in places in this region and is believed to contain the pocket of gas encountered at a depth of 850 feet in the Collins well, in sec. 20, T. 21 S., R. 17 E. In the area under consideration no part of the formation is known to be saturated with oil or asphaltum, as are some of the sandstone beds in the underlying formation.

MANCOS SHALE.

General character.—The Mancos shale consists of about 3,000 feet of bluish-drab shale, very sandy near the top and the base. Approximately 1,400 feet of the Mancos is exposed in the area under consideration. About 400 feet above the base occur sandy beds 50 to 100 feet thick, which are known as the Ferron sandstone member. (See below.) The rocks underlying and overlying the Ferron sandstone member are similar in appearance. They contain sandy beds which undoubtedly form the pockets for the gas encountered in the Klondike well and at 350 feet in the Collins well. The greater part of the small amount of gas encountered in the field was struck in the Mancos shale.

Ferron sandstone member.—The portion of the formation distinguished as the Ferron sandstone member contains sand and sandy material and is more resistant than the overlying and underlying rocks, and for that reason it outcrops in a hogback which extends the full length of the field. In the southeastern and eastern parts it is represented by two small hogbacks near each other, which suggests that the sandy material brought in at the time these rocks were laid down was more plentiful than farther west and northwest, where but one hogback is present. This sandy member of the Mancos shale can be definitely correlated with alternating sandstone, shale, and coal

[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field, between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, pp. 12, 14, Pl. III, 1909.

beds in the vicinity and south of Ferron, in Castle Valley, from which the member takes its name. A complete description of the sandstone at its type locality is given in another report in this bulletin.

STRUCTURE.

The structure in general in the western part of the field is that of a gently northeastward-dipping monocline, which, owing to the presence of a comparatively narrow, somewhat broken anticline extending northwest and southeast and lying mainly east and southeast of the area mapped, develops gradually toward the east into a flat syncline. From rather meager data collected in the extreme eastern part of the field it is believed that considerable strike faulting has disturbed the rocks on both sides of the anticline. In the southwestern part of the area mapped there are numerous variations in the general northeast dip of the strata, which are discussed below in detail. A prominent fault zone crosses the field in a northwest-southeast direction. Its direct bearing on the possible presence of an oil reservoir is fully discussed under "Conclusions." Another important fault zone, smaller than the one just mentioned, crosses Green River in the southern part of T. 21 S., R. 16 E., and extends a few miles into the area mapped.

The details of the structure are shown by dip symbols and fault lines on the map which accompanies this report (Pl. VI). The mapping of the outcrops of the formations, together with the hachured line representing the outcrop of the Salt Wash sandstone member of the McElmo formation, furnishes additional aid in interpreting the structure of the rocks.

The dips measured on the Dakota sandstone are characteristic of the overlying Mancos shale and the underlying McElmo formation. Hence a discussion of the structure of this sandstone applies equally well to the adjacent formations near the outcrop of the Dakota. Beginning near the town of Green River, where the dip is about 4°, and following the outcrop to the southeast, the dips increase to as much as 6° in sec. 25, T. 21 S., R. 16 E. This dip is constant for about 2 miles, then drops to 5° just north of the fault in sec. 32, T. 21 S., R. 17 E. South and southeast of the fault, through T. 22 S., Rs. 16, 17, and 18 E., and the northern part of T. 23 S., R. 18 E., the dips range from 4° to 5° NE. The outcrop of the Dakota is obscured by faults southeast of the northern part of sec. 10, T. 23 S., R. 18 E., for about 5 miles. Dips on the Ferron sandstone member of the Mancos shale show that the beds flatten gradually to 2° at the extreme southeast exposure of this sandstone, in the hogback in secs. 1 and 2, T. 24 S., R. 19 E., near the end of the syncline. At this locality the Dakota is again recognizable as the outcrop swings away from the fault and extends to the north and northwest along the east flank of the syncline above referred to. To the north and northwest the dips increase to as much as 9° SW. in sec. 12, T. 23 S., R. 19 E., just north of the State road connecting Thompson and Moab. The stratigraphically lower rocks along the east flank of the syncline dip more steeply than the Dakota.

South of the principal fault zone near the river, in secs. 26, 34, 35, and 36, T. 22 S., R. 16 E., and secs. 1, 2, and 3, T. 23 S., R. 16 E., variations in the dips suggest the presence of a small dome whose center is near the northwest corner of sec. 1. In secs. 7 and 8, T. 23 S., R. 17 E., other variations in structure give indications of a small dome, the center of which is near the east quarter corner of sec. 7. Irregular dips are numerous in secs. 15, 16, 17, 18, 19, 20, and 21 of the same township and indicate that the structure is undulating, with a fairly well defined dome of small extent in secs. 15, 16, 21, and 22. The southeastern part of this dome could not be determined on account of lack of exposures, as drifted sand covers the rocks in the White Wash. The center of the dome is probably in the SW. ¼ sec. 15. Adjacent to the main fault zone in secs. 11 and 12, T. 23 S., R. 18 E., the dips are very irregular and show a very small dome which is due partly to faulting, as the northernmost fault of the principal zone terminates near this place.

The faults are discussed below in order from north to south. As shown on Plate VI a fault extends through secs. 33, 34, 35, and 36, T. 21 S., R. 16 E., and secs. 31, 32, 33, and part of 34 (where it disappears), T. 21 S., R. 17 E., and carries the outcrop of the Mancos shale about 3 miles west of its position north of the fault. Its extent to the west is not definitely known but is probably not greater than to the east of the river. The maximum displacement of this fault, the downthrow of which is on the south side, is about 450 feet. Goin's oil seep, near the north boundary of the NE. ¼ sec. 2, T. 22 S., R. 16 E., and a former spring, now marked by a calcareous deposit, near the northeast corner of the same section are closely related genetically to the disturbed strata adjacent to the fault in that the disturbed rock, being more porous, furnished an outlet to the surface for the oil and calcareous material.

Block faults prevail in the western two-thirds of the field along the main zone of disturbance, whereas a single fault is the result of the earth movement in the eastern part. In sec. 26, T. 22 S., R. 16 E., and sec. 1, T. 23 S., R. 17 E., as many as four faults cut the rocks along Salt Wash in a distance of three-fourths of a mile, but throughout the remainder (and longer part) of that stream only two faults, a little less than half a mile apart, are present. The rocks between the two principal faults have been dropped as much as 500 feet, and the strata on the north side of the zone are about 300 feet higher than the corresponding strata to the south of the disturbed belt. This condition is well illustrated by the stratigraphic section shown on Plate VI. The other downfaulted block, extending through secs. 1 and 2, T. 23 S., R. 17 E., and secs. 3, 4, 5, 6, 8, 9, 10, 11, 14, and 15, T. 23 S., R. 18 E., carries the outcrop of the lower part of the Mancos shale about 3 miles west of its normal position. This block has a maximum displacement of about 400 feet.

Both of the principal down-faulted blocks have a synclinal structure, which is due to the bending up of the strata caused by dragging along the fault planes. This is especially noticeable along Salt Wash, in the western part of the field. Southeast of Tenmile Wash the disturbance has taken place for the most part along a single fault plane, the strata to the north of the fault showing more evidence of the effect of dragging than those to the south, as indicated by dip symbols on Plate VI. At Brink Spring, in sec. 10, T. 24 S., R. 19 E., the displacement is about 1,200 feet, the downthrow being on the north side of the fault. The La Plata sandstone, capped with a few outliers of the McElmo formation, forms the surface rocks south of the fault in this locality. The location of this fault east and southeast of a point about a mile southeast of Brink Spring is only approximate. Although conditions to the southeast were not studied in detail, it is believed that the amount of displacement increases in that direction.

In addition to the larger faults described above, there appears to be in sec. 1, T. 22 S., R. 16 E., about 1 mile southeast of Goin's oil seep, a short minor fault of slight throw.

THEORY OF OIL ACCUMULATION.

Oil operators are desirous of finding anticlines or domes if the rocks are saturated with water ("wet") and synclines or basins if the strata are "dry" or comparatively so. Generally, wherever the rocks contain water and oil disseminated throughout the pores of the mass, there is a tendency for the water, being the heavier, to collect below and thus force the oil to occupy a position above it. If the rocks are thoroughly saturated there will be a general migration of the globules of oil upward through the strata until they reach the surface of the earth or until their progress is stopped by the presence of rocks like clay, shale, and dense sandstone, which are almost impervious to oil. If the porous stratum and the impervious cover are flat lying probably there will be no large accumulations of oil, but if they are inclined slightly the oil will continue to migrate up the rise at or near the base of the impervious stratum until it reaches the upper limit of water saturation or the surface of the earth and escapes in an oil spring or seep. If the structure of the impervious stratum is that of a dome or anticline the oil will collect in the porous rock underlying the impervious cap in the top of the anticline and remain there until it can escape to the surface through natural or artificial openings, such as fault planes or drill holes. If the rocks are "dry" the disseminated oil particles, acted upon only by the force of gravity, tend to migrate downward. If the structure is that of a syncline or basin underlain by an impervious stratum, the oil will collect in the depression.

In the above discussion the simplest condition—that in which the rock containing the oil is a homogeneous sandstone overlain or underlain by a stratum impervious to oil—is assumed. It is believed that where the conditions are more complex, as where the oil is included in a shale or a compact fine-grained sandstone containing lentils of coarser sandy material, and the rocks are fairly well saturated with water, the oil will be forced into the lentils of rock whose pore spaces are larger, owing to the differential capillary attraction of water and oil. The presence of oil-saturated sandstone lentils in the more compact, finer-grained sandstones in the McElmo formation of the Green River field may be explained by this theory.

CONCLUSIONS.

The results obtained from drilling seven wells in this field, as indicated in the following table, have furnished but little encouragement for further exploration.

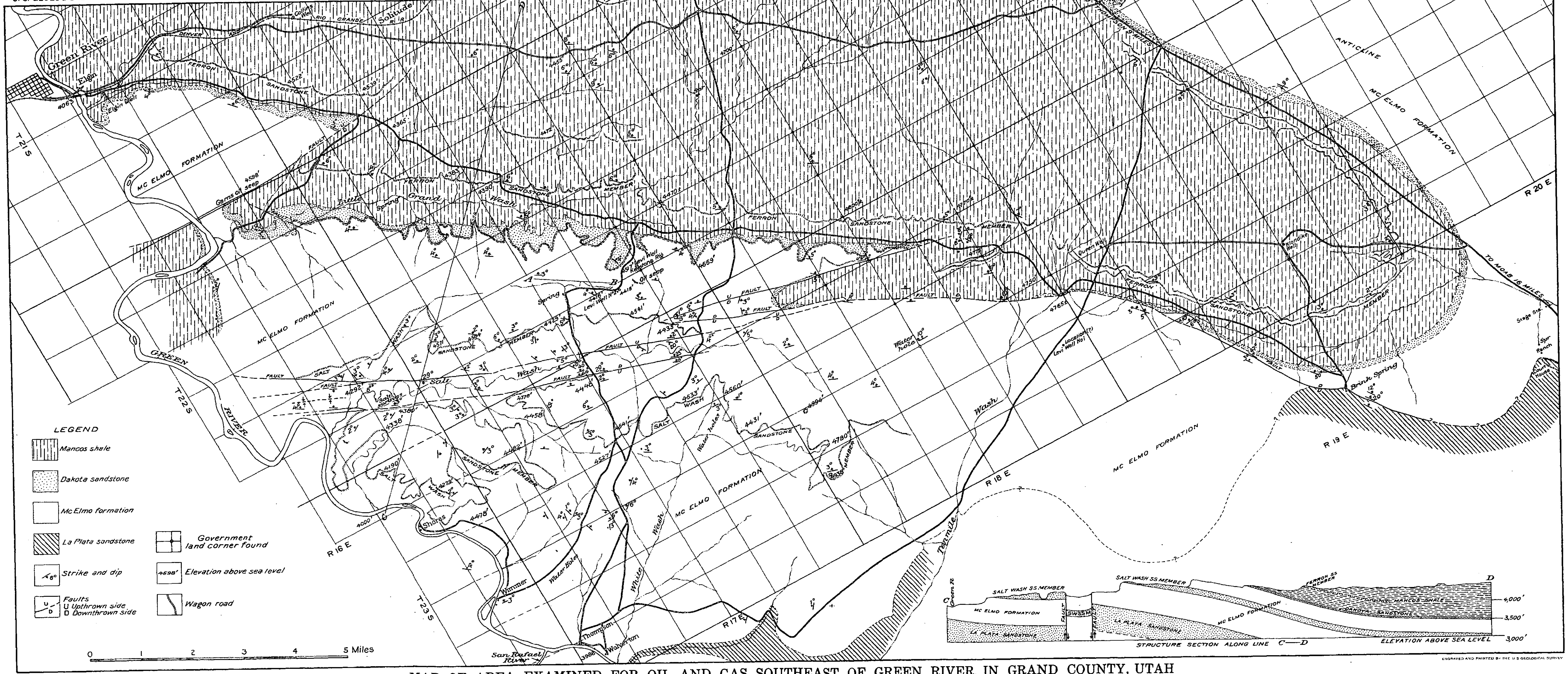
Wells drilled for oil or gas in the Green River field, Utah.

Name of well.	Location.	Depth.	Oil.	Gas.	"Dry."
		Feet.			
Elgin	Sec. 15, T. 21 S., R. 16 E.	1,000			×
Levi No. 1	Sec. 25, T. 23 S., R. 18 E.	530	Trace.	×	
Levi No. 2	Sec. 35, T. 22 S., R. 17 E.	1,500			×
Levi (Keystone)	Sec. 26, T. 22 S., R. 17 E.	425			×
Klondike	Sec. 26, T. 23 S., R. 19 E.	700		×	
Queen	Sec. 18, T. 23 S., R. 19 E.	920	Trace.	×	
Collins	Sec. 20, T. 21 S., R. 17 E.	2,100	Trace.	×	

Three of the wells have proved to be dry holes according to the most reliable reports obtainable, three encountered traces of oil and small quantities of gas, and one struck "pockets" of gas without oil.

Levi well No. 2 and the Collins well, which were drilled to depths of 1,500 and 2,100 feet, respectively, passed entirely through the McElmo formation and penetrated the upper part of the La Plata sandstone, proving conclusively that the McElmo contains no persistent oil-bearing stratum, although it may contain numerous small lenses of sandstone that may be partly or wholly saturated with petroleum. As stated under "History of development of the field," lentils of petroleum-saturated sandstone outcrop, and it is reasonable to assume that there may be others beneath the surface.

The pockets of gas encountered in the wells are for the most part in the Mancos shale, although the Collins well, in sec. 20, T. 21 S., R. 17 E., found pockets of gas in the McElmo formation also.



ENGRAVED AND PRINTED BY THE U S GEOLOGICAL SURVEY

MAP OF AREA EXAMINED FOR OIL AND GAS SOUTHEAST OF GREEN RIVER, IN GRAND COUNTY, UTAH

Structurally the area mapped in detail contains no anticlines or domes of importance in which large quantities of oil or gas could have collected. On the other hand, the eastern part of the field in the vicinity of the Klondike well includes some anticlines, but they are not believed to be especially favorable on account of the presence of probable faults on each side of the upfolds. Additional field work in this locality will definitely determine the character of the structure. The monoclinal character of the greater part of the remainder of the field is not promising, as discussed under "Theory of oil accumulation."

The small domes discussed under "Structure" and situated east of Green River, in Tps. 22 and 23 S., Rs. 16 and 17 E., are in the writer's opinion the most favorable places to drill for oil in this field. The favorable structure, however, does not mean that oil will certainly be encountered at these localities.

Faults and fault zones are usually unfavorable structures for the accumulation of oil or gas, because the rocks adjacent to the breaks in the strata are somewhat crushed and for that reason are rendered more porous, allowing an easy passageway to the surface for the oil, gas, or water that may be seeking an upward outlet. It is believed that the petroleum-saturated condition of the rocks in the vicinity of Goin's seep, situated near the north boundary of sec. 2, T. 22 S., R. 16 E., is due to the fault having cut a lentil of oil-saturated sandstone at some depth beneath the surface. The conditions along the faults and fault zones that cut the strata in the Green River field suggest either that the petroleum-saturated sandstone lentils cut by faults are comparatively few, or that if they are numerous the amount of oil they contain is small, not saturating the rocks at the surface.

From the evidence already obtained by drilling in this field and from the presence of gas in the Mancos shale in other fields, it seems safe to predict that a little gas will probably be encountered in every well drilled in the Mancos shale. It seems equally probable, considering the structure of the field, that gas in large quantities will not be found.

As stated under "History of development of the field," two wells are being drilled 45 to 50 miles southwest of Green River. The structure in this general region, to judge from the meager evidence collected on a reconnaissance trip, seems to be favorable for the accumulation of oil and gas in what appeared to be a broad, flat anticline extending in an east-west direction. It should be reiterated that the presence of favorable structure does not mean that oil or gas will be found in commercial quantities. Favorable structure is a necessary condition but not the only one. The underlying strata must contain oil or gas disseminated through them, or the reservoirs, however ideal they may be, are of no importance.

PETROLEUM NEAR DAYTON, NEW MEXICO.

By G. B. Richardson.

Introduction.—Interest in the possible occurrence of a commercially important quantity of petroleum in the Pecos Valley has been revived by the discovery, near Dayton, N. Mex., of oil in a well drilled for water. This well is reported to have a capacity of about 25 barrels of oil a day. Several companies have been organized, and in March, 1913, three standard rigs were in the field prepared to test

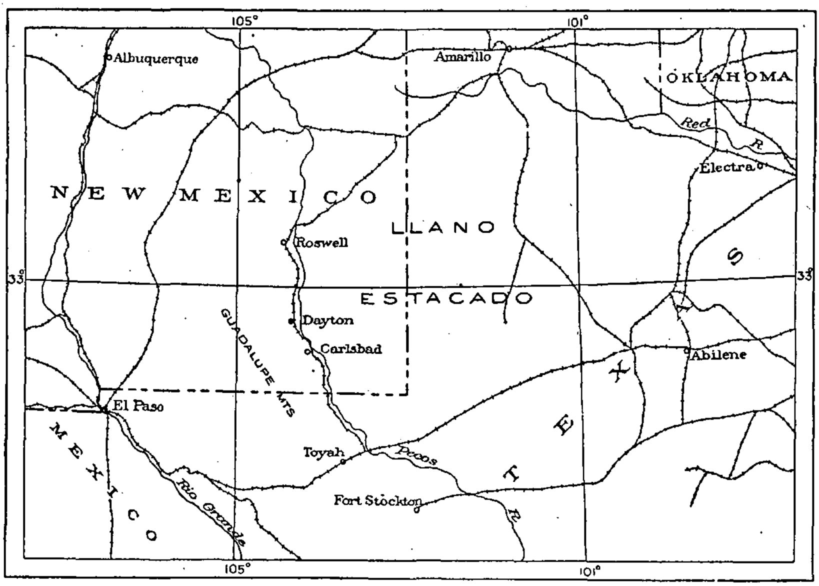


FIGURE 5.—Sketch map showing location of Dayton, N. Mex.

the area in the vicinity of Dayton. Although detailed geologic work has not yet been done in this region, and little is known about the field, the following statement, based on data obtained during a short visit in March, 1913, has been prepared in response to numerous requests for information.

Development.—Several hundred wells have been sunk for water in the Roswell artesian area,[1] in which Dayton is located. These range

[1] Fisher, C. A., Preliminary report on the geology and underground waters of the Roswell artesian area, New Mexico: U. S. Geol. Survey Water-Supply Paper 158, 1906.

from a few hundred to about a thousand feet in depth, and in the vicinity of Artesia and Dayton there are a number of wells which individually flow more than 1,000 gallons a minute. The water is obtained from a porous limestone member of the group of Permian red beds of the Pecos Valley and, as the oil occurs below the water-bearing bed, the casing off of this great flow will be a serious matter, but the first problem is to determine whether or not there is in this locality an important quantity of oil.

Traces of oil and gas have been found in a number of wells in this vicinity, and in 1909–10 local excitement was caused by the discovery of these substances in unusual quantity. Natural gas was struck in the Platt well, in the SW. ¼ sec. 26, T. 18 S., R. 26 E., 1½ miles southeast of Dayton. This well is reported to be 869 feet deep, the flow of water being encountered at 790 feet. Accurate measurement of the quantity of gas produced has not been made, although the pressure is said to have been great enough to break a 300-pound gage. In March, 1913, the gas, after being shut off for some time, was turned on, escaping with a roar and burning with a flame several feet high. Oil was not found in this well.

Another well, the Old Williams, now known as the Belt well, in the NW. ¼ sec. 25, T. 18 S., R. 26 E., 2½ miles east of Dayton, was driven to a depth of 1,002 feet (reported by some to be 1,340 feet) and encountered one flow of water at 783 feet and another at 820 feet. A small quantity of gas and oil flowed from the well with the water and at first was allowed to escape, but recently, by allowing the flow to enter a series of settling tanks and drawing off the water from below and the oil from above, a reported yield of about a barrel of oil a day has been obtained.

The best yield of petroleum yet obtained in the Pecos Valley is from the old Hammond, now known as the Brown well, in the NE. ¼ sec. 15, T. 18 S., R. 26 E., 2¼ miles northeast of Dayton. This well was sunk in 1909 to a depth of 950 feet. A flow of water was encountered at 660 feet, a little gas at 762 feet, and oil between 911 and 926 feet. An attempt was made to case off the flow of water, and in the summer of 1911 a yield, continuing for several months, of 6 to 10 barrels of oil a day was reported. In 1912 this well was acquired by Charles S. Brown, of Artesia, who succeeded in increasing the yield of oil and in cutting off more water, but the attempt to case off the water has been only partly successful. In March, 1913, Mr. Brown stated that he pumped approximately 800 barrels of liquid a day from this well, including about 25 barrels of oil. The oil is separated from the water by a series of settling tanks and is sold for fuel and for smudging orchards.

Not long after oil was found in the Old Hammond well a local association known as the Giant Gas & Oil Co. was organized, and in 1910 it sank a well close by, in the NE. ¼ sec. 15, T. 18 S., R. 26 E. This well is reported to have been put down 1,118 feet without finding either gas or oil. From lack of money the well was not drilled deeper, but as oil had been found between 911 and 926 feet in the adjacent well the test was thought to be fair. Nevertheless continued interest in the possibilities of the Dayton field has been maintained, and recently it was determined to test the area by sinking wells considerably deeper. Two companies were therefore organized, the Pecos Valley Oil & Gas Co., which is drilling a well in the SE. ¼ sec. 15, T. 18 S., R. 26 E., and the Dayton Petroleum Co., in the NW. ¼ sec. 23, T. 18 S., R. 26 E., both sites being between the Brown and Belt wells referred to above. Another test well said to be located in the SE. ¼ sec. 35, T. 19 S., R. 24 E., 12 miles southwest of Dayton, was started by the Seven Rivers Oil & Gas Co., which intended to sink it to a considerable depth, but in the spring of 1913 it was reported to be temporarily stopped at a depth of about 600 feet on account of lack of funds.

Quality of the oil.—Samples of oil from the Brown and Belt wells, collected by the writer in March, 1913, were analyzed by David T. Day with the following results:

Analyses of petroleum from the vicinity of Dayton, N. Mex.

	Belt well.	Brown well.
Color	Brown.	Brown.
Specific gravity	0.8974 at 26° B.	0.9097 at 23.9° B.
Distillation:		
Gasoline	None.	None.
Begins to boil at	170° C.	160° C.
Boiling below 300° C. (kerosene) ... per cent.	33	29
Specific gravity of above fraction	0.7903	0.8041
Residue ... per cent.	65.6	69.3
Specific gravity of residue	0.9223	0.7396
Total ... per cent.	98.6	98.3
Asphalt ... do.	2.0	0.35
Sulphur ... do.	1.0	2.3

These tests show that the oil is similar to that of the Beaumont field in Texas. It is a fuel oil which furnishes little or no gasoline but from which a fair yield of kerosene can be obtained.

Geology.—Although detailed geologic work has not yet been done in southeastern New Mexico, general conditions are known as a result of several reconnaissance surveys.

In this part of New Mexico Pecos River flows in a broad, open valley lying between the Llano Estacado on the east and the Guadalupe and Sacramento mountains on the west. The rocks are sedimentary and the general dip is eastward, decreasing from 5° or 10° in the mountains nearly to horizontality on the plains. The rocks of the mountains consist of at least 10,000 feet of limestone and subordinate sandstone, which are succeeded by the red beds that directly underlie the Pecos Valley. These rocks are of Carboniferous age, the lowermost being Pennsylvanian and the uppermost Permian. East of the river the red beds are overlain by Triassic and Tertiary strata, which for present purposes are unimportant. The bituminous limestones and sandstones which underlie the red beds constitute the probable source of the petroleum.

The greater part of the Pecos Valley is occupied by unconsolidated Quaternary deposits, consisting of gravel, sand, and clay, which are separable into river alluvium and material derived from the disintegration of the rocks of the mountains and transported as wash toward the river. These unconsolidated materials, as indicated by logs of wells, vary in thickness, reaching a maximum of a few hundred feet, and occupy a large area, in places having a width of 25 miles. The bedrock is therefore concealed beneath the valley and details of its character and structure are unknown.

The red beds of the Pecos Valley, which directly underlie the unconsolidated materials and outcrop on the highlands east and west of the river, consist of a complex group of lenticular beds of red sandstone and shale, magnesian limestone, and gypsum. Satisfactory measurements of the thickness of these beds have not been made, although they are locally known to be more than 1,600 feet thick. But the thickness varies greatly because the red beds are not confined between definite horizons, the red color extending irregularly across the strike in accordance with varying conditions of deposition. The red beds of the Pecos Valley, on the evidence of fossil shells and stratigraphic position, are believed to be of Permian age and are correlated with the well-known Permian red beds of north-central Texas and Oklahoma, which outcrop east of the Llano Estacado.

An idea of the composition of the red beds is indicated by the log of the Williams or Belt well, as reported by the driller.

Log of the Williams or Belt well, in the NW. ¼ sec. 25, T. 18 S., R. 26 E.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil	8	8	Concrete	50	750
Gumbo	7	15	Sand, red	8	758
Gravel	10	25	Hard rock	12	770
Gypsum, soft	60	85	Shale	13	783
Sand	65	150	Water rock	7	790
Gypsum	10	160	Shale, red	18	808
Sand, white	47	207	Water rock	12	820
Sand, red	6	213	Hard rock	15	835
Concrete	5	218	Sand, red	8	843
Sand, red	4	222	Sandstone	10	853
Shale, red	6	228	Hard rock	42	895
Gypsum, rock	12	240	Gypsum	5	900
Gumbo	10	250	Black sulphur rock	10	910
Sand, red	45	395	Clay, blue	2	912
Clay, blue	10	405	Sandstone	23	935
Shale, red	15	420	Limestone	11	946
Concrete	90	510	Sandstone, white	32	978
Sand, red	30	540	Hard brown rock	11	989
Hard rock	50	590	Light-brown rock	5	994
Shale	40	630	Sandstone, white	2	996
Water rock	50	680	Dark-brown rock	4	1,000
Clay, blue	20	700	Light-brown rock	2	1,002

Beneath the red beds of the Pecos Valley is a great mass of limestone with interbedded lenses of sandstone, having an estimated thickness of 10,000 feet, which outcrops in the Guadalupe and Sacramento mountains and dips eastward toward Pecos River at a low angle. This limestone in turn is underlain by a lower zone of red beds exposed on the western escarpment of the Sacramento Mountains, 90 miles west of Pecos River. Both the lower red beds and part of the overlying limestone and sandstone are of Pennsylvanian age.

Petroleum.—The petroleum in the vicinity of Dayton occurs at or near the base of the red beds of the Pecos Valley, beneath the water-bearing stratum of porous limestone that furnishes the artesian supply. Presumably the oil originated in the bituminous limestones and sandstones which outcrop in the mountains west of the Pecos Valley and underlie the red beds.

It is of interest that the oil in the Electra field, Texas, east of the Llano Estacado, occurs in a similar stratigraphic position. The significance of this similarity, however, is diminished by the fact that the fossils from the rocks below the Permian red beds of the Pecos Valley are different, according to G. H. Girty, from those occurring in the strata beneath the Permian red beds of north-central Texas, the difference indicating separate basins of deposition. Apparently the occurrence of oil in these two areas east and west of the Llano Estacado is distinct.

It should be noted also that the Dayton oil is quite different from the petroleum of the Electra field, Texas, which is reported by Udden and Phillips as a "high-grade light oil excellently adapted to refinery use."

The recent drilling in the vicinity of Dayton is but one of several attempts to find oil in the Pecos Valley between Roswell, N. Mex., and Fort Stockton, Tex. In this area indications of the presence of petroleum, such as rocks charged with bituminous matter, small oil seeps, and local occurrences of oil in water wells, have long been known. Although the hope of finding petroleum in paying quantity has thus been stimulated, so far experience has been disappointing. Among the prospect wells that have been sunk are some more than 2,000 feet deep in the vicinity of Toyah, Tex., and one almost 3,000 feet deep near Roswell, N. Mex., all of which were failures.

It should be realized that prospecting for oil in Pecos Valley is unusually difficult because of the widespread cover of unconsolidated deposits that conceals the structure of the underlying rocks, which in many fields is a controlling factor in the accumulation of oil. In the Roswell artesian area, however, an important clue to the structure may be obtained from the logs of water wells—in spite of the fact that logs of variable red beds are usually of little value—because apparently the main flow of water comes from a definite horizon. Study of well logs in this area is facilitated by the systematic records that are required by State law. Apparently this clue has not been utilized.

It should also be realized that petroleum is of widespread distribution and that a considerable accumulation is not necessarily implied by anything thus far known in Pecos Valley. As yet there is no basis for a conclusion one way or the other as to whether a commercially important oil pool exists anywhere in Pecos Valley. It is, nevertheless, most desirable that a thorough test be made in the vicinity of Dayton, where more oil has been found than elsewhere in the valley.

RECONNAISSANCE OF THE BARSTOW-KRAMER REGION, CALIFORNIA.

By R. W. Pack.

INTRODUCTION.

PURPOSE OF THE REPORT.

From time to time since 1900 the region between Mohave and Barstow in the Mohave Desert, Cal., has attracted attention as a possible oil field, and a report that valuable light-gravity oil occurs there has been widely circulated. Great stretches of land in the northern part of the desert have been located as oil claims, a considerable number of derricks have been erected, and wells have been drilled at four rather widely separated localities. Indications of oil have been reported in at least two of these wells. In the early part of December, 1912, the writer spent a few days in a reconnaissance of the eastern part of this region in order to obtain a general understanding of its broader geologic features and to determine if possible from such a study whether or not oil might reasonably be expected to occur there in sufficient amounts to be commercially valuable.

CONCLUSIONS.

The main conclusion arrived at as a result of this examination is entirely adverse to the idea that oil occurs in this region. Traces of oil and gas are present in different parts of the world in fine-grained sedimentary beds, and it is possible that similar traces of oil may exist in the fine-grained detrital beds of this region, but the writer believes it highly improbable that oil and gas occur here in greater amounts. The reasons for this conclusion are given in detail at the end of the report.

GEOLOGIC MAPPING.

The geology and structure of this region are far from simple, and although the work was detailed enough to fully warrant the preceding statement regarding the occurrence of oil, it was not sufficient to furnish data for more than a superficial description of the areal geology. On the sketch map (Pl. VII) the areal extent of the several groups of rocks has been shown. The boundaries of these areas have been located by rough compass triangulation and by pacing from section corners wherever such corners could be discovered. In parts of the region, notably along the eastern edge and in the north-central portion, the land lines have recently been resurveyed, and a considerable number of corners were found, but in much of it the geologic boundaries shown are only sketched. This is particularly true of the area between Barstow and the Chicago Oil Co.'s well, where very little effort was made to place accurately the line of contact between the complex of pre-Tertiary rocks and the Tertiary rhyolitic flows and tuffs.

ACKNOWLEDGMENTS.

Mr. R. G. Davies assisted in the examination, and the mapping of the northwestern portion of the region here discussed is largely the result of his work. Messrs. S. L. Gillan and Frank Farmer, mineral inspectors for the General Land Office, made a reconnaissance of this area in May, 1911, and the results of their work have been found most useful in the preparation of the present report.

The writer takes pleasure in acknowledging his indebtedness also to Mr. L. J. Pepperberg, of San Francisco; Messrs. C. E. Kendrick and G. D. Hutchinson, of Barstow; and Messrs. William F. Forsyth and J. P. Jacobs, of the Kramer Consolidated Oil Co., for information and assistance of various kinds.

GENERAL GEOGRAPHIC AND TOPOGRAPHIC FEATURES.

The area here described lies in the central part of the Mohave Desert in San Bernardino County, Cal. Its location is shown in the index map on Plate VII. Two railroads pass through it—the Atchison, Topeka & Santa Fe Railway, with two lines which join at Barstow, one to San Francisco and the other to Los Angeles, and the San Pedro, Los Angeles & Salt Lake Railroad, which, through most of this region runs over the Los Angeles branch of the Santa Fe. The only settlement of any considerable size is Barstow, which has about 800 or 900 inhabitants. It lies approximately 140 miles by rail east of Los Angeles.

The topography is typical of that existing throughout the Great Basin. Much of the region is occupied by broad, practically level stretches of desert sand and gravel, from which irregular barren ridges and hill groups rise rather abruptly to elevations of several hundred feet above the plain. These barren hills rising in the midst of a broad expanse of sand look not unlike islands rising out of the sea. The abruptness with which many of the hills rise from the desert gives the impression that the alluvial basins are deep. This idea is strengthened by the fact that one of the wells drilled here has, as nearly as can be judged from the imperfect record kept, penetrated many hundred feet of loosely consolidated sand and gravel. In the main, however, the thickness of the alluvium and the contour of the basins in which it was deposited can only be left to the imagination.

The granitic and older crystalline rocks weather to rounded somber-colored hills. The younger volcanic and clastic beds, however, are highly colored and present a wonderful array of reds, greens, browns, and blues, which, combined with the peculiar rugged topography characteristic of them, form a striking and in places fantastic landscape.

The region is very poorly watered, the annual rainfall being rarely over 5 inches and commonly less than 3 inches. Wells along the course of Mohave River and near the center of some of the inclosed drainage basins afford a small quantity of water, in places sufficient to irrigate a few acres. Small farms are tilled along the river and at a few places near the dry lakes where water can be obtained in shallow wells, but for the most part the land in this portion of the desert has at present little use other than as a rather poor range. Except for scattered ranches along the river and between Hinkley and Black's ranch the region outside of Barstow and Daggett is practically uninhabited. The vegetation is limited to the common desert types, mainly small shrubs, cacti, bunch grass, and yucca. A group of mesquite near Black's ranch are the only trees outside of the river valley.

The main drainage line is Mohave River, which flows to its sink in the east end of the desert, some 50 miles to the northeast. Much of the region, however, drains into inclosed basins whose centers are occupied in the wet season by shallow lakes, the largest of which, known as Harper Lake, is shown on the map. These lakes or playas are dry during the greater part of the year and their beds form hard pavement-like surfaces swept bare of all dust by the heavy winds that are characteristic of the region, but with a slight rain the playas become impassable bogs.

PREVIOUS KNOWLEDGE OF THE GEOLOGY.

But little has been published about the geology of this region. Most of the written accounts are either descriptions of brief reconnaissance trips, such as that on which the present paper is based, or else detailed descriptions of some very local mineral deposit, mainly the borax near Daggett. The only published account that attempts to give a comprehensive idea of the geology of the area here discussed is that by C. L. Baker entitled "Notes on the later Cenozoic history of the Mohave Desert region in southeastern California."[1] This paper gives also a bibliography of other papers describing the general region.

[1] Univ. California Dept. Geology Bull., vol. 6, No. 15, pp. 34–43, 1911.

GEOLOGY.

MAIN GROUPS OF ROCKS.

The rocks in this part of the Mohave Desert may conveniently be described as belonging to four main groups—(1) a complex association of rocks of pre-Tertiary age composed of more or less altered sedimentary and igneous rocks, (2) volcanic flows and tuffs with interstratified detrital beds, mainly fine sand and clay, of Tertiary age, (3) a basaltic flow of Quaternary age, and (4) Recent deposits of unconsolidated gravel, sand, and clay. The rocks included in the first three groups have been tilted from their original position, closely folded, and faulted, and their present structure is complex. They form the numerous hill groups which rise out of the level sandy plain and evidently also continue under the plain as the floor upon which the flat-lying sand beds were laid down. The Recent unconsolidated materials, which constitute the fourth group, have now practically the same attitude as they had when they were deposited. They not only occupy the centers of the topographic basins but in places extend for considerable distances up the flanks of the rocky hills, where they cap the interarroyo ridges. Besides these practically flat-lying beds of gravel and sand, thick masses of similar materials, having a slightly greater though still a low dip, occur south of the Chicago well and also south of Mohave River between Barstow and Daggett.

PRE-TERTIARY ROCKS.

The pre-Tertiary rocks in this part of the Mohave Desert comprise schist, gneiss, crystalline limestone, and some less altered sedimentary and volcanic rocks, together with granitoid rocks of various kinds, some of which are intrusive into the metamorphic rocks. This complex forms a large number of the rocky hill groups which rise above the desert in this and adjacent regions, and with little question was the basement upon which the Tertiary and Quaternary beds were deposited.

Metamorphic and granitic rocks of this general type are distributed widely over southeastern California and the neighboring parts of Nevada and Arizona. Only a small amount of geologic work has been done on them in the central part of the Mohave Desert, and in consequence little can be said definitely concerning their age. The nearest point to the Barstow-Kramer region at which the age of rocks of this type has been accurately determined is between 60 and 80 miles to the north, in the Funeral and Kingston ranges, where various altered early Paleozoic sedimentary formations rest upon nonfossiliferous rocks that are believed to be pre-Cambrian. The geology of these ranges is described by Gilbert,[1] Campbell,[2] and

[1] Gilbert, G. K., Report on the geology of portions of Nevada, Utah, California, and Arizona: U. S. Geol. and Geog. Surveys W. 100th Mer., vol. 3, pp. 33, 179, 181, 1875.

[2] Campbell, M. R., Reconnaissance of the borax deposits of Death Valley and Mohave Desert: U. S. Geol. Survey Bull. 200, p. 14, 1902.

Spurr.[1] The Randsburg district, which lies 15 or 20 miles northwest of the area shown on the accompanying map (Pl. VII), is described by Hess.[2] The oldest rocks there are granite and schist, the schist probably being the younger of the two, although the relationship is not entirely distinct. The quadrangle also contains a younger series of altered sedimentary rocks which on the evidence of a few poorly preserved fossils is regarded as not younger than Carboniferous. The granite, which according to Hess is probably the oldest rock in the Randsburg region, continues southeastward, forming Fremont Peak and the low hills in the northwest corner of the area shown on Plate VII. The San Bernardino Mountains, which lie 40 or 50 miles south of Barstow, are, according to Mendenhall,[3] formed largely of granitic and dioritic rocks. These rocks are intrusive into metamorphosed sedimentary rocks of unknown age. Hershey[4] briefly describes the complex of gneiss, schist, and old igneous rocks near Barstow, correlating them with the pre-Cambrian rocks of Inyo County, to the north. He also describes limestone and quartzite in the Granite Mountains, 15 or 20 miles south of Barstow, and correlates them with Lower Cambrian rocks in the White Mountains of Inyo County. These correlations by Hershey are based wholly upon the general lithologic similarity and degree of metamorphism of the rocks in the two places and can not be regarded as established.

Granitoid rocks form the greatest part of the surface in the areas shown on the accompanying map as occupied by the pre-Tertiary complex. Some of the granite is younger than the metamorphosed sedimentary rocks and may belong to the same general period of intrusion as the granite in the Sierra Nevada. Part of it, however, particularly that in the northwest corner of the area, which forms the continuation of the granitic rocks in the Randsburg district, may be much older.

TERTIARY ROCKS.

GENERAL CHARACTER AND CORRELATION.

Resting with marked unconformity upon the complex just described are rocks of Tertiary age, which comprise a variety of volcanic flows and tuffs interstratified with sedimentary beds of diverse kinds, from chemically deposited limestone to bowlder beds containing fragments several feet in diameter. Tertiary rocks of this general type are found in many parts of the Mohave Desert, from

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: U. S. Geol. Survey Bull. 208, pp. 187-200, 1903.

[2] Hess, F. L., Gold mining in the Randsburg quadrangle, California: U. S. Geol. Survey Bull. 430, pp. 23-47, 1910.

[3] Mendenhall, W. C., unpublished notes.

[4] Hershey, O. H., Some crystalline rocks of southern California: Am. Geologist, vol. 29, p. 286, 1902.

its western edge eastward far beyond the area described in the present report. About Barstow they form many of the rocky hills which rise above the desert and evidently extend over considerable areas beneath the Recent sand and gravel that constitute the surface of the desert.

The Tertiary rocks in this part of the Mohave Desert have been briefly described by Hershey,[1] who correlates all of them except some beds of reddish sandstone, conglomerate, and tuff exposed near Mohave River between Barstow and Daggett with the "Rosamond series," which he describes as typically exposed in the western part of the desert. The reddish beds mentioned above he believes to be younger than the "Rosamond" and the same as rocks which he terms the "Escondido series," also typically exposed in the western part of the desert. In a later paper the same author published a map[2] on which the distribution of the "Rosamond" and "Escondido" about Barstow are shown.

The name "Mohave beds" was applied by Merriam[3] to the Tertiary rocks which contain mammalian remains in the Barstow syncline. He says:

> According to a sketch map published by Hershey the point at which the collection was made would fall within the limits of what is designated by Hershey as the Rosamond series. This series has not, however, been characterized in any way, so that the nature of the formation is unknown. As geographic location is one of the important factors concerned, the horizon at which this collection was obtained may be referred to under a geographic designation as the Mohave beds.

Baker[4] in describing the Tertiary rocks about Barstow restricted the term "Rosamond" to the part of the section that is composed predominantly of sedimentary rocks, offering evidence that these rocks rest unconformably upon older volcanic rocks which Hershey included in the "Rosamond."

Tertiary rocks like those in the Barstow-Kramer region occur in Red Rock Canyon, about 60 miles northwest of Barstow. These rocks were described by Fairbanks,[5] who found in them a few fossil leaves that Knowlton determined as of Tertiary and probably of Eocene age. These beds were described as the "Mojave formation" and correlated with the Eocene by Smith,[6] who based his correlation entirely on Fairbanks's description. The Tertiary rocks in and

[1] Hershey, O. H., Some Tertiary formations of southern California: Am. Geologist, vol. 29, pp. 367, 368, 1902.

[2] Hershey, O. H., The Quaternary of southern California: Univ. California Dept. Geology Bull., vol. 3, No. 1, Pl. I, 1902.

[3] Merriam, J. C., A collection of mammalian remains from Tertiary beds in the Mohave Desert: Univ. California Dept. Geology Bull., vol. 6, pp. 167, 168, 1911.

[4] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: Univ. California Dept. Geology Bull., vol. 6, pp. 333-383, 1911.

[5] Fairbanks, H. W., Notes on the geology of eastern California: Am. Geologist, vol. 17, pp. 67, 68, 1896.

[6] Smith, J. H., The Eocene of North America west of the 100th meridian: Jour. Geology, vol. 8, p. 455, 456, 1900.

about Red Rock Canyon were later described by Baker,[1] who correlated them as a whole with the "Rosamond series," on the evidence of mammalian remains which he collected and which Merriam determined as of upper Miocene age.

The field work that forms the basis of the present report was too meager to admit of any definite correlation of the rocks about Barstow with the "Rosamond series," and it was impossible to work out the sequence of the various effusive rocks and their relation to the sedimentary rocks. The Tertiary rocks have in consequence been shown as a unit on the map. An attempt will be made, however, to indicate the general character of the rocks in the different areas and to describe the lithology of the sedimentary beds.

LITHOLOGY.

The sedimentary beds are best exposed in the Barstow syncline, where they have a thickness of not less than 3,000 feet and probably considerably more, but on account of the numerous faults which have in part duplicated the section it is impossible to give an accurate estimate of the thickness. The beds vary greatly in character, both vertically and along the strike, and it is difficult to group them into any definite formations which may be followed consistently. They may, however, be divided roughly into three parts. The lowest of these divisions has a thickness of not less than 1,200 feet and is composed largely of coarse to fine grained tuff, volcanic ash, various thin lava flows, and especially, near the base, a few beds of coarse granitic bowlders and brownish sandstone. This division weathers to ragged, irregular hills and shows a remarkable variety of bright colors ranging from green, blue, or almost purple to various shades of yellow, brown, and red.

The middle division is composed mainly of slightly greenish gray clay, with thin beds of brownish arkose sandstone, numerous layers of white calcareous clay and somewhat impure limestone, beds of white ash, and, toward the base, beds of coarse granitic fragments. It has a thickness of not less than 1,500 feet. The greenish clay which forms the bulk of the division is in places thin bedded, but in other places it forms masses 20 or 30 feet thick without trace of stratification and the intermittent streams have intrenched themselves in it, leaving almost vertical cliffs 50 or 60 feet high. The coarse beds near the base are formed almost wholly of unsorted granitic fragments, the largest 3 or 4 feet in diameter. They are embedded in an arkose matrix, in places firmly cemented, and to casual observation look like granite in place. The calcareous beds

[1] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: Univ. California Dept. Geology Bull., vol. 6, pp. 354-357, 1911; Physiography and structure of the western El Paso Range and the southern Sierra Nevada: Idem, vol. 7, pp. 123-134, 1912.

are of two types. The most numerous are layers of calcareous clay whose composition is in general like that of the greenish clay with which they are stratified, but owing to their lime content they weather almost pure white. They are more resistant than the clay, and the consequent unequal erosion results in the formation of fantastic badlands. Besides the calcareous clay there are numerous beds of yellowish to dark brown limestone which vary in thickness, the maximum being about 10 feet. Many of the calcareous beds emit a peculiar fetid odor when struck. This odor, which is not unlike that of petroleum, has been considered by many persons as an indication of oil. A sample of the fetid limestone was examined by D. T. Day, of the United States Geological Survey, who reported that no trace of liquid hydrocarbons could be extracted from it by various solvents. After treatment with sulphuric acid he detected a trace of resin, but this was too small in amount to account for the odor. The limestone contains a considerable amount of sulphur and the odor is probably due largely to hydrogen sulphide.

Locally the remains of fresh-water mollusks and somewhat more rarely fossil bones similar to those occurring in the overlying division were found in the beds in the upper part of this division. In contrast to both the overlying and underlying divisions this division is well bedded, and the writer believes that it was deposited in water.

The uppermost division is formed of poorly consolidated beds of coarse angular rock fragments, fine gray ashy sand, and clay. The materials are much more poorly stratified than those of the preceding division and resemble slightly the Recent flat-lying gravel and sand. The beds in this division form rounded buff-colored hills, in marked contrast to the badland of the middle division and the multicolored hills of the lower division. Fossil bones occur abundantly in this division, especially in the finer-grained beds.

Baker[1] has grouped the Tertiary rocks exposed in the Barstow syncline into five members. Although these members may be recognized in the central part of the syncline, the writer found that they could not be followed consistently and rather doubts the advisability of attempting to divide the section so minutely. The divisions are, beginning with the base, "(1) basal breccia, (2) tuff-breccia, (3) fine ashy and shaly tuff, (4) resistant breccia, (5) fossiliferous tuff." The first two of these members correspond roughly with what is described in the present paper as the lowest division, the third and fourth members with the middle division, and the fossiliferous tuff with the uppermost division.

West of Black Mountain the oldest Tertiary rocks appearing along the axis of the small anticline are clay shale, fine sand, and ash

[1] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: Univ. California Dept. Geology Bull., vol. 6, pp. 342-347, 1911.

similar to those forming the middle division in the Barstow syncline. Layers of fetid limestone are abundant and on that account this part of the region has been considered as the most favorable locality for prospecting for oil. Several thin beds of basic lava, usually less than 6 feet thick, are bedded with the clay, and a somewhat thicker though lenticular bed occurs near the contact with the overlying buff-colored gravel. This bed of basalt forms the hill immediately north of the Giroux well. Overlying the clay and occupying most of the area mapped as Tertiary to the northwest are buff-colored gravel and ashy sand much like the upper division in the Barstow syncline.

A belt of outcrop from a quarter to half a mile in width, formed mainly of friable sandstone and clay, trends east and west along the south flank of the Calico Mountains, passing approximately through the old town of Calico. These beds rest upon the rhyolitic tuffs and lava flows which form the main mass of the Calico Mountains on the north and are separated from the desert on the south by volcanic rocks which Lindgren[1] believed to be younger. Isolated patches of sandstone and limestone occur also high on the slope of the Calico Mountains, in the south half of T. 11 N., R. 1 E.

The central part of the area of Tertiary rocks on the north side of Mohave River between Barstow and Daggett is formed of fine-grained clayey sand, calcareous clay, and limestone interstratified with numerous thin beds of volcanic rock. Fetid limestones are exceptionally abundant. The northwestern edge of this area is composed of tuffs and solid lavas, which weather out prominently and form rugged hills in sec. 25, T. 10 N., R. 1 W. A dark rocky ridge trending approximately north and south and meeting the river a mile or two west of Daggett is also composed predominantly of tuff and volcanic flows.

The Tertiary rocks near the old Alpha and Omega mines, about 4 miles north of Barstow, and also those between that place and Black's ranch consist almost wholly of tuff and lava, although with these are intercalated beds of coarse detrital material 10 or 12 feet thick.

The Tertiary rocks on both the north and the south sides of Mohave River at Barstow are wholly rhyolitic flows, but calcareous clay and limestone form two small hills about three-quarters of a mile to the north.

AGE.

Remains of several extinct species of horses, camels, and other mammals occur abundantly in the Barstow syncline in the uppermost division of the Tertiary beds. These fossils have been studied

[1] Lindgren, Waldemar, The silver mines of Calico, Cal.: Am. Inst. Min. Eng. Trans., vol. 15, p. 719, 1887.

by Merriam,[1] who believes them to be of upper Miocene age and similar to mammalian remains found in other parts of the Great Basin.

QUATERNARY ROCKS.

BASALT.

The blanket of basalt which covers Black Mountain rests with marked unconformity upon the uptilted Tertiary rocks and is probably of Quaternary age. The flow is not thick, averaging over much of the hill less than 50 feet, but the numerous faults traversing it in places exaggerate the thickness. The diagrammatic section given by Baker [2] is rather misleading, for the surface of the south flank of the mountain is not formed by an unbroken tilted sheet of basalt. Numerous normal faults traverse the basalt and the south flank of the mountain is really a succession of small fault blocks. The basalt varies from a massive fine-grained porphyritic black rock to vesicular or even scoriaceous material. Massive fine-grained material is probably the most abundant.

RECENT SAND AND GRAVEL.

All the topographic basins in this region are filled with masses of gravel, sand, and clay which have been laid down since the uptilting of the Miocene rocks and largely, perhaps wholly, since the outpouring of the lava that now caps Black Mountain. These materials were probably deposited under much the same condition as those now existing in the desert, the coarser material being carried in by running water, the finer material, perhaps largely wind carried, forming drifts in sheltered places or settling in the shallow lakes that intermittently occupy the playas. The thickness of these masses of material is not known. The well of the Chicago Oil Co. and also that of the Kramer Consolidated Oil Co. were drilled in the center of broad alluvial flats. Both these wells penetrated several hundred feet of material, which, as nearly as may be judged from the record kept, is probably part of the Recent alluvial desert filling. Besides the flat-lying gravel in the topographic basins, a thin veneer of similar material caps the interarroyo ridges in the low foothills. This material evidently records an epoch when the country was lower and the hill groups even smaller than at present.

Thick masses of sand and gravel like that in the present desert flats form low rolling hills south of Barstow and a mile or so south of the Chicago well. These beds have about the same degree of indura-

[1] Merriam, J. C., A collection of mammalian remains from Tertiary beds on the Mohave Desert: Univ. California Dept. Geology Bull., vol. 6, pp. 167–169, 1911.

[2] Baker, C. L., Notes on the later Cenozoic history of the Mohave Desert region in southeastern California: Univ. California Dept. Geology Bull., vol. 6, p. 348, 1911.

tion as the Recent alluvium, but unlike it they dip at slight angles, their attitude probably being due to tilting and not to inclined deposition.

STRUCTURE.

The structure about Barstow is irregular and complicated. For the most part the rocks are broken by innumerable faults and the stratified Tertiary rocks are tilted at irregular angles. In places the beds are bent into folds, the largest of which is the Barstow syncline, but most of these folds are small, irregular, and discontinuous and are a minor feature of the structure.

WELLS DRILLED FOR OIL.

Although this region has attracted considerable attention for the last 12 years, only four wells have been drilled to any considerable depth. These are the Kramer Consolidated Oil Co.'s well, in the NW. ¼ sec. 11, T. 10 N., R. 5 W.; the Chicago Oil Co.'s well, in the SW. ¼ sec. 35, T. 11 N., R. 1 W.; the Giroux well, in the SE. ¼ sec. 17, T. 32 S., R. 44 E.; and the Mojave Oil Co.'s well, in the SE. ¼ sec. 14, T. 11 N., R. 12 W.

The well of the Kramer Consolidated Oil Co. is located about 3 miles north of Hawes, a station on the Santa Fe Railway, in the midst of a broad expanse of desert, the nearest outcrops of rock in place being the granite in the hills some 5 miles to the northwest. Drilling has been carried on here at irregular intervals for the last 12 years, and the well is said to have been drilled to a depth of almost 3,000 feet. It is asserted that a little oil was obtained in the well, and small samples of light-gravity oil and of paraffin wax were seen at the Los Angeles office of the company. At the time of the writer's visit to the well the lower part of the hole had been lost and no evidence corroborating the reported discovery of oil was obtained.

The abandoned Giroux well is located about a mile west of Black Canyon, at the foot and on the south side of a small hill determined by a bed of basalt which is interstratified with the fine-grained Tertiary clay. According to Mr. C. E. Kendrick, this well was started in 1902 and drilled to a depth of 440 feet. It is said that a trace of oil was obtained in the well at a depth between 300 and 400 feet. The basalt forming the hill on the north dips 70°–80° S., and the well was probably drilled into it.

The well of the Chicago Oil Co. is located in the desert on the west side of the Calico Mountains, about a mile from the nearest hills in which the Tertiary or older rocks are exposed. In December, 1912, it had reached a depth of more than 2,000 feet and drilling was still being carried on. "Showings" of oil are reported in the well.

The well of the Mojave Oil Co. is located about 2½ miles southeast of Mohave. It was started in 1907 and has been drilled to a depth of a little more than 1,100 feet. "Showings" of oil are reported, but no greater quantity was found and the well is now abandoned.

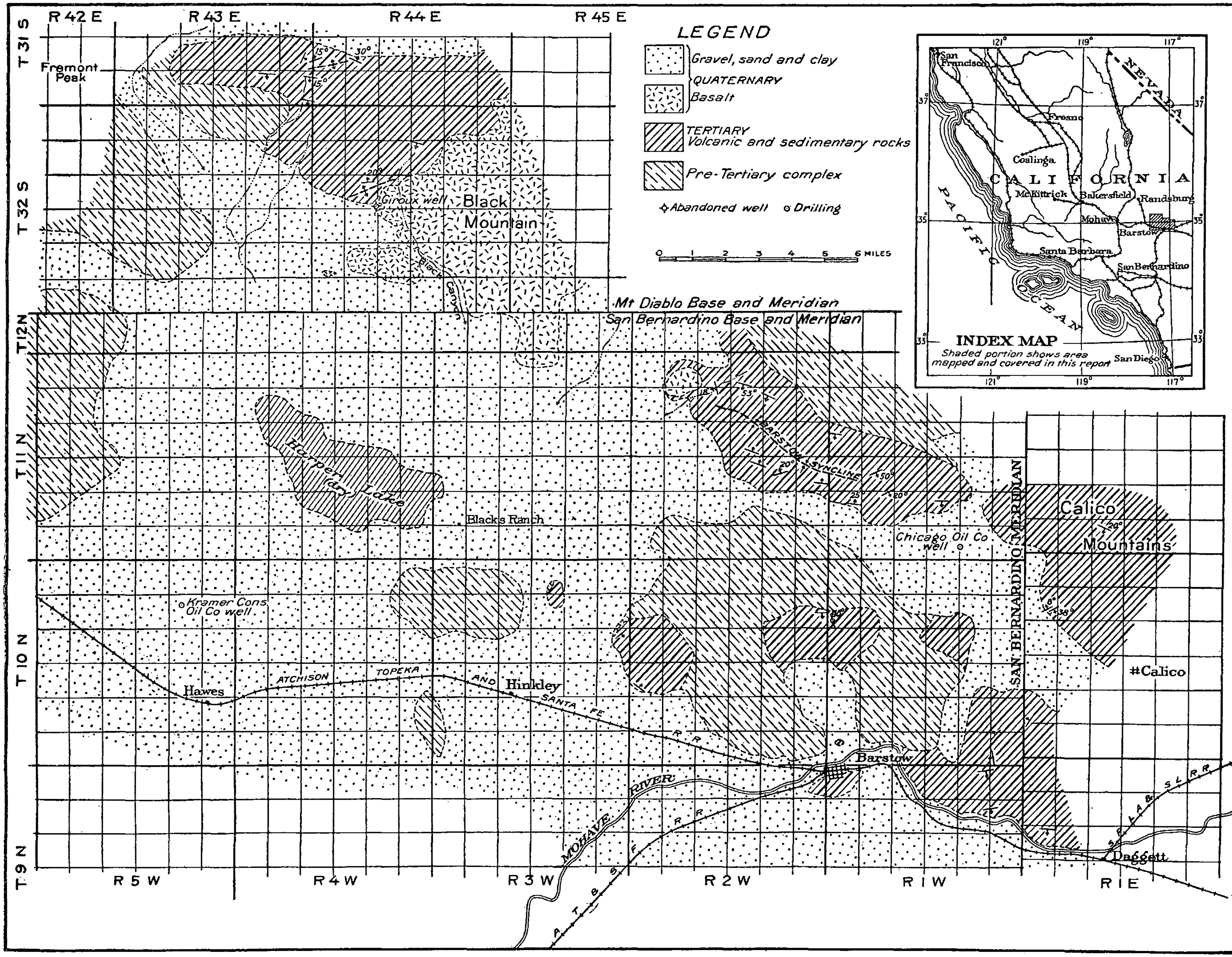
CONCLUSIONS AS TO THE PRESENCE OF PETROLEUM.

The writer believes that the northern part of the Mohave Desert between Barstow and the town of Mohave offers practically no promise of becoming a productive oil field, and that further drilling will prove but a waste of money. The principal reasons for believing that this land will not prove productive are (1) the lack of strata from which it would seem reasonable to believe that oil might have been formed, especially the lack of thick masses of organic material (diatomaceous and foraminiferal shale) such as those which occur in or near all the oil fields in the southern half of California and in which the oil is believed to have originated; (2) the lack of structural features favorable for the collection of petroleum even if it existed disseminated through the strata.

The pre-Tertiary rocks can not reasonably be regarded as a source of petroleum. Only a small portion of these rocks are of sedimentary origin, and they are so metamorphosed that even had oil once existed in them it is hardly conceivable that they should still contain it. The granitic rocks in the complex are if possible an even less likely source of petroleum, as their texture is so dense that they would offer practically no reservoir in which oil might collect if it existed in the near-by rocks. Oil has been found in rocks lithologically similar to some of the pre-Tertiary rocks of the Mohave Desert at only a single locality in California. This occurrence, at Placerita Canyon, about 20 miles north of Los Angeles, has been described by Eldridge.[1] The oil at this place occurs in fractured schists which rest upon the granite of the San Gabriel Mountains. The most logical explanation for the presence of the oil here is that it has migrated from early Tertiary organic shales which may have at one time rested upon the metamorphic rocks and which may now occur in the vicinity beneath the unconformably overlying late Tertiary beds. In the Santa Clara River valley, a few miles west of Placerita Canyon, the early Tertiary strata and the beds in contact with them are filled with oil. As organic materials similar to those in the Santa Clara River valley are unknown in the Barstow-Kramer region, it can not be expected that a similar accumulation of oil will be found in the metamorphic rocks in this region.

The Recent coarse gravel, sand, and clay which form the filling in the topographic basins and which in places extend as a veneer over

[1] Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U. S. Geol. Survey Bull. 309, pp. 100–101, 1907.



RECONNAISSANCE MAP OF THE BARSTOW-KRAMER REGION, SAN BERNARDINO COUNTY, CAL.

By R. W. Pack.

the lower hills are equally as unlikely a source of petroleum as the pre-Tertiary complex. They are composed almost or quite completely of fragments derived from the older rocks in this or in adjacent regions, and it is not reasonable to believe that these masses of rock fragments would be more likely to produce petroleum than the same rocks in place. The Tertiary volcanic rocks are likewise not to be considered as a source of petroleum, for much the same reasons as apply to the granitic rocks in the pre-Tertiary complex.

It remains then but to consider the Tertiary sedimentary rocks. The coarse-grained Tertiary beds are formed of fragments of various types of granitic, volcanic, and metamorphic rocks and are evidently no more probable a source of petroleum than are the Recent beds of sand and gravel. On the other hand, to casual observation the fine-grained Tertiary rocks of the Barstow-Kramer region appear to be similar to the Tertiary rocks in many of the oil fields of this State, and it is not so very surprising that in this region they have been regarded as a possible source of oil. A careful examination of them shows, however, that they are really very different from the Tertiary shales in the productive oil fields, and in place of being composed very largely of the remains of organisms they are formed almost wholly either of fine volcanic ash or of detrital material derived from rocks of various types. They thus resemble the coarse-grained beds in the same region, differing from those beds mainly in the size of the particles they contain, and are not to be compared with the masses of organic material in the large productive oil fields of California. The only indications of organic matter seen in these beds were small particles of carbonized terrestrial vegetation scattered through some of the clayey and finer sandy beds, but the total amount of organic matter is entirely too small to be considered as a possible source of more than the merest traces of oil.

It is, of course, possible that in the broad, level desert areas rocks of different types from any exposed in the hills may lie buried beneath the desert gravel. It is also possible that such rocks, if they occur, are like those in the Tertiary formations in the San Joaquin Valley on the opposite side of the Tehachapi Mountains. There is, however, nothing in the geology of this region, or, so far as known, in that of the desert as a whole, to support such a hypothesis.

No surface indication of petroleum was seen anywhere in the region. It is commonly rumored that a seep occurs in the Tertiary rocks northwest of Black Mountain, but a careful search failed to reveal it nor did persistent questioning discover anyone who could describe its location. The structure of the Tertiary rocks is complex. In many places they are tilted to high angles and intricately faulted, and if oil occurs in them it is surprising that it does not at some place show at the surface.

Even if oil was originally distributed in minute quantities through the rocks, the structure is not such that it would have tended to collect or trap the oil. Irregular and faulted folds occur in at least three places northwest of Barstow—the Barstow syncline in T. 11 N., R. 2 W., a small anticline just north of the Giroux well in T. 32 S., R. 44 E., and an irregular fold or folds in T. 31 S., R. 44 E. It is generally reported that a well-marked anticline passes through the hills north of Barstow. Indeed, it is believed by some that such a fold extends along the north side of the desert from Tehachapi Pass nearly to Barstow. This idea is erroneous, for the only folds here are small, discontinuous, and much faulted. Faults, not folds, dominate the structure. Thus the structure is much more favorable for the escape of any oil that might possibly have been found here than it is for its concentration in appreciable quantities.

COAL AND LIGNITE.

RHODE ISLAND ANTHRACITE.[1]

By George H. Ashley.

INTRODUCTION.

Rhode Island anthracite has long been a puzzle to mining men and capitalists. Is it a fuel or is its best use for making refractory linings for blast furnaces? This paper has been prepared after a study of the Rhode Island anthracite field and summarizes the location, character, and qualities of the coal, the results of tests of its use in house and steam furnaces, in the making of briquets and coke, and describes the results of attempts to utilize it after conversion into water gas or producer gas. The conclusions will be of special interest to those who may be considering investments in mines in this field.

The coal has been known in Rhode Island for 150 years or more and during the last 100 years scores of attempts have been made to mine it commercially in many places. With one exception these attempts have not had marked success and most of the mines have been abandoned within three years. The one company which attained a measure of success mined the anthracite for over 20 years and used it in the smelting of copper ores. The location of the anthracite on tidewater and near the large manufacturing establishments of New England has seemed to give it an advantage over other coals for use in that area and this apparent advantage has led to the repeated attempts to utilize it. Unfortunately many of these attempts at exploitation appear to have been merely excuses for the organization of corporations for the sole purpose of the sale of stock.

In response to numerous inquiries for information in regard to Rhode Island coal and its value, the writer visited the field in October, 1913, and has prepared a bulletin bringing together in detail all the data available bearing on the past utilization of the coal, its chemical

[1] Although the work described in this paper was done in 1913, on account of the unavoidable delay in the publication of the volume for that year this paper has been included in the volume for 1912.

composition, results of tests under steam boilers and in house-heating furnaces, in the making of briquets, and in the manufacture of producer gas. The bulletin, which will give all the data, together with a discussion of their meaning, will require several months for completion and publication, so that this preliminary statement is made to meet immediate demands and inquiries.

LOCATION OF THE COAL FIELD.

The location of the Rhode Island coal field and the places at which the coal has been mined are shown by the sketch map (Pl. VIII, p. 162). The field occupies a structural basin whose axis extends from Newport northward up Narragansett Bay to a point west of Warren, thence northeastward into Massachusetts, past Taunton and Bridgewater to Hanover Four Corners, within 6 miles of Massachusetts Bay. It underlies practically the whole of Narragansett Bay. The west boundary lies several miles west of the bay and extends north to the west of Providence, Pawtucket, and Diamond Hill, then turns eastward and passes north of Mansfield and Brockton. The eastern boundary lies east of Sakonnet and Taunton rivers, then swings eastward to include an area about Middleboro. The locations of anthracite mines and prospects are shown on the map. Recent work has been confined to three places—Portsmouth, Cranston, and Fenners Ledge.

THE ROCKS OF THE AREA.

The rocks of this basin consist of shale, slate, sandstone, and conglomerate and have a total estimated thickness in the center of the basin of more than 10,000 feet. The anthracite beds are as a rule associated with shale interbedded with sandstone. In parts of the field the rocks are considerably metamorphosed, shale being changed to slate and sandstone to quartzite, and in places the conglomerate pebbles have been distorted by pressure.

This field is not a regular simple basin, but contains basins, or synclines, and anticlines within its limits. In parts of the field the rocks have been closely folded and faulted.

THE ANTHRACITE BEDS.

In the great thickness of shale and sandstone there are many layers of carbonaceous shale and locally beds of anthracite. Little is yet known of the extent of these beds. At Portsmouth a single bed has been followed on the surface and underground for several thousand feet, and near Providence a carbonaceous belt, containing 10 or more beds of anthracite or graphite, has been traced with interruptions from the vicinity of the boys' school at Sockanosset northward, west of Providence and Pawtucket, to a point beyond Valley Falls. Whether or not any single bed has such an extent is not known.

The thickness of individual beds can only be assumed by averaging a large number of measurements. Such measurements may show from a few inches to 20 feet, but it is evident that where the anthracite is thicker it has become so by being squeezed in from adjacent areas in which it is thin. From measurements where the anthracite has been most extensively mined the original thickness of the beds seems to have been small, probably not over 2 or 3 feet, and most of the beds appear to have been much thinner. Wider knowledge will possibly reveal thicker average anthracite than now appears, although the opposite is anticipated. Layers of coaly shale of much greater thickness are found.

The coal beds have been folded with the other rocks, so that the anthracite generally pitches downward at steep angles or in places stands vertical, but as it is softer and less resistant than the other rocks it has not only been folded, but has yielded to the pressure which folded the other rocks and has been squeezed out from points of greatest pressure and accumulated at points of less pressure as plastic clay may be squeezed through the fingers. This squeezing gives rise to irregular lenses, many of them 20 feet thick, the average thickness in the Portsmouth mine being between 4 and 5 feet. These lenses are separated by wide areas of thin anthracite, where the bed may be only a few inches thick or may be pinched out entirely.

THE ANTHRACITE.

PHYSICAL CHARACTER.

The coal is a graphitic anthracite, high in ash and moisture, which has been changed locally to graphite that contains a high percentage of ash. Structurally it has been much changed by the pressure. At Portsmouth it breaks down into rhombs of all sizes. At Cranston and Fenners Ledge the pressure appears to have squeezed it into flakes with smooth faces that feel greasy and are apparently coated with graphite. The anthracite ranges in color from steel-gray to dull black, commonly having a bluish cast, so that much of it has little resemblance to the well-known forms of coal. The faces of the coal that have apparently been rubbed in the squeezing are here and there covered with a thin film of quartz, which in many places even attains a thickness of an inch or more. The anthracite is very heavy, its specific gravity being 1.65 to 2.45 as against 1.43 for Pennsylvania anthracite and 1.30 to 1.35 for the better known semi-bituminous and bituminous coals. It has generally been considered that coals of such high specific gravities can not be used for fuel.

CHEMICAL COMPOSITION.

Analysis of the anthracite shows it to contain from 42 to 78 per cent of fixed carbon, from 2.3 to 4 per cent of volatile matter, from 13 to 33 per cent of ash, from 4.5 to 23 per cent of moisture, and from 0.03 to 1.34 per cent of sulphur. The calorific value ranges from 6,000 to 11,000 British thermal units, and averages about 9,000.

The accompanying table gives the analyses of a number of mine samples, properly sampled and analyzed by the Bureau of Mines.

Analyses of coal samples from the Rhode Island anthracite coal field.

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

Newport County.

Laboratory No.		Air-drying loss.	Form of analysis.[b]	Proximate.				Ultimate.					Heating value.	
				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
9328	Portsmouth, Portsmouth mine at Marshalls Landing.	14.0	A	16.8	2.3	64.4	16.47	0.59	2.12	62.63	0.27	17.92	5,130	9,230
			B	3.3	2.7	74.9	19.15	.69	.65	72.82	.31	6.38	5,965	10,730
			C	......	2.8	77.4	19.80	.71	.30	75.27	.32	3.60	6,165	11,090
			D	......	3.4	96.6	......	.89	.37	93.85	.41	4.48	7,685	13,830
9329	.....do..........	9.6	A	13.2	2.6	65.3	18.88	.30	1.88	64.23	.22	14.49	5,175	9,310
			B	4.1	2.8	72.2	20.89	.33	.90	71.05	.24	6.59	5,725	10,300
			C	......	2.9	75.3	21.77	.35	.47	74.05	.25	3.11	5,965	10,740
			D	......	3.8	96.2	......	.45	.60	94.66	.32	3.97	7,625	13,720
9330	.....do..........	23.1	A	23.7	3.0	42.5	30.77	.03	3.15	42.36	.10	23.59	3,320	5,980
			B	.8	3.9	55.3	40.01	.04	.75	55.09	.13	3.98	4,315	7,770
			C	......	3.9	55.8	40.32	.04	.68	55.50	.13	3.33	4,350	7,830
			D	......	6.6	93.4	......	.05	1.14	93.00	.22	5.59	7,290	13,120
9331	.....do.........	21.10	A	22.9	2.8	58.4	15.93	.10	2.84	58.46	.18	22.49	4,740	8,530
			B	2.4	3.5	73.9	20.17	.13	.65	74.00	.23	4.82	6,000	10,800
			C	......	3.6	75.7	20.67	.13	.38	75.85	.23	2.74	6,145	11,060
			D	......	4.6	95.4	......	.16	.48	95.62	.29	3.45	7,750	13,950
9335	.....do..........	14.8	A	15.9	2.5	49.8	31.76	.12	2.39	47.88	.18	17.67	4,055	7,300
			B	1.2	3.0	58.5	37.28	.14	.88	56.20	.21	5.29	4,760	8,570
			C	......	3.0	59.3	37.74	.14	.75	56.90	.21	4.26	4,820	8,680
			D	......	5.0	95.0	......	.22	1.20	91.39	.33	6.86	7,740	13,930
9336	.....do..........	15.5	A	16.5	3.5	46.1	33.89	.15	2.11	45.54	.10	18.21	3,635	6,540
			B	1.2	4.0	54.7	40.11	.18	.46	53.89	.12	5.24	4,300	7,740
			C	......	4.0	55.4	40.61	.18	.32	54.57	.12	4.20	4,355	7,840
			D	......	7.0	93.0	......	.30	.54	91.88	.20	7.08	7,335	13,200
9337	.....do..........	13.8	A	14.1	4.0	61.9	19.96	.09	1.93	62.53	.08	15.41	4,945	8,900
			B	.3	4.5	72.0	23.15	.10	.46	72.54	.09	3.66	5,735	10,320
			C	......	4.5	72.3	23.23	.10	.43	72.78	.09	3.37	5,755	10,360
			D	......	6.0	94.0	......	.13	.56	94.80	.12	4.39	7,495	13,490
9338	.....do..........	11.4	A	13.9	2.5	63.2	20.40	1.34	1.84	62.09	.19	14.14	5,025	9,040
			B	2.8	2.5	71.7	23.02	1.51	.64	70.08	.22	4.53	5,670	10,210
			C	......	2.5	73.8	23.70	1.56	.33	72.13	.22	2.06	5,835	10,510
			D	......	3.5	96.5	......	2.04	.43	94.53	.29	2.71	7,650	13,770

[a] Bureau of Mines Bull. 22, pt. 1, pp. 184-185.

[b] A, Coal as received; B, air-dried coal; C, moisture-free coal; D, coal free from moisture and ash.

Analyses of coal samples from the Rhode Island anthracite coal field—Continued.

Providence County.

Laboratory No.		Air-drying loss.	Form of analysis.[a]	Proximate.				Ultimate.					Heating value.	
				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
7769	Cranston, Cranston mine near Providence.	9.1	A	9.7	2.6	62.0	25.7	0.07	......	......	......	......	4,900	8,820
			B	.7	2.8	68.2	28.3	.08	......	......	......	......	5,390	9,700
			C	......	2.9	68.6	28.5	.08	......	......	......	......	5,430	9,770
			D	......	4.0	96.0	......	.11	......	......	......	......	7,590	13,660
7770	.....do..........	4.0	A	4.5	3.4	59.7	32.4	.12	......	......	......	......	4,675	8,410
			B	.5	3.6	62.2	33.7	.13	......	......	......	......	4,870	8,760
			C	......	3.6	62.5	33.9	.13	......	......	......	......	4,895	8,810
			D	......	5.5	94.5	......	.20	......	......	......	......	7,405	13,320
7771	.....do..........	4.1	A	4.5	3.0	78.7	13.76	.83	0.94	78.65	0.11	5.71	6,165	11,100
			B	.5	3.1	82.1	14.35	.86	.51	82.01	.12	2.15	6,430	11,570
			C	......	3.2	82.4	14.41	.87	.46	82.39	.12	1.75	6,460	11,620
			D	......	3.7	96.3	......	1.02	.54	96.26	.14	2.04	7,545	13,580
7772	.....do..........	6.8	A	7.3	1.7	73.1	17.9	.11	......	......	......	......	5,760	10,360
			B	.6	1.8	78.4	19.2	.12	......	......	......	......	6,180	11,120
			C	......	1.8	78.9	19.3	.12	......	......	......	......	6,210	11,180
			D	......	2.3	97.7	......	.15	......	......	......	......	7,700	13,860

[a] A, coal as received; B, air-dried coal; C, moisture-free coal; D, coal free from moisture and ash.

No. 9328: Portsmouth, Portsmouth mine at Marshalls Landing; heading 1,150 feet south of south shaft in 900-foot gallery, 500 feet vertical depth. Sampled by C. W. Brown.

No. 9329: Same mine; south slope, on 800-foot level, 1,200 feet south of main slope, "Middle" 6-foot bed. Sampled by C. W. Brown.

No. 9330: Same mine; 69 feet south of north shaft, 150 feet vertical depth, 27½-inch bed, weathered. Sampled by N. C. Dale and J. C. Martin.

No. 9331: Same mine; 900 feet north of north shaft at heading in gallery, 23-inch bed. Sampled by N. C. Dale and J. C. Martin.

No. 9335: Same mine; north slope, 324 feet south and 70 feet east of landing, on main slope. Sampled by C. A. Fisher.

No. 9336: Same mine; south slope, 200 feet south of west end of crosscut heading from 600-foot level of main bed, "Back bed." Sampled by C. A. Fisher.

No. 9337: Same mine; 800-foot level, 250 feet south of main slope. Sampled by C. A. Fisher.

No. 9338: Same mine; 800-foot level, 1,200 feet south of main slope. Sampled by C. A. Fisher.

Nos. 7769–7772: Cranston (near Providence), Cranston mine, pit in outcrop. Sampler unknown.

In comparison with these results, Pennsylvania anthracite ranges from 12,000 to 13,500 British thermal units, whereas Pocahontas and other semibituminous and bituminous coals now being shipped into New England yield from 14,000 to 15,000 British thermal units. In general the calorific value of Rhode Island anthracite is from 40 to 80 per cent of the calorific value of coals with which it must compete.

STEAMING TESTS.

A number of detailed test runs have been made with Rhode Island anthracite, both alone and briquetted with other coals. In a run at the Providence waterworks pumping plant in 1874 this anthracite gave an efficiency of 72 per cent of Lackawanna anthracite. The run was continued for some time, apparently under the direct supervision of a representative of the coal company. Test runs under standard conditions on carload lots, by the Bureau of Mines, gave results very closely in accord with the relative heating value of the coal as shown by the analyses. For example, test 401 by the Bureau of Mines [1] gave for Rhode Island anthracite 117.1 horsepower as compared with 239.2 for Georges Creek (Md.) coal, 213 for Pocahontas, 213 for New River, and 211 for Kanawha. The same test gave the equivalent evaporation from and at 212° F. of 4.81 pounds of water per pound of fuel, as compared with 9.87 for Georges Creek coal, 10.12 for Cambria County (Pa.) coal, 8.01 for Pennsylvania anthracite culm, 8.49 for Pocahontas, 9.88 for New River, and 9.11 for Kanawha. The figures given for other coals are selected from a large number as fair averages, as will be shown in the bulletin that is to follow. In general the results with Rhode Island anthracite gave from 50 to 70 per cent of the efficiency of the high-grade semibituminous coal with which it must compete.

In addition to its low efficiency, the anthracite ignites slowly and with difficulty, usually popping so as to be thrown out of the fire box. When once ignited it burns with a very hot flame for a short time, tending to destroy furnace linings and stove tops and making a difficult fire to handle. The ignition and burning are improved somewhat by breaking it down fine and carefully screening and drying under cover.

HOUSEHOLD USE.

Tests in household boilers by the Bureau of Mines gave results in close accord with the figures obtained from steaming tests. Although the anthracite has been used to a small extent at the mines and in the surrounding country for many years, most of the people, even in the neighborhood, prefer Pennsylvania anthracite, for which they have had to pay from one and a half to two times the price of anthracite from the local mines.

BRIQUETTING TESTS.

Two commercial attempts have been made to briquet Rhode Island anthracite without financial success. The Bureau of Mines conducted some tests, using mixtures of Rhode Island anthracite with other

[1] Breckenridge, L. P., and others, Steaming tests of coals: Bur. Mines Bull. 23, pp. 116-129, 1912.

coals and 6 per cent of hard pitch. Some of the briquets were of good quality. The pitch binder was found to yield abundant smoke in the low-temperature fire of the household furnace, but in the steam furnace the briquets gave better results, yielding from 163 to 191 horsepower in comparison with the figures given above, and equivalent evaporation of 4.95 to 8.36 pounds of water as compared with the figures for evaporation given above.

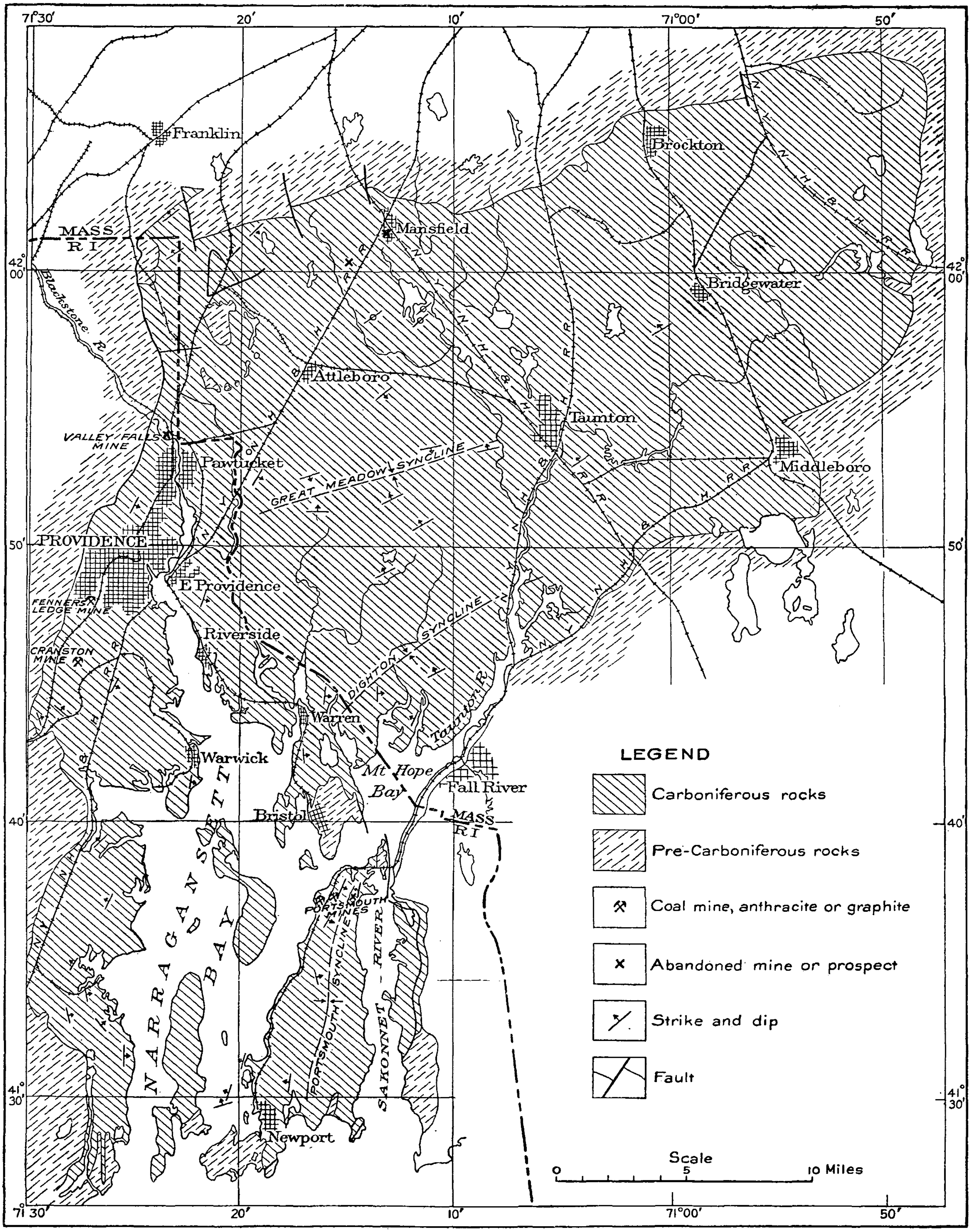
METALLURGIC USE.

In the past Rhode Island anthracite has been used successfully in the smelting of copper and iron. At one time it was even shipped to Pittsburgh. It has not, however, been used for this purpose during the last 30 years and it does not seem probable that it could compete with coke for use in the modern blast furnace.

USE BY CONVERSION INTO GAS.

It has long been hoped that Rhode Island anthracite could be successfully used at the mine for making water gas or producer gas, which could be used locally in manufacturing or in the generation of electricity by the gas engine for transmission to Providence, Boston, and other neighboring cities and towns. A number of careful tests of such use have been made by the Bureau of Mines. One of these tests failed entirely. Others gave results ranging from one-fourth to one-third of the power to be derived from Pocahontas coal under similar conditions. A study of the tests leads to the belief that with specially devised apparatus probably half the power equivalent obtained from the other coals could be procured. In other words, in order to compete with Pocahontas coal in Providence, it would be necessary to mine and deliver Rhode Island anthracite at a gas plant at the mine for less than one-half the price of bituminous or semibituminous coal at Providence. In October, 1913, the wholesale price of Pocahontas coal at Providence was under $4 a ton. Experience seems to show that the cost of mining Rhode Island anthracite on a large scale, under the peculiar conditions of its occurrence, will not be less than $2.50 a ton. As the figures just given seem to be prohibitive, it is suggested that on account of the nongaseous character of the anthracite it might be converted into water gas or producer gas in chambers in the mine, and the gas might be delivered to a gas engine at the surface cheaply enough to compete with other coals at points of distribution, provided that the beds are regular enough in thickness and have sufficient extent not to raise the price of mining beyond the figures cited.

In general the detailed figures given in the bulletin now in preparation show conclusively that Rhode Island anthracite is difficult to handle and that the cost of handling, on account of the large amount required to produce a given amount of heat and the higher percentage of ash, will be greater than that of other coals, and further, that when burned it can produce only from 40 to 80 per cent of the heat units produced by the coals with which it necessarily must compete. In general it may be said to show about two-thirds the heat value of Pocahontas coal and when to this is added the extra cost of handling the coal and ash, it may be estimated that 1 ton of Rhode Island anthracite will yield not over one-half the heat value. on the dollar basis, of Pocahontas coal.



MAP OF THE CARBONIFEROUS AREA OF THE NARRAGANSETT BASIN, SHOWING LOCATION OF ANTHRACITE AND GRAPHITE MINES AND PROSPECTS.

By G. H. Ashley.

COKING COAL IN POWELL MOUNTAIN, SCOTT COUNTY, VIRGINIA.

By Marius R. Campbell.

As a recent test has shown that coal from the Milner mine on Stony Creek on the south side of Powell Mountain, Scott County, Va., will make an excellent coke, the United States Geological Survey desires to publish the fact in order to correct the statement in a previous report[1] "that most of the coals of this field will coke with difficulty, if at all."

In April, 1910, the Powell Mountain coal field was examined by E. G. Woodruff and the writer for the purpose of determining the extent and thickness of the coal beds and the quality of the coal, as a previous report[2] by the writer had not been very complimentary to the field. In making the examination, all the coals were subjected to the Pishel test for coking. This consists in pulverizing some of the fresh coal in an agate mortar. If the fine coal adheres to the mortar and pestle it is regarded as possessing coking properties, but if it leaves the mortar and pestle free and clear it is supposed not to possess such properties and to be of the ordinary noncoking variety.

As this test had been applied to several hundred different samples of coal with satisfactory results it was regarded at that time as a conclusive indication of coking or noncoking character. Accordingly in the paper giving the results of the field examination[3] the following statement was made regarding the coking quality of the coal:

> It is reported that the Duncan coal from Coalpit Branch will coke in an open fire, but so far as known this is the only coal in Powell Mountain that has this property. When the Pishel test is applied the Duncan coal shows some adhesion to the mortar and so will probably coke, but the Milner coal shows no such tendency, nor does any other that was tried. From this it is concluded that the most of the coal of this field will coke with difficulty, if at all.

Since the publication of the statement given above, reports have been current that certain coking coals of the central Appalachian

[1] Campbell, M. R., and Woodruff, E. G., The Powell Mountain coal field, Scott and Wise counties, Va.: U. S. Geol. Survey Bull. 431, pp. 147-162, 1911.

[2] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, pp. 40 and 93, 1893.

[3] Campbell, M. R., and Woodruff, E. G., op. cit., p. 162.

field showed no adhesion to the mortar when subjected to the Pishel test, and the owner of the Milner mine also claimed, that despite the negative results obtained by the Pishel test, his coal would make excellent coke.

In order to test the matter thoroughly so that the exact value of the Pishel test could be determined, and also to correct if necessary any statement that had previously been made regarding the non-coking quality of this coal, T. K. Harnsberger, geologic aid and member of the Virginia State Geological Survey, who was working in the vicinity, visited the Powell Mountain field in November, 1913, and made a thorough practical test of the coal. In company with an engineer representing the owner, Mr. Harnsberger went to the Milner mine on the Mountain Fork of Stony Creek and procured a sample for the test. The coal was broken to about one-half inch, although some lumps were 1 inch in diameter. Two nail kegs were filled and headed, the total weight of the coal being about 110 pounds. These samples were shipped by Mr. Harnsberger to Coeburn, where a test was made under his supervision in an oven belonging to the Virginia Iron, Coal & Coke Co. The kegs were placed in a 14-foot oven about 3 feet apart and 4 feet from the door. The charge was coked for 70 hours, producing a fine hard silvery coke that compares favorably with coke from the Connellsville district.

The result shows clearly that the coal in the Milner mine is a good coking coal and that the Pishel test is not a reliable test of certain coals in the central Appalachian region.

THE COAL RESOURCES AND GENERAL GEOLOGY OF THE POUND QUADRANGLE OF VIRGINIA AND KENTUCKY.[1]

By Charles Butts.

INTRODUCTION.

The Pound quadrangle includes parts of Pike and Letcher counties, Ky., and of Wise and Dickenson counties, Va. It is located a few miles northwest of the Toms Creek coal field, in the territory between the great Pocahontas coal field on the northeast and the Big Stone Gap field on the southwest. Until recently the region was entirely undeveloped, and little information concerning it was available. It has not, however, escaped the attention of the coal operators, and some of the largest corporations have acquired lands in this region with a view to active development. Within the past three years railroad communication has been established with the outside world, and in the Kentucky area 14 shipping mines are in active operation. In the Virginia area only one large mine has been operated, but doubtless others will be opened in the near future.

The number of coal beds in the quadrangle is probably greater than elsewhere in the Appalachian coal field and in the thickness and extent of its beds the area will compare favorably with most others in that field. These factors, combined with the excellent quality of the coal, insure the field a prominent place among the future fuel-producing centers of the Appalachian province.

The survey of the Virginia portion of the Pound quadrangle was carried on jointly by the United States Geological Survey and the Virginia Geological Survey. The United States Geological Survey had charge of all field work, but it was ably assisted by men and money supplied by the State organization. The Kentucky portion was examined by the United States Geological Survey only. An accurately contoured topographic map of the quadrangle was made and this will soon be ready for distribution.

In the survey of the Virginia area the writer was assisted by D. D. Condit and W. A. Nelson, who represented the Virginia State Survey. The Clinchfield Coal Corporation, which has extensive holdings in Wise, Dickenson, Buchanan, and Russell counties, Va., has con-

[1] The Virginia portion of the area was surveyed in cooperation with the State Geological Survey.

tributed valuable data, such as triangulation surveys, surveys of coal outcrops, and diamond-drill borings. Extensive prospecting by this company has opened several of the more important coal beds to more thorough examination. The Consolidation Coal Co., operating in Kentucky, and the Virginia Coal & Iron Co., operating in Virginia, have also made many openings and have contributed maps of outcrops and maps of triangulation surveys which have been of great

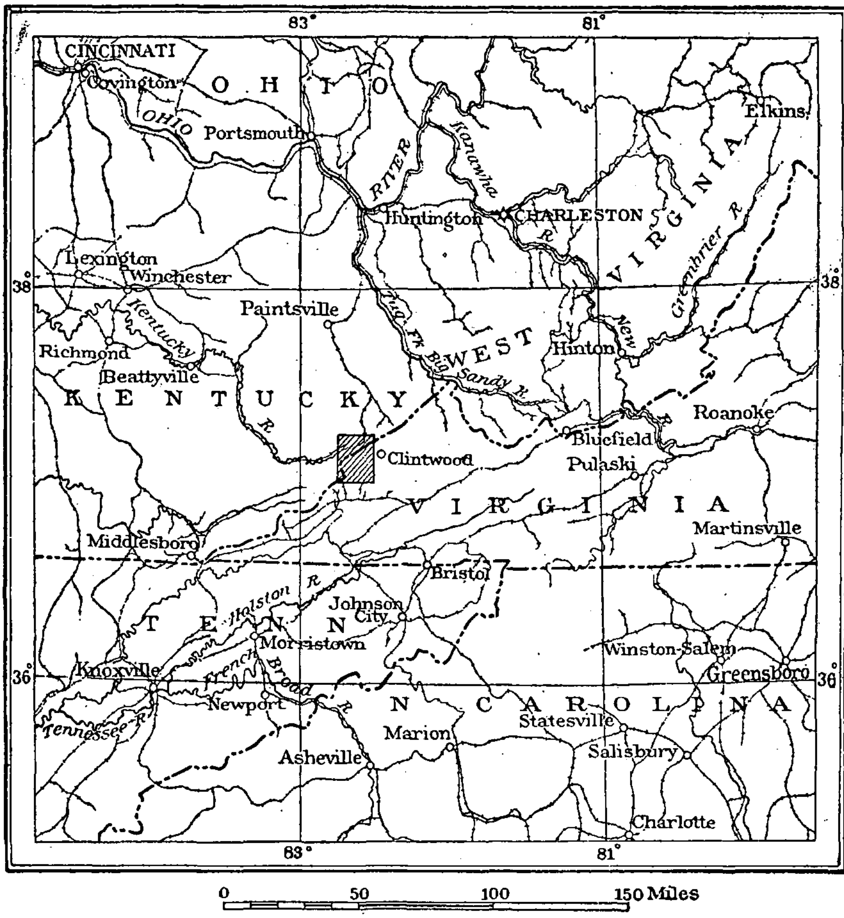


FIGURE 6.—Index map showing location of the Pound quadrangle of Virginia and Kentucky.

assistance. The Estillville and Bristol folios of the Geologic Atlas of the United States, by M. R. Campbell, and Bulletin 348 of the United States Geological Survey, by R. W. Stone, have also been drawn upon for material that could be used in the preparation of this report.

As shown by the map (fig. 6), the Pound quadrangle, which coincides with the southeastern quarter of the old Whitesburg 30-minute quadrangle, lies partly in eastern Kentucky and partly in southwestern Virginia. The line between the two States follows the crest of Pine Mountain nearly to the western boundary of the quadrangle, where it turns south along the watershed between Cumberland and Pound rivers. The quadrangle is bounded by parallels 37° and 37° 15′, and by meridians 82° 30′ and 82° 45′. Its area is about 240 square miles and it lies entirely in the Appalachian coal region.

TOPOGRAPHY.

RELIEF.

The surface of the country is hilly or even mountainous, the maximum range of altitude from Pound River to Black Mountain being 2,300 feet. Pine Mountain, with peaks rising 3,500 feet above sea level, crosses the northern half of the area from northeast to southwest, and Black Mountain, whose summit is about 3,800 feet above sea level, 1,800 feet above Roaring Fork, and 1,550 feet above Guest River, lies in the southwestern part of the quadrangle. These mountains are the dominant features of the region. Buck Knob and Bowlecamp Knob, at an altitude of about 1,500 feet above Indian Creek, are also striking objects in the landscape.

The northwest slope of Pine Mountain is an escarpment 1,500 to 2,000 feet high, and as the crest is scarcely a mile from the valleys at the foot of the slope a very bold and striking front is presented. The southeast slope of the mountain, approximately a dip slope on the Lee formation, is more gentle, the total descent being somewhat less and the distance to the foot nearly twice as great as it is on the opposite side of the mountain.

The quadrangle is deeply dissected by the streams, the valleys of which are deep, narrow, and V-shaped. The slopes are very steep and rise 500 to 1,000 feet to the ridge crests, which are narrow, commonly only a few feet broad, and at many points capped with heavy cliff-forming sandstone. Even the larger streams have very narrow flood plains, and some of them none at all. Probably a liberal estimate of the area of flat land would be 5 per cent of the total area of the quadrangle. The ridges and valleys are arranged in an irregular pattern over most of the area that lies in Virginia, but in the Kentucky area a radial arrangement of the main ridges about the higher knobs as centers prevails.

DRAINAGE.

The principal streams of the quadrangle in Virginia are Pound River, including North and South forks, which traverses the quadrangle from southwest to northeast near the middle; Roaring Fork, Powell River, and Guest River in the southwestern part; Indian Creek, which traverses the middle of the southern part of the quadrangle in a due north direction and joins Pound River at Pound; and Birchfield

Creek in the southeastern part, which joins Cranesnest River just beyond the eastern margin of the quadrangle, that stream being a tributary of Pound River.

In Kentucky, Elkhorn Creek in the northeastern part flows northeast and joins Big Sandy River at Elkhorn City, several miles northeast of the quadrangle; North Fork of Kentucky River and Boone Fork traverse the western part and Beefhide and Shelby creeks the northern part of the quadrangle.

Pound River is the largest stream. It is doubtful whether the smaller streams or even Pound River carries much water in times of prolonged drought.

The Pound quadrangle includes parts of four drainage basins. The area drained by Pound River and its tributaries, including Indian and Birchfield creeks, in Virginia, and by Elkhorn, Shelby, and Beefhide creeks, in Kentucky, belongs to the Ohio-Big Sandy basin; that drained by Guest and Powell rivers to the Tennessee-Clinch basin; that drained by Poor Fork of Cumberland River, comprising a small area on the west side, belongs to the Ohio-Cumberland basin; and that drained by North Fork of Kentucky River, Boone, Fish, and Rockhouse creeks belongs to the Ohio-Kentucky basin.

ACCESSIBILITY.

In a potential mining country such as this, the matter of transportation, and consequently the conditions affecting railroad construction, are of great importance. The nearest main lines of railroad are the Norfolk & Western Railway and the Louisville & Nashville Railroad at Norton, Va., about 4 miles south of the quadrangle; the Louisville & Nashville Railroad at Pineville, Ky.; the Chesapeake & Ohio Railway along Big Sandy River in Kentucky; and the Carolina, Clinchfield & Ohio Railway, now being extended from Dante, Va., to Elkhorn City, Ky., near the "Breaks of Sandy."

The Kentucky part of the quadrangle has recently been brought into communication with the outside world by the extension of the Lexington & Eastern Railway into the territory, with terminus at McRoberts, and by the Sandy Valley & Elkhorn Railway, running from Shelbiana (Shelby station), on the Chesapeake & Ohio Railway, to Jenkins. Owing to the obstacle to transportation presented by Pine Mountain these railroads can be of little service to the Virginia part of the quadrangle except for travel and light traffic.

The part of the quadrangle that lies in Virginia is still poorly provided with transportation facilities. The territory drained by Guest River could easily be reached by railroad from Norton, but the Pound River drainage area presents serious obstacles to railroad construction. To build a railroad from the south would involve steep grades or an expensive tunnel at the head of Indian Creek. The railroad now existing along Indian Creek is a narrow-gage road built to haul logs from Pound River to a sawmill at Glamorgan, where it connects with the standard-gage road to Norton. A branch line from the Carolina, Clinchfield & Ohio Railway up Pound River would, on account of the narrow and crooked valley, be expensive to construct and operate. The area drained by the upper part of Pound River and its tributary, Indian Creek, could perhaps be most advantageously reached by a line from the Louisville & Nashville Railroad at Pineville, Ky., following Cumberland River and crossing the low divide at Flat Gap. Just beyond the southwest corner of the quadrangle a railroad is in operation which connects with the Interstate Railroad at Blackwood, a few miles to the south, and follows Roaring and Whitley forks to the Pardee mine. It seems perfectly feasible to build a spur up the main branch of Roaring Fork to the base of Black Mountain. The territory tributary to Birchfield Creek and Georges Fork could apparently be best reached from the Carolina, Clinchfield & Ohio Railway along Pound and Cranesnest rivers.

GEOLOGY.

STRATIGRAPHY.

DIVISIONS OF THE ROCKS.

The rocks that outcrop in the Pound quadrangle belong to the Devonian and Carboniferous systems. The Devonian rocks, the lowest and oldest exposed in the quadrangle, outcrop only on the west escarpment of Pine Mountain in Kentucky, and consist of about 800 feet of dark to black shale, comprising the black Chattanooga shale of this region and the lower part of the Grainger shale. The Carboniferous system is divided into the Mississippian series (lower Carboniferous) below and the Pennsylvanian series (upper Carboniferous or "Coal Measures") above. Each of these series is made up of a number of formations, which are described below.

MISSISSIPPIAN SERIES.

The Mississippian series in this area is 1,500 to 1,600 feet thick and comprises, in ascending order, the upper part of the Grainger shale, the Newman limestone, and the Pennington shale. The upper or Mississippian part of the Grainger shale is composed chiefly of green shale and brownish sandstone, but in the upper 50 feet there is considerable red sandstone. The Mississippian part of the Grainger shale appears to be 400 to 500 feet thick. It is succeeded above by the Newman limestone, which is about 300 feet in thickness, oolitic and thick bedded in the lower half, but thinner bedded and continuing only a few oolitic layers in the upper half. The Newman is overlain by the Pennington shale, which is about 800 feet thick and is composed of red and green shale, thin-bedded fine-grained green sandstone, and one persistent stratum of hard siliceous sandstone 100 feet thick.

The Mississippian rocks outcrop only on the northwest front of Pine Mountain in Kentucky, and dip southeast under the coal measures in Virginia. The Mississippian part of the Grainger shale is exposed on the Pound Gap road and also on the Blowing Rock road, some 2 or 3 miles northeast of the east margin of the quadrangle. The red sandstone layers are especially well shown on the Blowing Rock road at the part known as the Red Winds. The Newman limestone is exposed on the Pound Gap road and outcrops as a cliff for much of the distance along the mountain front. The Pennington shale is fairly well exposed on the Pound Gap road immediately west of the summit. Its siliceous sandstone member outcrops as a cliff near the road, and about one-half mile north of the road it makes another cliff, known as the Raven Rock. The Pennington was penetrated at the depth of about 2,000 feet in diamond-drill boring No. 1 on Cranesnest River near the mouth of Lick Fork, a short distance east of the quadrangle. (See Pl. IX, section 1.)

PENNSYLVANIAN SERIES IN THE VIRGINIA AREA.

The Pennsylvanian series in the Virginia area is 4,800 feet thick and consists of shale and sandstone that contain 46 or more coal beds. These rocks, all of Pottsville age, were divided by Campbell[1] into the following formations, named in ascending order: Lee formation, Norton formation, Gladeville sandstone, Wise formation, and Harlan sandstone. The character of the rocks, the sequence of formations, and the number, position, and succession of coal beds are shown in the columnar section accompanying this report (Pl. XI, p. 68). This section is partly generalized, but the section of the Lee is taken from the log of a bore hole on Cranesnest River, just outside the east margin of the quadrangle, and the part of the section of the Wise formation above the Bolling (5-foot) coal beds and the section of the Harlan sandstone were measured at the head of South Fork of Pound River, the section extending from the base of Black Mountain to the summit. The Black Mountain section of the Pennsylvanian is probably the thickest in the Appalachian province outside of the Coosa and Cahaba troughs in Alabama.

LEE FORMATION.

The Lee formation, as delimited by the writer in the well boring on Cranesnest River (Pl. IX, section 1), is 1,030 feet thick. It is predominantly sandstone, which at the top and bottom of the for-

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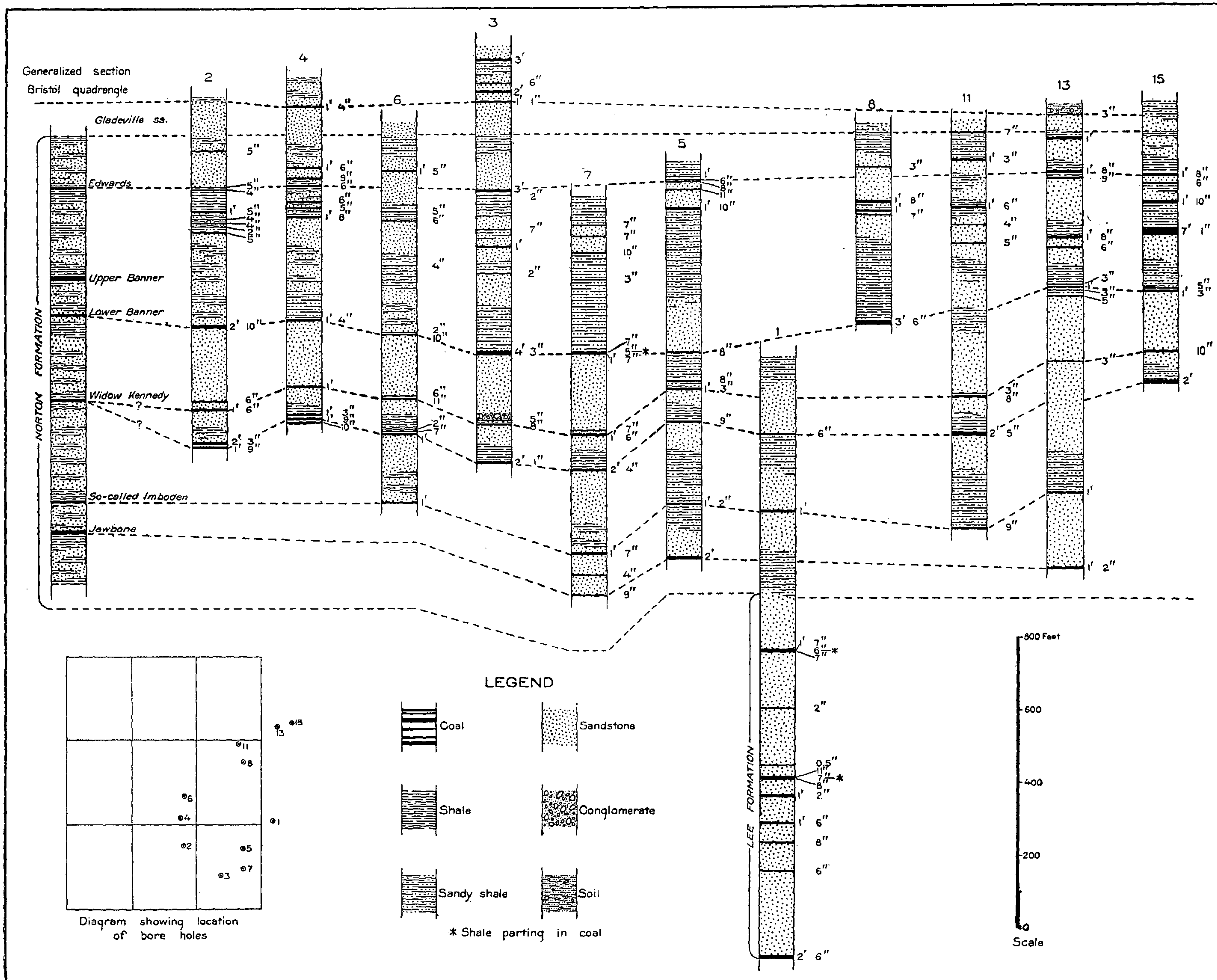
[1] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, pp. 33-36, 1893.



SECTIONS OF DIAMOND-DRILL HOLES IN THE POUND QUADRANGLE AND VICINITY, KENTUCKY AND VIRGINIA, AND GENERALIZED SECTION OF THE BRISTOL QUADRANGLE.

The bore holes were drilled and the records furnished by the Clinchfield Coal Corporation and bear the serial numbers of the company.

mation is conglomeratic. At the base lies about 230 feet of massive conglomeratic sandstone, which forms the crest of Pine Mountain, where it outcrops for long distances as a cliff. Above the basal sandstone occurs 250 feet of alternating shale and sandstone, in which there are six coal beds at about equal stratigraphic intervals and from 6 inches to 2 feet 2 inches thick. Three of these beds are workable, being 1 foot 2 inches, 1 foot 6 inches, and 2 feet 2 inches thick. Above this group of coal beds the well log shows 550 feet of sandstone containing a coal bed 2 inches thick 225 feet above its base and a bed 1 foot 7 inches thick 400 feet above its base, the two beds being 700 and 875 feet, respectively, above the bottom of the formation. The upper 160 feet of the Lee is a hard siliceous conglomeratic sandstone, the pebbles being small and scattered. This stratum, which dips southeastward, forms the lower part of the southeast slope of Pine Mountain, and its outcrop on the slope is marked by a subordinate ridge or line of knobs parallel with the general direction of the crest of the mountain.

The Lee formation outcrops in a zone about 2 miles wide, which extends diagonally across the quadrangle from the northeast corner. Its base forms the crest of Pine Mountain, and, owing to the southeastward dip, the outcrops of successively higher beds of the formation are encountered on the descent of the southeast slope. In reality the presence of a mountain ridge here is determined by the inclined beds of this hard resistant sandstone and conglomerate. Besides this main area of outcrop the Lee is exposed in a long, narrow outcrop low down on the northwest escarpment of Pine Mountain, in contact with the Devonian or with the Mississippian part of the Grainger shale on the east, and with coal-bearing rocks, probably equivalent to the Wise formation, on the west. This narrow area is an outcrop of a segment of the Lee, which was broken off and thrust upward along a fault, as described in the section on geologic structure. The massive sandstone strata of the formation are well exposed in the "Breaks of Sandy," 12 miles northeast of the Pound quadrangle, where the Lee forms canyon walls nearly 1,000 feet high.

NORTON FORMATION.

Thickness and character.—A fairly reliable determination of the thickness of the Norton formation is made by combining the upper part of the section of the bore hole on Cranesnest River (Pl. IX, section 1) with the surface section of a high knob immediately adjacent to the hole. The contact between the Lee and the Norton, as the log is interpreted, is 879 feet above sea level and the horizon of the bottom of the Gladeville sandstone, which is the top of the Norton formation, is approximately 2,070 feet above sea level. The thickness of the Norton is therefore 1,191 feet.

The character of the Norton formation is well shown in the group of bore-hole sections in Plate IX, from which the generalized columnar section of the formation in this quadrangle is taken. Its most striking feature is the irregularity in the number and position of the coal beds, a feature which makes difficult a satisfactory brief general description of the formation. In general the formation is made up of shale and sandstone with coal beds, the more valuable of the coal beds lying approximately 190, 320, 410, 560, 730, and 930 feet above the bottom of the formation. Eighty feet below the Gladeville lies the top of a conglomeratic sandstone 50 feet thick, which may prove to be the same as the Bearwallow conglomerate of the Tazewell quadrangle, 30 miles east of this area.

In the Pound quadrangle the Norton formation outcrops in a belt about 1½ miles wide that extends diagonally across the quadrangle parallel to Pine Mountain and is bounded roughly on the northwest by the base of the mountain and on the southeast by Pound River. Along the southeast boundary it dips beneath younger rocks and remains under cover as far as Cranesnest River and Birchfield Creek, where it is again exposed, forming the lower part of the valley walls. A narrow area is also exposed along the upper course of Indian Creek. The formation disappears beneath Sand Ridge and Black Mountain and is concealed in the southern part of the quadrangle, but outcrops several miles south of the quadrangle along the southern margin of the coal field.

Correlation of coal beds.—The correlation of the Norton coals of this area with the Norton coals of the southern margin of the Virginia coal field as classified by Campbell[1] is more fully discussed on pages 185–186, and only a brief statement of conclusions need be given here. The coal bed lying 190 feet above the bottom of the Norton formation is the Jawbone; the one at 320 feet is the so-called Imboden; the coal at 410 feet apparently is not present in the section given in the Bristol folio; the coal at 560 feet is equivalent to the Widow Kennedy bed; and the coal bed at 730 feet above the bottom of the formation is the Lower Banner bed. The Upper Banner coal is not present unless it is represented by the group of thin coal beds 250 to 270 feet below the Gladeville sandstone, including the 7-foot bed in well No. 15, east of the quadrangle. The Edwards-Imboden horizon is represented by another group of thin coal beds 150 feet below the Gladeville sandstone. The coal just below the Gladeville sandstone appears to be the Yellow Creek bed, which is mined east of Wise, 2 miles south of this quadrangle.

Nearly all the coal beds of the Norton formation, except the thick bed in boring No. 15 (Pl. IX), are less than 3 feet thick, and most of

[1] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, pp. 33–36, 1893; U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), 1894; idem, Bristol folio (No. 59), 1899.

them are less than 2 feet thick. Several sections of bore holes show a number of thin coal streaks associated with the thicker beds, and this suggests that, owing to rapid sedimentation, the continuity of accumulation of vegetal matter in this area was more or less interrupted during the deposition of the coal beds, and that these conditions resulted in the formation of a number of thin beds at the different coal horizons instead of one thick bed, such as occurs at the same horizon at Toms Creek, Norton, and other places along the southern margin of the Virginia coal field, although the total accumulation of vegetal matter may have been about equally great at all these places.

GLADEVILLE SANDSTONE.

The Gladeville sandstone was named by Campbell from Gladeville, now Wise, a town 2 miles south of the quadrangle, which is built on the outcrop of the sandstone. On account of its importance as a horizon marker it is rather fully described.

The Gladeville underlies Sand Ridge and is exposed on Steele Fork of Cranesnest River, and on Birchfield and Indian creeks. It underlies Bowlecamp Knob, and a few feet of the top of the sandstone outcrops along Mullin and Dotson Forks of Bowlecamp Creek as far as Pound River. It is also exposed on Camp Creek and Georges Fork. The outcrop follows the general course of Pound River across the quadrangle, the sandstone rising northwestward toward Pine Mountain and underlying only the higher knobs near the river. It is a very persistent bed and exceedingly serviceable as a key rock. On the map its outcrop is shown by the stipple pattern between the lines representing the outcrops of the Glamorgan and Yellow Creek coal beds or their horizons.

At Wise the Gladeville sandstone is hard, white, and siliceous and appears to be about 100 feet thick. In all the region north of Sand Ridge, however, it is less purely siliceous and thinner than at Wise. It contains more argillaceous matter and more feldspar and mica, and its thickness does not exceed 60 feet.

WISE FORMATION.

Character and distribution.—The Wise formation includes a mass of shale and sandstone 2,070 feet thick, with many coal beds lying between the Gladeville sandstone below and the Harlan sandstone above. It includes at least 19 distinct coal beds, and it is probable that there are others which have not yet been discovered. The Wise formation constitutes the surface rock in most of that portion of the quadrangle lying south of Pound River. North of the river it also caps some hills and ridges, and southeast of Birchfield Creek it occurs only on the hills, the Norton formation outcropping in the valley bottoms and well up on the hillsides.

Glamorgan coal.—Immediately above the Gladeville sandstone lies the Glamorgan coal, named from Glamorgan, just beyond the south margin of the quadrangle, where the bed is mined. It attains its maximum known thickness in the hills south of the heads of Birchfield Creek and Dotson Fork, northeast of Glamorgan. On Birchfield Creek and Dotson Fork of Bowlecamp Creek the bed is divided by partings, but there is generally a bench 2 feet or more thick. Along Pound River northeast of Pound a persistent thickness of 2½ to 3 feet is shown at numerous openings, but here also the bed includes several partings.

Above the Glamorgan coal occurs 230 feet of shale and sandstone containing five coal beds. The sandstone is highly siliceous, hard, and white, differing in these respects from the prevailing type of sandstone in this region, which is softer, more highly feldspathic, and micaceous. The sandstone bed at the top, just above the uppermost of the five coal beds (Clintwood coal) and in places in contact with that bed, is especially noteworthy, for it is persistent over a large area and either outcrops as a ledge or makes a distinct shelf along the hillside, by which the position of the outcrop of the underlying coal can be determined. All these sandstones and associated coal beds are exposed along the road on Guest River from the south margin of the quadrangle to a point 1½ miles north of Lipps. The first important coal bed above the Glamorgan occurs 60 feet above the Gladeville sandstone. The bed is 2 feet or more thick and appears to persist over the southeastern quarter of the quadrangle.

Blair coal.—About 40 feet above the bed that occurs 60 feet above the Gladeville sandstone lies a coal bed here named the Blair, because it was opened by a man of that name on Lick Branch, 3 miles above the mouth of Indian Creek. This coal is also persistent in the southeastern part of the quadrangle and appears to range from 2 to 5 feet in total thickness.

Clintwood coal bed.—The Clintwood coal lies 100 feet above the Blair coal and 200 to 250 feet above the Gladeville sandstone. It is named from the town of Clintwood, about 1½ miles east of the quadrangle. On Georges Fork and Lick Fork of the Cranesnest River drainage the Clintwood is 6 to 12 feet thick, including partings. Elsewhere it is thinner, though persistent throughout the quadrangle. As noted above, everywhere in the quadrangle the Clintwood is overlain by a sandstone 20 to 40 feet thick, which either rests on the coal bed or is separated from it by only a few feet of shale.

Above the sandstone just mentioned there is a coal bed that has a maximum thickness of 2 feet, or at least such a bed is present in certain localities. It is succeeded by 150 to 200 feet of soft shale, which, over a large area, is followed by about 50 feet of coarse feldspathic and micaceous sandstone.

Bolling coal beds ("Five-foot" bed).—Above the top of the coarse micaceous sandstone, which is about 250 feet above the Clintwood coal, lie two coal beds 20 to 40 feet apart, the upper one being designated the "Five-foot" bed on the outcrop maps of the Clinchfield Coal Corporation. The name Bolling is here applied to both beds because they have been opened near the head of Pound River by several persons of that name. The Lower Bolling coal is 18 inches to 4 feet thick, and the Upper Bolling is 3 to 5 feet thick. The two beds are separated by 20 to 40 feet of shale. These coal beds underlie Black Mountain, Buck Knob, and Bowlecamp Knob, and their horizon is a little below the tops of several knobs and ridges in the southeast corner of the quadrangle. Above the Upper Bolling lies 50 to 80 feet, or in places a greater thickness, of coarse micaceous sandstone, which for long distances outcrops as a low cliff or forms a low escarpment. This sandstone persists throughout the area underlain by the Bolling coals. On South Fork of Pound River the coarse sandstone is overlain by about 140 feet of shale and sandstone, capped by a 40-foot bed of sandstone.

Standiford coals.—Within 100 feet above the Bolling coals there are one or more thin coal beds, and about 260 feet above these coals two beds occur, 20 feet apart, which are here called the Standiford coals because they are mined near the head of South Fork of Pound River by a man of that name. At the type locality the lower Standiford coal is 2 feet 6 inches and the upper about 3 feet thick. These coals appear to underlie the Black Mountain and Buck Knob region, but it is probable that they have been removed by erosion in the country farther east, except possibly in a small area near the top of Bowlecamp Knob.

Taggart coal.—On South Fork of Pound River the strata for 90 to 100 feet above the Standiford coals seem to be chiefly sandstone, and above this sandstone occur two thin coal beds separated by 6 feet of shale, the upper bed being 3 feet and the lower bed 2 feet 6 inches thick. On Roaring Fork of Powell River the name Taggart is applied to a bed believed to be the same as the double bed above described, and that name is adopted here. On Roaring Fork the bed, which has been thoroughly prospected, is double at some points, and one section examined by the writer contains four coal beds in the space of about 75 feet, as shown in the section at location 68 (p. 49). It is supposed that at least the upper two beds of this section represent the horizon of the Taggart coal, the two benches of coal being separated by 20 feet of shale and sandstone. At most points where it has been prospected only one bench is recorded, either because only one bench is present or because only one of two or more benches possibly present was discovered.

Low Splint coal.—The name Low Splint is applied to a coal bed about 200 feet above the Taggart, on the head of Roaring Fork. At the head of South Fork of Pound River a bed opened on the George Phillips place, 160 feet above the Taggart, is correlated with the Low Splint. It appears to be persistent, and to range in thickness from 2½ to 4 feet, but as it lies high in the hills it is present only in Black Mountain and Buck Knob. It is probably the Buck Knob bed of the Clinchfield Coal Corporation.

Phillips coal.—The Low Splint bed is succeeded by 260 feet of shale and sandstone, in which no coal was seen in this region, and at the top of this shale and sandstone lies a coal bed named the Phillips coal because it has been opened at the Ambrose Phillips place, at the head of South Fork of Pound River, where it is reported to be 26 inches thick and to be all coal.

In the 390-foot interval between the Phillips and the Pardee coal beds, at the head of South Fork of Pound River, the rocks comprise shale and sandstone that contain thin coal beds as follows: An 18-inch bed of coal 80 feet above the Phillips, a 1-foot bed 210 feet above the Phillips, a 2-foot bed 225 feet above the Phillips, and a 6-inch bed 340 feet above the Phillips, or 50 feet below the Pardee bed. Between 210 and 225 feet above the Phillips coal occurs an 8-inch limestone bed, which is the only limestone found in the entire Pennsylvanian section except some nodules in the shales on Elkhorn Creek in Kentucky.

Pardee (Limestone) coal.—The Pardee bed, 390 feet above the Phillips bed, or 1,670 feet above the Gladeville sandstone, is mined at Pardee just west of the southwest corner of the quadrangle. This coal is the Limestone coal bed of the Kentucky Geological Survey reports and the Parsons bed of the Virginia Coal & Iron Co. At Pardee, and for a mile or two to the east within the Pound quadrangle, the bed contains about 10 feet of solid coal, but farther east and northeast it is in places divided by thick partings into two or three benches. It lies 2,800 to 3,100 feet above sea level, and therefore outcrops near the summit of Black Mountain and its radiating spurs. Above the Pardee bed lies about 100 feet of shale overlain by rather coarse grained but flaggy sandstone 300 feet thick, making 400 feet in all to the next higher coal bed, which is known in this region as the High Splint coal.

High Splint coal.—The High Splint coal is 400 feet above the Pardee bed and is a genuine splint coal 4 to 5 feet thick. It occurs so high in the hills that it underlies only a small area on Black Mountain.

HARLAN SANDSTONE.

Above the High Splint coal just described appears to be a few feet of shale, which is followed above by a massive cliff-making sandstone, in places conglomeratic, which is 40 feet thick and which is taken as the basal stratum of the Harlan sandstone. The Harlan sandstone, which extends from the High Splint coal bed to the top of the highest summits of Black Mountain, is a little over 400 feet thick. It is mostly coarse, thick-bedded to massive sandstone but contains shale beds with at least two coals of unknown thickness, fragments only being seen at two places. One of these coal beds is 100 and the other 300 feet above the High Splint bed.

PENNSYLVANIAN SERIES IN THE KENTUCKY AREA.

Formations present.—In Kentucky the rocks above the Lee formation correspond to the Norton formation and the lower part of the Wise formation of Virginia, and the part corresponding to the Wise probably also represents the Breathitt formation of Campbell[1] in the western part of the Appalachian coal field of Kentucky. (See columnar section, Pl. XI, p. 220.) On account of uncertainty as to the identification of boundaries in Kentucky it is thought best not to attempt a separation of the formations at this time, and it may be found expedient to treat all the rocks above the Lee as a unit in Kentucky. The Lee formation does not outcrop in the part of the quadrangle that lies in Kentucky except as a long narrow block along the Pine Mountain fault. (See p. 182.) The lower 600 feet of rocks corresponding to the Norton formation likewise do not outcrop, but according to Stone,[2] who studied the region farther north on Elkhorn Creek and Big Sandy River, they are composed of shale and sandstone with three coal beds, none of which is over 3½ feet thick. These beds were named by Stone, in ascending order, the Elswick, Auxier, and Milliard beds, and they are 70, 280, and 440 feet, respectively, above the top of the Lee.

Bingham coal.—According to Stone,[3] the Bingham coal lies 600 feet above the top of the Lee. A coal 2½ feet thick outcropping on Shelby Creek for 1½ miles south of the north border of the quadrangle is here regarded as the Bingham. It does not outcrop elsewhere in the quadrangle, but its extension under cover is probably shown in drill holes in which a coal bed was encountered 400 feet below the Upper Elkhorn bed.

Lower Elkhorn coal.—The Lower Elkhorn coal lies 200 feet above the Bingham, and other thin coal beds are associated with it within 40 feet both above and below it. It is 2 to 4 feet thick and has a characteristic laminated bench by which it can be identified. It outcrops on Elkhorn Creek and its tributaries northeast of the mouth of McPeak Branch and also at the headwaters of Beefhide Creek.

Coal 140 feet above the Lower Elkhorn.—The rocks for 140 feet above the Lower Elkhorn bed are largely sandstone, and above this

[1] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, London folio (No. 47), 1898.

[2] Stone, R. W., Coal resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull. 348, 1908.

[3] Idem, pp. 25–26.

sandstone lies a coal bed 2 feet thick, which is exposed at Consolidation No. 201 mine. A coal bed 4 feet thick and 150 feet above the Lower Elkhorn on Pigeon Branch in the northeastern part of the quadrangle is probably the same bed.

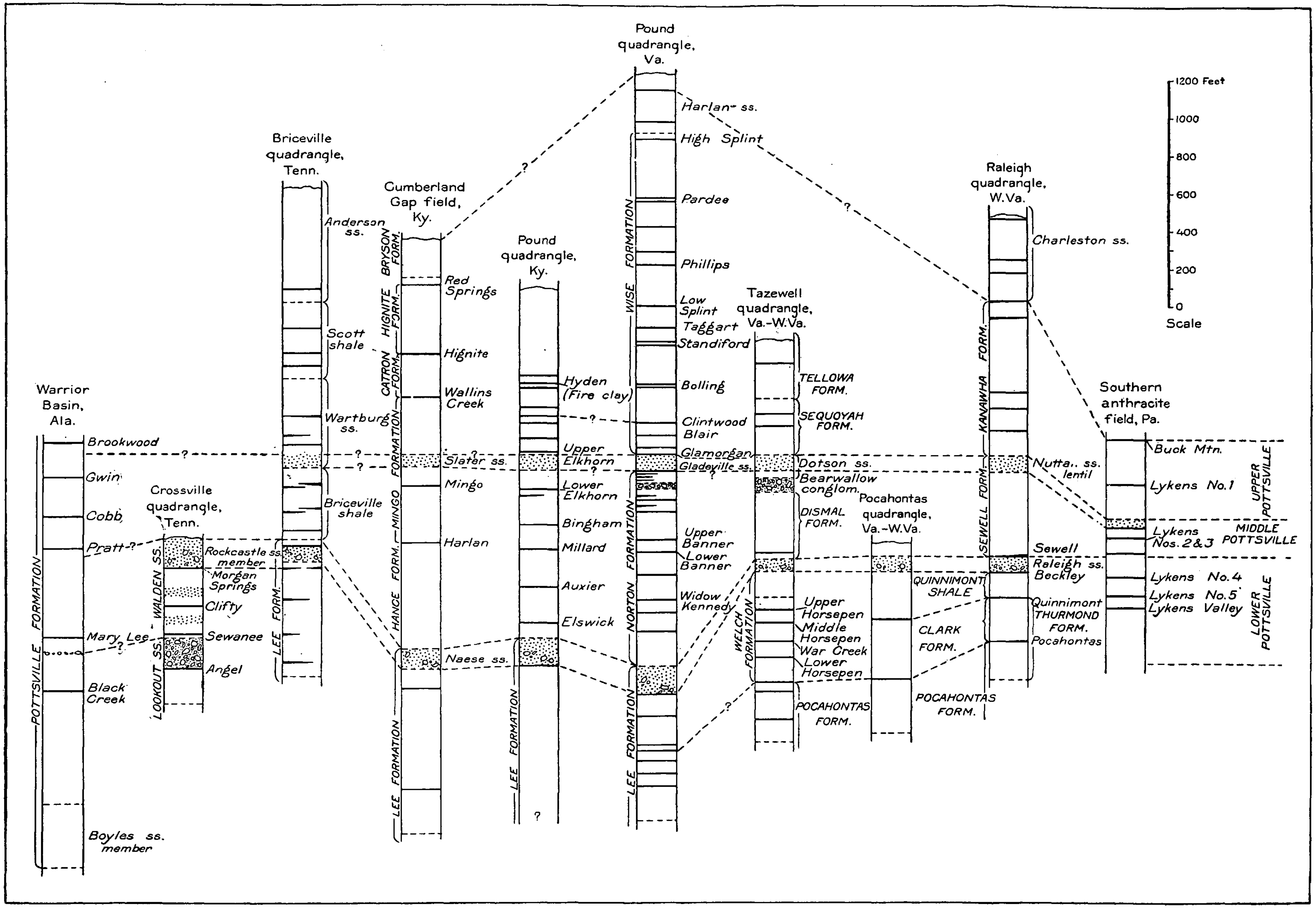
Above the coal bed last described occurs about 70 feet of sandstone that may correspond to the Gladeville sandstone of Virginia. As the Upper Elkhorn coal bed, which is about 40 feet above the top of this sandstone, is, according to Stone,[1] 1,000 feet above the Lee formation, the thickness of the rocks that possibly correspond to the Norton formation of Virginia is 930 feet in this part of Kentucky. Within 20 feet above the sandstone just described lie two coal beds, both of which are generally thin so far as seen, but one of which appears to be 2 to 3 feet thick on Elkhorn Creek 1 mile above Jenkins. The Upper Elkhorn bed lies 30 feet above the upper of these coals and is separated from it by shale.

Upper Elkhorn coal.—The Upper Elkhorn bed is the thickest and most important coal bed in the part of this quadrangle that lies in Kentucky. In the northwestern part it is 4 feet thick; elsewhere its prevailing thickness is 6 to 8 feet, and throughout most of the area in which this thickness prevails it has near the middle a clay parting 1 inch to 1 foot thick. If the sandstone 50 feet below this coal is the Gladeville of Virginia, the Upper Elkhorn bed corresponds in position to the unnamed bed 60 feet above the Gladeville in Virginia (described on p. 173) and the thin coals at the top of the sandstone correspond to the Glamorgan coal.

Coals between the Upper Elkhorn and Hyden (Fire Clay) bed.—For a distance of 400 feet above the Upper Elkhorn bed there are shales and sandstones that include a number of coal beds as follows: A coal, generally about 1 foot thick, 70 feet above the Upper Elkhorn bed and separated from it by shale; a dirty coal bed, 2 to 3 feet thick, in sandstone, 175 feet above the Upper Elkhorn; a bed 3 feet 4 inches thick 200 feet above the Upper Elkhorn; a bed 2 feet thick 240 feet above the Upper Elkhorn; and a bed 2½ feet thick 340 feet above the Upper Elkhorn.

Hyden (Fire Clay) coal.—A bed probably persistent throughout the Kentucky area, and called the Hyden or Fire Clay bed in the reports of the Kentucky Geological Survey,[2] lies 400 feet above the Upper Elkhorn bed. Its thickness appears to be generally 3 to 4 feet, but it reaches a thickness of over 6 feet on Meadow Fork in the western part of the quadrangle. A persistent parting of flint clay renders its identification certain over a large area in eastern Kentucky. As it occurs high in the hills, it underlies comparatively small areas. At

[1] Stone, R. W., op. cit., p. 37.
[2] Kentucky Geol. Survey Bull. 13, 1912.



SECTIONS SHOWING CORRELATION OF POTTSVILLE FORMATION ALONG THE EAST SIDE OF THE APPALACHIAN COAL FIELD.

the points examined there is a thin bed above and another below the Hyden bed, and reports indicate that these beds are also persistent.

Fortunately, all these beds above the Upper Elkhorn are exposed along the new highway between Elkhorn Creek and McRoberts, and the part of the generalized section in Kentucky including them is taken directly from this road section.

Above the Hyden bed lie 500 feet of strata which are mostly sandstone, in places finely conglomeratic. The conglomeratic phase was seen only in certain bowlders, and, to judge from the distribution of these bowlders, the small quartz pebbles occur in pockets at some horizon high in the mass. The ridges in the northwest part of the quadrangle are capped by this sandstone, which in many places makes a cliff.

GENERAL CORRELATION OF THE FORMATIONS.

From incomplete paleobotanic studies David White refers all the coal measures of Virginia and easternmost Kentucky and the region southwestward into Alabama to the lowest division or Pottsville group of the Pennsylvanian series. The type location of the Pottsville group is Pottsville in the southern anthracite field of Pennsylvania. The Pottsville is for convenience subdivided by White into lower, middle, and upper Pottsville, the subdivisions being based primarily on the presence in each division of certain distinctive species of fossil plants. Some of the subdivisions of the Pottsville may be distinguished over large areas by lithologic characters, as, for example, the Lee formation in Virginia and Tennessee, which is shown by the paleobotanic evidence to coincide nearly if not completely with the lower Pottsville. In localities where the subdivisions are not lithologically distinct the boundary between any two may be marked by a particular stratum which is widely identifiable, especially where one of the formations marks an extension of the sea over the land. Thus throughout the southern part of the Virginia and West Virginia coal fields the boundary between the lower and middle Pottsville as paleobotanically determined is approximately marked by the Raleigh sandstone. Where lithology fails as a criterion for fixing boundaries or where localities are widely separated, as those in different coal fields or basins, it is necessary to resort to the fossil plants.

The probable stratigraphic equivalence of the Pottsville formations and coal beds in the Pound quadrangle to those of other areas along the eastern border of the Appalachian coal field is indicated in the plate of sections (Pl. X). In this plate the correlations of formations and beds between districts or basins distant from the Pound quadrangle are based on partial studies of the fossil floras by White, and are regarded by him [1] as provisional and subject to revision when either

[1] White, David, Appalachian coal field: U. S. Geol. Survey Prof. Paper 71, pp. 430–455, 1912.

the paleobotanic material of the formations is more completely studied or, where possible, the beds are stratigraphically traced from point to point in detail and the depositional characteristics of the formations are more fully recognized. The correlations of the formations and beds in and near the Pound quadrangle are made by the present writer.

As already noted, the Lee formation is lower Pottsville. This formation extends southwestward into Tennessee and is equivalent to the Lookout and the greater part of the Walden sandstone of southern Tennessee. Northeastward the Lee corresponds to the Pocahontas, Welch, and Raleigh formations of the Tazewell quadrangle; to the Pocahontas, Clark, Quinnimont, and Raleigh formations of the Pocahontas quadrangle; to the Thurmond, Quinnimont, and Raleigh formations of the Raleigh quadrangle; and approximately to the lower 800 feet of the Pottsville of the southern anthracite field of Pennsylvania, including "Lykens No. 4" coal.

The Norton formation is classed by White as middle Pottsville, and the overlying Gladeville sandstone is regarded by him as probably near the horizon of the Corbin conglomerate lentil of the Lee formation as the strata are mapped in the London folio, the London quadrangle lying in Kentucky 75 miles due west of the Pound quadrangle. The Gladeville seems to represent the Slater sandstone member of the Mingo formation of the Cumberland Gap region, and lies within the limits of the Wartburg sandstone in the Wartburg quadrangle, Tennessee. Northeastward the Gladeville is supposed to be represented by the Dotson sandstone of the Tazewell quadrangle and the Nuttall sandstone lentil at the top of the Sewell formation in the Raleigh quadrangle. The Sharon conglomerate member of the Pottsville (upper Pottsville) of western Pennsylvania is also regarded as lying at about the same stratigraphic horizon, though it is thought that it may be higher. It is not maintained that the sandstone strata at the different points are parts of one continuous stratum or that they are exactly at the same stratigraphic horizon and of precisely the same age, but it is fairly well established on stratigraphic and paleobotanic grounds that they do not vary greatly from the same horizon and age throughout.

Southwestward from the Virginia coal field the Norton formation is represented by beds between the Rockcastle conglomerate member and the base of the Corbin conglomerate lentil of the Lee formation as mapped in the London folio; by the Hance and the lower three-fifths of the Mingo formation of the Cumberland Gap region, and by the Briceville shale and possibly by the lower part of the Wartburg sandstone of the Briceville and Wartburg quadrangles, in Tennessee. Northeastward the Norton correlates with the Dismal and Bearwallow formations of the Tazewell quadrangle; with all the Sewell formation below the Nuttall sandstone lentil in the Raleigh quadrangle, and with that part, 200 feet thick, of the Pottsville of the southern anthracite field extending roughly from 370 to 570 feet below the Buck Mountain coal bed and including the Lykens coal beds Nos. 2 and 3 near the middle.

The Wise formation is shown by the fossil plants to be upper Pottsville. It represents the greater part at least of the Breathitt formation of the London quadrangle of Kentucky. It also represents the Bryson, Hignite, Catron, and probably the upper two-fifths of the Mingo formation of the Cumberland Gap field, and the upper part of the Wartburg sandstone, with the Scott shale, and the greater portion, at least, of the Anderson sandstone of the Wartburg and Briceville quadrangles. Beds of Wise age are also included in the Sequoyah and Tellowa formations of the Tazewell quadrangle, the Kanawha formation of the Raleigh quadrangle, and in the upper 370 feet of the Pottsville of the southern anthracite field, Pennsylvania. The Kanawha formation, which together with the Nuttall sandstone lentil of the Sewell formation presents the most typical section of the upper Pottsville in southern West Virginia, apparently represents also the equivalent of the lower part of the Harlan sandstone of the Estillville quadrangle.

STRUCTURE.

GENERAL FEATURES.

By geologic structure is meant the "lay" or attitude and arrangement of the rocks considered as extensive strata composing the earth's crust. Stratified rocks are deposited in a nearly horizontal attitude. Over most of the area of the Pound quadrangle, however, they are not now horizontal but are very gently inclined, though in some places, as along the west escarpment of Pine Mountain, they dip steeply. There are also breaks, called faults, which extend to great depths and along which the strata on one side have been raised to higher levels than the corresponding strata on the other side or even thrust over on top of them.

In the great period of movement during which the rocks of the Appalachian region were tilted and broken, a large wrinkle or anticline was produced along the eastern side of the coal region, about 20 miles west of the margin. The rocks lying between this wrinkle and the margin of the field were compressed into a troughlike synclinal fold which extends from northern Tennessee to Big Sandy River. Toward the northern extremity the fold is less pronounced than it is farther to the southwest, and in the Pound quadrangle it is so broad and flat as to be scarcely recognizable.

The great upward wrinkle or anticline that bounds this trough on the northwest was compressed so severely that the rocks broke, forming a fault. In the Pound quadrangle this fault and the inclined strata bounding it on the east are the dominating features of the geologic structure. Northwest of the fault the rocks are comparatively undisturbed, and they lie approximately in the horizontal attitude in which they were deposited.

FOLDS AND FAULTS.

Pine Mountain fault.—The Pine Mountain fault is the major structural feature of the region. It extends in a nearly straight line diagonally across the quadrangle, near but somewhat above the west base of Pine Mountain in Kentucky. The fault is compound. There are two breaks, which, for the purpose of description, may be conceived as having occurred at different times. By the earlier break a thin wedge of conglomeratic sandstone extending several miles both northeast and southwest of Jenkins was thrust into contact with rocks 1,200 feet higher than the top of the Lee. Also in the northeastern corner of the quadrangle and extending a mile beyond its edge a mass of hard siliceous conglomeratic sandstone (Lee) that lies in a vertical attitude has been pushed, probably by the earlier fault, half a mile westward over flat-lying rocks stratigraphically 1,000 feet, at least, above the top of the Lee. Later another break occurred along which the displacement differs. On the west side of the quadrangle the Mississippian part of the Grainger shale is in contact with the wedge of the Lee, brought up by the earlier fault; 3 miles east of the west margin the fault brings the black Devonian shale into contact with the Lee, and in the northeast quarter of the quadrangle the movement was so great that the upper 800 feet of the black shale has been thrust over the earlier fault plane and is in contact with Pennsylvanian rocks 2,000 feet above the base of the Lee, the total displacement here being about 4,000 feet. Sections A–B, C–D, and E–F (Pl. X) illustrate the structural and stratigraphic relations brought about by these faults.

Pound syncline.—From Pine Mountain the rocks dip southeastward to an axis following the general course of Pound River, and named the Pound syncline. The southeastward dip on the west escarpment of Pine Mountain is generally steep, but ranges from 20° to nearly vertical. Along the crest of Pine Mountain the dip is 20° to 40°. At the east base it is 10° and diminishes thence gradually to zero at the axis of the Pound syncline.

Buck Knob anticline and Indian Creek syncline.—In the southeastern part of the quadrangle south of the Pound axis the rocks in general dip northwest to that axis, but near Buck Knob the general northwest dip is interrupted by a subordinate anticline that extends nearly north and south through Buck Knob and is called the Buck Knob anticline. The existence of this low anticline involves a corresponding syncline, the axis of which is parallel to the anticline and to Indian

Creek, which lies one-half to 1 mile to the west. This syncline is here named the Indian Creek syncline. On the east side of this syncline steep dips occur locally. At Glamorgan the dip is 10° W., and three-fourths of a mile north, at the intersection of the highway with the tramroad, it is 40° W. On the west side of Indian Creek, 5 miles above the mouth, the Clintwood coal and overlying sandstone dip 10° W. On the Buck Knob axis north of the knob the Bolling coals are about 2,200 feet above sea level; on the Indian Creek axis they are about 2,000 feet, the eastward dip being 200 feet in 2 miles; and on the Pound axis, west of Dewey, the same coals are about 1,900 feet above sea level, giving a west dip from the Buck Knob to the Pound axis of 300 feet. Apparently both the Indian Creek and Buck Knob folds flatten out and become imperceptible to the east of Dewey; southward both axes rise but maintain the same relative position, the Bolling coals on the south margin of the quadrangle being as nearly as can be determined 2,700 feet above sea level on the Buck Knob anticline and 2,500 feet in the Indian Creek syncline.

SUMMARY.

Aside from these comparatively subordinate folds, the general structure of the part of the quadrangle which lies in Virginia is that of a broad and comparatively shallow unsymmetrical trough. At the southeast corner of the quadrangle the Gladeville sandstone is 2,500 feet above the sea and descends thence to about 1,500 feet above the sea along the Pound axis, the average dip being about 1°. Along the crest of Pine Mountain the Gladeville would, if restored, lie 5,000 feet above sea level, so that the total dip is 3,500 feet from the crest of the mountain to the axis of the Pound syncline, an average dip of 18°.

In Kentucky the rocks dip gently and nearly uniformly northwestward about 300 feet from the base of Pine Mountain to the northwest corner of the quadrangle, as shown by a great number of spirit-level determinations on the Upper Elkhorn coal beds. The elevation of this bed is 1,600 feet above sea level along the west side of the Pine Mountain fault, except in the extreme southwestern corner of the Kentucky area, where it drops to less than 1,500 feet. Low domes on which this bed rises to 1,640 and 1,720 feet occur between Cane and Joes branches, and also near the mouth of Marshall Branch, but with these exceptions it dips with a nearly uniform gradient to about 1,350 feet above sea level on Rockhouse Creek, in the northwest corner of the quadrangle.

DETAILED DESCRIPTION OF THE COAL BEDS.

On account of the uncertainty of correlation between the parts of the quadrangle that lie in Virginia and Kentucky the coal beds of the two areas are separately described.

COAL IN THE VIRGINIA AREA.

A comprehensive idea of the number, thickness, and sequence of the coal beds in the Virginia part of the Pound quadrangle can be obtained by an examination of the generalized columnar section for that area (Pl. X, p. 178).

COAL BEDS OF THE LEE FORMATION.

In this area very little is known of the coal beds of the Lee formation, which outcrop only along the southeast slope of Pine Mountain. Elsewhere they are buried deeply beneath overlying formations and have been penetrated at only one point by a diamond drill. On the outcrop along the eastern slope of Pine Mountain the surface is heavily timbered. No prospecting appears to have been done in this unfavorable belt, and, as natural exposures of the coal beds are few, opportunities to examine the beds are very rare indeed. Only on the Pound Gap road, where the formation has been exposed in road making and by the wear incident to a highway, was any coal seen in outcrop.

However, considerable coal is known to exist in the Lee in beds 14 inches or more thick and at depths not exceeding 2,000 feet. The most definite knowledge of the number, thickness, and stratigraphic relations of these beds is derived from the record of a drill hole on Cranesnest River, 1 mile east of the quadrangle and a short distance below the mouth of Lick Creek. (See section 1, Pl. IX, p. 170, in which details of the beds are shown.) In this well a coal 2 feet 6 inches thick is shown near the base of the Lee and eight beds 2 inches to 2 feet 2 inches thick are shown within the Lee. Six of these beds are grouped in the 300 feet just below the middle of the formation. As shown in Plate X, the Pocahontas coal appears to be represented in this group of beds.

On the Pound Gap road five beds are exposed. In the well section the greater number of beds is grouped just below the middle of the formation. In the road section the greater number, so far as shown, seems to be above the middle of the formation.

The lowest bed in the Pound Gap road section is imperfectly exposed 500 feet east of the summit at location 1.[1] It is about 200 feet above the base of the Lee and has a thickness of 2 feet 6 inches. Farther down on the east slope of the mountain, near the abandoned narrow-gage railroad station, four beds are exposed at locations 2, 3 4, and 5. At locations 2 and 3 the following sections were measured:

[1] Numbers refer to locations on the map (Pl. XI, p. 220).

Sections of coal bed on Pound Gap road.

Location 2.

	Ft.	in.
Coal, dirty		6
Clay		1
Coal, dirty		8
Clay, white.		
	1	3

Location 3, at narrow-gage railroad station.

	Ft.	in.
Shale and sandstone	10	
Clay, carbonaceous		7
Coal		3
Clay		2
Coal		2
Shale	20	
Total coal		5

The carbonaceous clay at this point is crowded with fern pinnules.

At location 4, which is 500 feet nearly east of location 3, a bed has been prospected superficially and 18 inches of clean coal was exposed. This bed is probably but a short distance above the bed at location 3. At location 5, near location 4, another bed 3 inches thick and 20 feet above the bed at location 4 is exposed.

COAL BEDS OF THE NORTON FORMATION.

General character.—The coal beds of the Norton formation are the principal beds mined along the southern margin of the Virginia coal field from Dump Creek to Big Stone Gap, but in the Pound quadrangle they are not so well developed as farther south. This feature is shown by diamond-drill borings in the southeast part of the quadrangle and by such few exposures as are known along the outcrop of the formation between Pound River and Pine Mountain.

Sections of the diamond-drill borings are shown on Plate IX (p. 170). The wells are too few and too widely separated to give full information regarding the coal beds, but they seem to afford a fairly reliable indication of the general condition and possible value of the Norton coal beds in the eastern half of the quadrangle. They reveal a great number of coal beds, but most of them are only a few inches thick. Every well, however, shows one or more beds 14 inches or more thick and less than 1,000 feet below the surface. In a few borings thicker beds were penetrated, for example, a bed 2 feet 10 inches thick at a depth of 629 feet in well No. 2; a bed 4 feet 3 inches thick at 832 feet in well No. 3; a bed 2 feet 5 inches thick at 847 feet in well No. 11; and a bed 7 feet 1 inch thick at 351 feet in well No. 15, which is, however, 2 miles east of the quadrangle. Details of the section of the thicker beds are shown in the figures. The ultimately workable coal is therefore considerable, although such coal will not be available until after the exhaustion of the thicker and more easily accessible coal beds of the country.

Correlation.—The identification of the individual coal beds of these sections and their correlation with the beds of the Norton formation along the southern margin of the field, where they seem to be more constant in number and position, are rather uncertain. For the purpose of comparison with the better-known section to the south the generalized (average) section from the Bristol folio is given on Plate IX (p. 170). The tentative correlations are indicated by the broken lines on Plate X. The sections are arranged on the horizon of the bottom of the Gladeville sandstone, which is identified throughout the region with a reasonable degree of certainty. All the coal beds recognized in the Toms Creek region appear to be present in the Pound quadrangle, except the Upper Banner, which is the most important bed in the Toms Creek region. The Jawbone and so-called Imboden beds appear to be persistent but thin. There are two persistent beds 100 feet apart in proximity to the horizon of the Kennedy coal, and it is uncertain which is the true Kennedy. The Lower Banner is persistent and at some points has considerable thickness, as in boring No. 3, but more generally it is thin or so broken by partings as to be worthless. In boring No. 3 the section is as follows:

Section of Lower Banner coal in drill hole No. 3, Birchfield Creek.

	Ft.	in.
Shale.		
Coal	3	6
Clay		3
Coal		6
	4	3

In boring No. 8 the bed is 3 feet 6 inches thick, but the coal is intimately mixed with shale and is probably worthless.

It is possible that the persistent group of thin coal beds below the Edwards coal or group represents the Upper Banner, which is separated from the Lower Banner by more than twice the thickness of rocks separating the two beds on the southern outcrop of the Norton formation. If this rather doubtful supposition is correct, the 7-foot bed in boring No. 15 might be regarded as representing the Upper Banner coal.

The upper group of thin beds represents the Edwards or, as is supposed, the horizon of the true Imboden coal. In boring No. 3 this group is 3 feet thick with a thin parting; elsewhere it is widely parted.

Outcrops.—At only a few places in the quadrangle or just outside its eastern and western margins were exposures of any of the coal beds of the Norton formation seen. On Rumley Branch, about 2 miles north of Flat Gap, at location 6, a bed of clean coal 2 feet thick has been opened and worked on a small scale. About 2 miles south of Osborns Gap, toward the eastern side of the quadrangle, at locations 7, 8, and 9, coal 18 inches in thickness is exposed, and about 1 mile farther east, at location 10, a blossom indicates a thin coal. All these coal beds seem to lie in the lower half of the Norton formation.

On Cumberland River, one-half mile beyond the western margin of the quadrangle, a bed of clean coal 30 inches thick has been worked on the Ira Sturgill place. On Pine Creek, three-fourths of a mile west of the east boundary of the quadrangle, at location 11, a bed 1 foot 9 inches thick is exposed at creek level. These outcrops occur apparently near the middle of the Norton formation and the bed possibly represents one of the Banner coals.

On North Fork of Pound River, about 1 mile west of Donkey, at location 12, a bed is opened that has the following section:

Section of coal bed 1 mile west of Donkey, at location 12.

	Ft.	in.
Shale.		
Coal		10
Bone		3
Coal	1	9
Sandstone.		
	2	10

At location 13, one-half mile west of location 12, two thin coal streaks are exposed in the bottom of a ravine. These coals appear to be 150 to 200 feet below the Gladeville sandstone and therefore at the horizon of the Edwards or Imboden coal.

Yellow Creek coal.—One-half mile beyond the western margin of the quadrangle a coal bed is exposed just beneath the Gladeville sandstone. The same bed is exposed at the schoolhouse one-half mile west of Flat Gap (location 14). The sections at these localities are as follows:

Sections of Yellow Creek coal bed.

One-half mile west of quadrangle on Cumberland Valley road.	Ft.	in.	At schoolhouse on Cumberland River one-half mile west of Flat Gap (location 14).	Ft.	in.
Sandstone.			Sandstone.		
Coal		5	Coal		5½
Clay		1	Shale		2
Coal	2	4	Coal		9
Clay.			Clay.		
	2	10		1	4½

The same bed has also been opened on a small stream at a point 1 mile northeast of Flat Gap (location 15) but could not be seen. It has also been exposed in grading the railroad along North Fork of Pound River at a point 2 miles southwest of Donkey (location 16), where it has the following section:

Section of coal bed 2 miles southwest of Donkey, at location 16.

	Ft.	in.
Coal	1	1
Clay		1½
Coal		6
	1	8½

Other beds.—The only other locality at which Norton coals are known in outcrop sufficiently near this quadrangle to be considered is on the new road between Wise and Clintwood, 1½ miles south of Cranesnest River and one-third of a mile east of the quadrangle margin, where the coal beds have been exposed in grading. Nine coal beds are exposed in a vertical distance of about 350 feet below the Gladeville sandstone, but only one bed, about 250 feet below the sandstone, is of possible workable thickness. Its section is given below:

Section of coal on new Wise-Clintwood road, about 2 miles south of Cranesnest River.

	Ft.	In.
Shale.		
Coal		10
Clay		4½
Coal	1	6
Sandstone.		
	2	8½

The other beds are all thin and worthless. This section is in full agreement with the upper part of the diamond-drill sections.

The facts in hand appear to warrant the conclusion that though the Norton coal beds of this quadrangle are of less value than they are along the southern margin of the Virginia coal field, drilling has demonstrated that there are considerable areas of workable coal in the different beds underlying this area. Exploitation of these coals, however, can only be safely undertaken after the location and extent of the workable areas have been determined by thorough prospecting with the diamond drill.

COAL BEDS OF THE WISE FORMATION.

The Wise formation contains a greater amount of coal in workable beds than any of the other formations of the quadrangle. The full thickness of the formation is present only in Black Mountain in the southwestern corner of the quadrangle, because east of that area a progressively greater thickness of the formation has been eroded.

Glamorgan coal.—Immediately above the Gladeville sandstone lies the Glamorgan coal bed, named from the town of Glamorgan, located just south of the quadrangle opposite the head of Indian Creek. The bed is best developed in the hills to the north and northeast of Glamorgan. In the Glamorgan mine, which extends 7,000 feet northeastward toward Birchfield and Dotson creeks, the bed is divided into two benches by a parting which is one-fourth inch thick at 7,000 feet from the mouth, 1 inch at 6,000 feet, 10 feet or more at 1,000 feet and 30 feet thick at the mine mouth. At 6,000 and 7,000 feet from the mine mouth the bed has the following section:

Sections of Glamorgan coal bed in the Glamorgan mine.

Section 7,000 feet from mouth.

	Ft.	in.
Shale.		
Coal[1] (one-fourth inch parting near middle)	3	8
Bone		1
Coal[1]		7
Shale.		
	4	4

Section 6,000 feet from mouth.

	Ft.	in.
Shale.		
Coal[2]	1	9
Bone		1
Coal[2]	1	10
Bone		1½
Coal[2]		8
	4	5½

On account of the split described above only the lower bench is mined in the first 1,000 feet along the main entry of the mine, and nowhere else in the quadrangle is the bed known to be so thick as in the deeper part of the Glamorgan mine. On the new Wise-Clintwood road near the eastern margin of the quadrangle (location 17) the bed is 2 feet 1 inch thick.

On Indian, Dotson, and Birchfield creeks and on the forks of Bowlecamp Creek the Glamorgan coal is 1 foot 6 inches to 2 feet 6 inches thick, including partings.

On Birchfield Creek, 2 miles above the mouth of Dotson Fork, at locations 18 and 19, the thickness of the bed is 1 foot 9 inches and 2 feet 4 inches, respectively. On the west side of Indian Creek, three-fourths of a mile below Riley School (location 20), the bed has been opened and shows the following section:

Section of Glamorgan coal on Indian Creek, three-fourths of a mile below Riley School, at location 20.

	Ft.	in.
Shale.		
Clay, with coal streaks		4
Coal	2	
	2	4

The clay with coal streaks in the roof is characteristic of the bed northeast of Pound.

Along the lower course of Indian Creek, in the vicinity of Pound, and on the lower courses of the three forks of Bowlecamp Creek, the Glamorgan bed is split into two or three thin beds of no value. Toward the head of Dotson Fork of Bowlecamp Creek, at locations 21 and 22, it is in better condition, as shown by the following sections, which also show its irregularity in short distances:

Sections of the Glamorgan coal bed near the head of Dotson Fork of Bowlecamp Creek.

Location 21.

	Ft.	in.
Shale.		
Coal	1	6
Shale	8	
Coal		6
Sandstone, Gladeville.		
	10	

Location 22.

	Ft.	in.
Sandstone.		
Coal	2	2½
Shale		2
Coal		2
Clay.		
	2	6½

[1] Included in sample, analysis 15101, p. 218.

[2] Included in sample, analysis 15100, p. 218.

One mile northeast of Pound the bed is barely of workable thickness, but it improves farther northeast along the river, as shown by the sections at location 23, on Mill Creek, 1 mile northeast of Pound, and at location 24, on Camp Creek near its mouth.

Sections of Glamorgan coal bed on Mill and Camp creeks.

Location 23, on Mill Creek.

	Ft.	in.
Shale.		
Coal		6
Clay	1	2
Coal		10½
Bone		2
Coal		3
Clay.		
	2	11½

Location 24, on Camp Creek.

	Ft.	in.
Shale.		
Coal		6½
Clay	1	4
Coal	3	2
Clay		½
Coal		¾
Clay.		
	5	1¾

These sections show the range in thickness and character of the bed in this part of the quadrangle. Its improvement continues northeastward as far as Freeling, about a mile east of the edge of the quadrangle.

Along North Fork of Pound River, southwest of Pound, to a point within 2 miles of Flat Gap post office the presence of the Glamorgan coal is shown by several exposures and openings, but so far as definite knowledge of it could be obtained it is not of workable thickness.

Coal bed 50 to 70 feet above the Gladeville sandstone.—A persistent coal bed lies 50 to 70 feet above the Gladeville sandstone and is generally about 2 feet thick over a considerable area. This bed is exposed on Guest River for a mile north of the quadrangle boundary, on the South Fork of Pound River to the vicinity of Dewey, on the forks of Bowlecamp Creek, and along the new Wise-Clintwood road. Three-fourths of a mile northeast of Dewey (location 25) and at Glady School, at the mouth of Glady Creek (location 26), the following sections were measured:

Sections of coal bed 50 to 70 feet above the Gladeville sandstone.

Location 25.

	Ft.	in.
Shale.		
Coal, dirty		4
Coal, clean	1	3
Coal, bony		7
Clay.		
	2	2

Location 26.

	Ft.	in.
Coal		10
Parting, slaty, thin coal	1	8
Coal, bony		6
	3	

Along South Fork of Pound River, between Glady School and Donkey, at least four coal beds that lie close together appear to occur at about the horizon of the bed here described, but the exact identification is doubtful.

On Mullins Fork, 2½ miles above the mouth, at location 27, this bed seems best developed, as shown by the following section:

Section of coal bed on Mullins Fork, 2½ miles above its mouth, at location 27.

	Ft.	in.
Shale.		
Bone		6
Coal	1	3
Clay	1	2
Coal	1	10
	4	9

Near the head of Dotson Fork of Bowlecamp Creek, at location 28, the bed is 38 inches thick and consists of clean coal, On the new Wise-Clintwood road, at locations 29 and 30, the bed has an upper bench of coal 1 foot 6 inches thick, underlain by thin coal streaks and clay partings 1 to 2 feet thick.

On Guest River, between Lipps and a point a mile northwest along the road, five coal beds dip northward and pass in succession below the road level. By projecting the beds into a plane as nearly as possible according to the dip, the following section is obtained:

Section of coal beds along Guest River road, for 1 mile north of Lipps.

	Ft.	in.
Coal, reported thickness	2	
Sandstone, hard, siliceous	20	
Interval, not exposed	20	
Coal, Clintweed (?)	2	
Sandstone	10	
Shale	10	
Coal, Clintwood split (?)	2	3
Sandstone	15	
Interval, not exposed	10	
Sandstone	5	
Interval, not exposed	20	
Coal, Blair (?)	2	
Sandstone, partly hard, siliceous	40	
Coal, reported thickness 3½ feet (next above Glamorgan bed); thickness seen	2	
	160	3

This section includes the group of coal beds between the Gladeville sandstone and the Clintwood bed (described on p. 174), except that it does not extend down to the Glamorgan coal. This bed, however, shows in the road at the quadrangle boundary one-half mile south of Lipps.

The coal next above the Glamorgan bed is opened at Lipps (location 31), but the opening is partly closed. Two feet of solid coal was seen and the bed is reported to be 3½ feet thick.

Blair coal.—On Lick Branch of Indian Creek, 3 miles above its mouth, a coal bed of good thickness has been opened on the Blair property and therefore named the Blair bed. At this place it has the following section:

Section of Blair coal bed at the Blair opening on Lick Branch of Indian Creek, at location 32.

	Ft.	in.
Shale.		
Coal	2	
Shale	10	
Coal	1	2
Coal, shaly		3
Coal	1	3
Coal, shaly	1	8
Coal	1	
Total coal, lower bed	5	4

There are really two beds here, separated by 10 feet of shale, and it is possible that the lower represents the bed 50 to 70 feet above the Gladeville sandstone previously described, the situation being similar to that on South Fork of Pound River between Glady School and Donkey. (See p. 190.) On McFall Fork, at location 33, the bed is split by many partings, as shown below:

Section of Blair coal bed on McFall Fork at location 33.

	Ft.	in.
Shale, black at bottom.		
Coal		6
Parting		½
Coal		2½
Clay		5½
Coal		11
Bone		2
Coal		3
Clay (2 feet).		
	2	6½

On Mullins Fork, 2½ miles above its mouth, at location 34, the bed has been opened and consists of clean coal 2 feet 2 inches thick. On the new Wise-Clintwood road, at location 35, the following section was measured:

Section of Blair coal bed on the Wise-Clintwood road at location 35.

	Ft.	in.
Shale.		
Coal	1	2
Clay	1	6
Coal		7
	3	3

In the southeast portion of the quadrangle this bed is 2 to 5 feet thick, including partings.

On the head of Dotson Fork of Birchfield Creek, at locations 36 and 37, the Blair bed is over 5 feet thick and its section is very similar to that at the Blair opening (location 32), described above.

On Guest River just north of Lipps, at location 38, the bed is composed of clean coal 2 feet or more thick. (See section, p. 191.)

Clintwood coal bed.—The Clintwood coal is a thick bed throughout the region bounded roughly by Pound River and Birchfield and Indian creeks and extending eastward to Clintwood, 2 miles east of this quadrangle, from which place the bed takes its name. It persists as a thinner and parted bed over the rest of the quadrangle, where the rocks at its stratigraphic horizon have not been eroded. It is thickest on Georges and Lick forks, where it is made up of two or more benches of coal separated by clay partings, some of which are 1 foot or more thick. In other parts of the quadrangle it seems to be split into two distinct beds separated by a considerable thickness of shale and sandstone. It everywhere maintains a nearly uniform distance of 200 feet above the Gladeville sandstone, and over a large part of its area it is overlain by a hard siliceous sandstone by which its outcrop may be determined.

The bed has been extensively prospected by the Clinchfield Coal Corporation throughout the area of its best development. A few sections out of many are given below to show its thickness and character. On the head of Lick Fork, at location 39, the bed is 15 feet thick, as shown below:

Section of Clintwood coal bed on head of Lick Fork, at location 39.

	Ft.	in.
Shale.		
Coal and bone		3
Coal	1	2
Clay (average)	1	3½
Coal	3	1½
Clay		1½
Coal		3½
Bone		2½
Coal	6	10¾
Shale		9½
Coal	1	3½
	15	5¼

This appears to be about the maximum thickness of the bed.

The general condition shown by the section just given holds for the Georges Fork region, although there is considerable range in the total thickness of the bed and in the number and thickness of its component parts. The clay partings in this region are a serious detriment to the value of the bed. North of the ridge north of Georges Fork the bed decreases in thickness and deteriorates in general character as shown in the following two sections:

On a small stream just east of Camp Creek, at location 40, and on Pound River, 1¼ miles south of Phipps, at location 41, the bed is made up as follows:

Sections of Clintwood coal bed east of Camp Creek and 1¼ miles south of Phipps.

Location 40, west of Camp Creek.

	Ft.	in.
Sandstone.		
Coal		10
Clay		10
Coal	1	8
Clay		½
Coal		4
Clay		½
Coal	1	5
Clay.		
	5	2

Location 41, 1¼ miles south of Phipps.

	Ft.	in.
Shale.		
Coal	1	4
Clay	3	2
Coal		9
Clay		1
Coal		9
Clay.		
	6	1

The bed is thus of less value at location 41 than at location 40.

North of Birchfield Creek, 1½ to 2 miles west of the quadrangle boundary, at locations 42 and 43, the bed is in good condition and is immediately overlain by sandstone.

Section of Clintwood coal bed north of Birchfield Creek and 1½ miles west of quadrangle boundary, at location 42.

	Ft.	in.
Sandstone (40 feet).		
Coal		8½
Clay		½
Coal	3	2½
Clay		½
Coal		2
Bone		4
Clay	1	6
Coal	1	
Clay		5
Coal		2
Bone		1½
Coal		1½
Bone		1½
Coal		8
Clay (5 feet).		
	8	7½

The bed at this point carries 3 feet 11 inches of workable coal at top, the remainder of the bed being practically worthless.

At location 43, 1½ miles southwest of location 42, the bed is 3 feet 10 inches thick and has a clay roof and floor.

Surface indications of the Clintwood bed were seen at a number of places in the southeastern corner of the quadrangle south of Birchfield

Creek and on its headwaters, but no good exposures were found from which its thickness and character could be determined. It rises to the top of the ridges and knobs in the southeast corner. On Indian Creek, 3 miles above its mouth, at location 44, the bed is directly overlain by heavy sandstone, is broken by many partings, and is about worthless.

Section of Clintwood coal bed on Indian Creek, 3 miles above its mouth, at location 44.

	Ft.	in.
Sandstone.		
Coal	2±	
Clay	1	9
Coal		6
Clay		1
Coal		3
Clay		5
Coal		3
Clay		6½
Coal		6
Clay (?).		
	6	3½

Another bed, 1 foot or more thick, that may be split from the Clintwood, lies 30 feet below the bed shown in the preceding section.

In all the region west of Indian Creek and on Pound River southwest of Pound, the Clintwood bed, including partings, is generally a little over 3 feet thick and commonly has a 2-foot bench of solid coal. At location 45 just west of Donkey, the Clintwood shows the following section:

Section of Clintwood coal bed just west of Donkey, at location 45.

	Ft.	in.
Sandstone.		
Coal	1	11
Clay		10
Coal		10
	3	7

At this place the bed lies in the bottom of the Pound syncline, which here forms a narrow trough, the southeast limb of which dips 30° NW.

On North Fork of Pound River, three-fourths of a mile northeast of Flat Gap post office, at location 46, the Clintwood bed has been opened and is reported 18 inches to 2 feet thick, but it could not be seen. Near the west margin of the quadrangle, one-half mile south of Cumberland River in Kentucky, at location 47, the Clintwood bed has been opened and shows the section given below. On Guest River, three-fourths of a mile north of Lipps, at location 48, the Clintwood seems to be represented by two beds 20 feet apart under heavy siliceous sandstone, as shown in the following section.

Sections of the Clintwood coal bed at locations 47 and 48.

Location 47, one-half mile south of Cumberland River near west margin of quadrangle.

	Ft.	in.
Shale.		
Coal	2	
Clay		2
Coal		3
Clay		1
Coal		7
Clay (1 foot exposed).		
	3	1

Location 48, on Guest River, near Lipps.

	Ft.	in.
Sandstone	30	
Coal	2	
Shale and sandstone	20	
Coal	1	
Clay		1
Coal	1	2
Clay (3 feet).		
	54	3

The Clintwood bed has been opened at several places on the east branch of Guest River, but it is apparently thin and of little value.

The general chemical composition of the Clintwood coal was not well determined because there was no opportunity in the quadrangle to collect unweathered samples for analysis. Samples were collected from working banks at Clintwood and southward, the analyses of which are given as Nos. 14766 and 14767 in the table on page 218. These analyses show a high-grade coal.

Coal bed at top of sandstone above Clintwood coal.—Locally a workable coal bed occurs at the top of the sandstone above the Clintwood coal. It is generally a thin bed, for ordinarily only shale is seen in the 200 feet above the sandstone. The best development of this bed, so far as observed by the writer, is on Mullins Fork, at location 49.

Section of coal bed on the west side of Mullins Fork, at location 49.

	Ft.	in.
Coal		6+
Clay	1	
Coal	2	
	3	6+

This bed shows on the hilltops near Hurricane, on the new Wise-Clintwood road, but no good section of it was obtained. It is also exposed on the road west of Flat Gap post office near the west side of the quadrangle, at location 50, where it is 2 feet thick.

Thin coal.—On the head of North Fork of Pound River about 1 mile southwest of Flat Gap post office, at location 51, a coal bed about 150 feet above the Clintwood and 1 foot thick has been opened on a small scale.

BOLLING COAL BEDS.

The names Upper and Lower Bolling are here applied to two beds 20 to 40 feet apart, the upper one of which is also known as the Five-foot coal. The Lower Bolling is 250 to 300 feet above the Clintwood bed. The name is adopted because one or both beds are worked at several places in the southwestern part of the quadrangle by members of the Bolling family. The beds underlie an unbroken area of about 25 square miles in the quadrangle west of Guest River and south of North Fork of Pound River. They also underlie an extensive area in the Buck Knob region and a number of smaller areas on the high knobs east of Indian Creek and south of Georges Fork. In the areas east and northeast of Indian Creek the beds are generally in their best condition.

Sections fairly typical for this region were measured north of the head of McFall Branch, at location 52.

Section of Bolling coal beds north of head of McFall Branch, at location 52.

Upper bed.

	Feet.
Shale (5 feet).	
Coal	4
Clay.	
Interval 40 feet.	

Lower bed.

	Ft.	in.
Shale (4 feet).		
Coal	3	4
Bone		3
Clay.		
	3	7

These coal beds are present on the high hills between the heads of Indian and Birchfield creeks, probably on other knobs in the southeast corner of the quadrangle, and on the high knob between the two branches of Guest River southeast of Pinnacle Gap.

Between Indian Creek and Guest River in the Buck Knob region one or both of the coal beds are of good thickness, except on the long spur north of Buck Knob. Between Indian and Glady creeks, at location 53, the beds are exposed as shown below:

Section of Bolling coal beds between Indian and Glady creeks, at location 53.

Upper bed.

	Ft.	in.
Shale.		
Coal		3½
Shale	1	6½
Coal		½
Shale		5
Coal	3	4½
Interval 18 feet.		
	5	8

Lower bed.

	Ft.	in.
Shale.		
Coal	3	
Clay		5
	3	5

The upper bed shows shale and coal in the upper part, a feature that is common in the bed farther west.

On the spur north of Buck Knob, at location 54, a number of pits on both beds show only 1 to 2 feet of coal. This condition is shown in the following section, which may be regarded as typical for the locality:

Section of Bolling coal beds on spur north of Buck Knob, at location 54.

	Ft.	in.
Coal, upper bed	1±	
Interval 18 feet.		
Coal, lower bed	1	5
Clay.		
	2	5±

South of Buck Knob the Upper Bolling bed changes to a somewhat "rashy" and laminated character in its upper part, as shown by the following section, measured at location 55:

Section of Upper Bolling coal bed 2 miles southeast of Buck Knob, at location 55.

	Ft.	in.
Shale.		
Coal, laminated	1	3
Coal, soft, shaly		3
Coal, hard, bright	2	
Clay.	3	6

At this place a bed reported to be 18 inches thick lies 70 feet below the Upper Bolling. This is probably the Lower Bolling, but the distance between them is abnormally large.

On the upper courses of both North and South forks of Pound River the Bolling coal beds are of fair thickness and quality, the upper bed being about 4 feet and the lower bed 2½ feet thick.

At J. E. Bolling's place, 1½ miles west of Dewey (location 56), both beds are opened and have the following section:

Section of Bolling coal beds 1½ miles west of Dewey, at location 56.

Upper bed.	Ft.	in.	Lower bed.	Ft.	in.
Shale.					
Coal	2		Coal	2	6
Coal, bony		2	Shale.		
Coal	1	9			
Interval 20 feet.	3	11			

At location 57, about 1 mile southwest of Flat Gap post office on the land of W. A. Bolling, both beds have been opened and show the following sections:

Section of Bolling coal beds on W. A. Bolling's land, about 1 mile southwest of Flat Gap post office, at location 57.

Upper bed.	Ft.	in.	Lower bed.	Feet.
Shale.				
Coal and bone		4	Coal (reported 3 feet exposed)	2
Clay		6		
Coal	1	6		
Clay		½		
Coal	1	7½		
Shale 15 feet.	4			

On the west side of the quadrangle, 1 mile south of Cumberland River, in Kentucky, at location 58, both beds have been opened, but only the lower bed was accessible.

Section of the Lower Bolling coal bed on the J. H. Mullen estate, on west side of quadrangle, 1 mile south of Cumberland River, in Kentucky, at location 58.

Upper bed.

	Feet.
Coal (reported 3+ feet exposed)	2

Lower bed.

	Ft.	in.
Coal [1]	2	3
Clay		2
Coal [1]	1	6
Clay		4
Coal [1]		4
	4	7

On Powell River, on the south margin of the quadrangle, at location 59, a bed believed to be one of the Bolling coals has been opened and shows the following section:

Section of one of the Bolling coal beds on Powell River, near margin of quadrangle, at location 59.

	Ft.	in.
Shale.		
Coal		8
Clay		1
Coal	1	8
	2	5

On account of their extent and comparative uniformity as workable beds throughout, the Bolling coals rank among the most valuable coal beds of the Virginia part of the Pound quadrangle.

STANDIFORD COAL BEDS.

The Bolling coals are succeeded above by 260 feet of barren shale and sandstone. On South Fork of Pound River a thin coal bed 80 feet above the Bolling coal was seen at two places, but east of Indian Creek a fully exposed section extending 150 feet above the Bolling coal beds is without coal and no bed of value is known anywhere in the interval.

The Standiford coal beds are named from a man named Standiford, who has worked both beds on South Fork of Pound River. The beds are 20 feet apart at the type locality and constitute a pair in all respects similar to the Bolling coals.

The Standiford coal beds are present only in the Buck Knob and Black Mountain regions west of Guest River, and their area is therefore much less than that of the Bolling beds.

On the David Sturgill place at the head of South Fork of Cumberland River, at location 60, the Lower Standiford bed is worked. At this bank the bed has a shale roof and clay floor and consists of 3 feet 2 inches of clean coal. The analysis of a sample representing the entire bed is given as No. 15172 in the table on page 219. A few rods east of the Sturgill bank, at location 61, is an opening into the Upper

[1] Included in sample, analysis 15173, p. 219.

Standiford bed, in which the coal is 2 feet 6 inches thick and has a sandstone roof and clay floor. The beds here are about 20 feet apart.

At the Standiford place on South Fork of Pound River, at location 62, the upper bed is opened on the east side and the lower on the west side of the valley.

The lower bed at this point has a thickness of 31 inches of clean coal and the upper bed has the section shown below:

Section of the Upper Standiford coal at the Standiford place, on South Fork of Pound River, at location 62.

	Ft.	in.
Shale (6 feet).		
Coal	2	2
Parting		½
Coal		11½
Clay.		
	3	2

A bed identified as the Upper Standiford outcrops about 2,235 feet above sea level on the road both north and south of Fox Gap between Guest and Pound rivers. This bed is 2 to 4 feet thick, including partings, and is underlain by purple shale.

The rocks rise southeastward down Guest River and carry the outcrop of the coal beds upward into the hillsides, which makes it probable that the Standiford coals are among those prospected by the Clinchfield Coal Corporation between the Low Splint (Buck Knob) and Bolling coals on the north and south sides of Buck Knob.

On Critical Fork of Guest River two beds exposed at location 63 are regarded as the Standiford coals, although on account of a rather strong westward dip the distance between them seems greater than that known elsewhere.

Section of Standiford coal beds on Critical Fork of Guest River, at location 63.

Upper bed.	Ft.	in.	Lower bed.	Feet.
Shale.			Shale.	
Bone		3	Coal (exposed)	2
Coal		2		
Clay, bone, and dirty coal		2		
Coal	3	5		
Clay		2		
Coal		3		
Clay.				
Interval 40 ± feet.	4	5		

On Powell River, at location 64, a bed regarded as one of the Standiford coals is exposed in the stream.

Section of one of the Standiford coal beds on branch near head of Powell River, at location 64.

	Ft.	in.
Coal		1
Clay		½
Coal	1	9½
	1	11

It appears from the foregoing account that the Standiford coal beds are of workable thickness throughout the Black Mountain and Buck Knob regions. They should also be present near the summit of Bowlecamp Knob.

TAGGART COAL BED.

About 80 feet above the Standiford coals lies a bed known locally as the Taggart bed, which appears to be the same as the Keokee bed of the Kentucky reports. It has been extensively prospected by the Virginia Coal & Iron Co. on the head of Roaring Fork of Powell River, where it ranges from a bed of solid coal 3½ feet thick to a bed 6 feet thick that contains a shale parting. A bed, supposedly the Taggart, exposed at one place on South Fork of Pound River, at location 65, has the section given below. On the hill south of Critical Fork of Guest River the section of the Taggart bed at location 66 is also given.

Sections of the Taggart coal bed.

Location 65, on South Fork of Pound River.

	Ft.	in.
Shale.		
Coal	2	10
Shale	6	
Coal	2	6
Clay.		
	11	4

Location 66, on hill south of Critical Fork.

	Ft.	in.
Shale.		
Bone		3
Coal		11
Clay		2
Coal		10½
Clay.		
	2	2½

On Powell River, at locations 67 and 68, the bed is in good condition, as shown by the following sections:

Sections of the Taggart coal bed on Powell River.

Location 67.

	Ft.	in.
Coal	2	10
Bone		1½
Coal	1	5
	4	4½

Location 68.

	Ft.	in.
Coal	3	7
Shale	10	
Sandstone	10	
Coal	3	
Sandstone	40	
Coal	3	6
Shale and unexposed	10	
Coal	1	
	81	1

A few feet away the upper coal bed of the above section is 4 feet 5 inches thick, all coal. Probably the upper bed is the Taggart and the lower beds are either not present or not exposed in other sections.

On Roaring Fork of Powell River the following sections furnished by the Virginia Coal & Iron Co. have been selected as typical from many others.

Sections of the Taggart coal bed on Roaring Fork of Powell River.

Location 69.

	Ft.	in.
Shale.		
Coal	2	11
Shale	3	10
Coal	2	
Shale		8
Coal		4
Clay.		
	9	9

Location 70.

	Ft.	in.
Shale.		
Coal	4	2
Clay.		

Attention is called to the similarity of the section at location 69 to the section of the same bed at location 65 on South Fork of Pound River.

On Whitley Fork, in the southwest corner of the quadrangle, at location 71, the bed is 37 inches thick.

LOW SPLINT AND ASSOCIATED COAL BEDS.

Low Splint coal.—The name Low Splint is applied by the Virginia Coal & Iron Co. and by the Kentucky Geological Survey to a bed about 220 feet above the Taggart bed.

The Low Splint bed is opened at the George Phillips place, on South Fork of Pound River (location 72), where it shows the section given below. In a ravine a short distance east of the new road north of Fox Gap, at location 73, the Low Splint bed is opened, and the section at this place is also given.

Sections of the Low Splint coal bed at locations 72 and 73.

Location 72, on the George Phillips place on South Fork of Pound River.

	Ft.	in.
Shale.		
Coal	2	1
Clay		1½
Coal		6½
Clay.		
	2	9

Location 73, east of new road north of Fox Gap.

	Ft.	in.
Shale.		
Coal		8
Bone		½
Coal	2	4½
Clay		2
Coal, slaty		3
Coal		9
Clay		3
Coal	1	2
Clay.		
	5	8

A coal bed prospected on Buck Knob by the Clinchfield Coal Corporation and called by it the Buck Knob bed is probably the Low Splint.

On the head of Critical Fork, at location 74, a bed that seems likely to be the Low Splint shows 23 inches of coal that contains a parting and is reported to have also a lower bench.

The Low Splint at an opening south of Powell River (location 75) shows the following section:

Section of Low Splint coal bed south of Powell River, at location 75.

	Ft.	in.
Shale.		
Coal		1
Bone		1
Coal	3	4
	3	6

The Low Splint bed has been thoroughly prospected on Roaring Fork by the Virginia Coal & Iron Co., and two representative sections are given below:

Sections of Low Splint bed on Roaring Fork.

Location 76, on west side.

	Ft.	in.
Shale.		
Coal	1	7
Shale		3
Coal	1	1
Shale		3
Coal		4
	3	6

Location 77, on head of river.

	Ft.	in.
Shale.		
Coal	2	9
Shale.		

Phillips coal.—At the head of South Fork of Pound River, near the house of Ambrose Phillips, a coal bed 260 feet above the Low Splint bed and provisionally named the Phillips bed, has been opened at location 78. It is reported to be a splint coal 2 feet 2 inches thick, all clean coal at this location. On the head of Critical Fork of Guest River (location 79) a bed reported to be 4 feet thick appears to lie at the horizon of the Phillips coal. Near by the same bed is at least 2 feet thick but is not fully exposed. The Phillips coal may be the same as the Dean coal of Kentucky.

Coal bed 80 feet above the Phillips coal.—At the Phillips place (location 80) an 18-inch bed not observed elsewhere occurs 80 feet above the Phillips coal.

Coal bed 215 feet above the Phillips coal.—At the head of South Fork of Pound River, at location 81, a bed is exposed 215 feet above the Phillips bed. A bed regarded as the same as that at location 81 is exposed on the head of Critical Fork (location 82). The sections at locations 81 and 82 are as follows:

Sections of coal bed 215 feet above the Phillips bed.

Location 81, on head of South Fork of Pound River.

	Ft.	in.
Shale.		
Coal	1	4
Shale		6
Coal		6
Clay		2
Coal	1	7
Clay.		
	4	1

Location 82, at head of Critical Fork.

	Ft.	in.
Sandstone.		
Coal	1	2
Clay		2
Coal, hard	2	
	3	4

PARDEE (LIMESTONE OR PARSONS) COAL BED.

The Pardee coal bed takes its name from the Pardee mine, which lies just beyond the southwest corner of the quadrangle. It is called the Limestone bed in reports of the Kentucky Geological Survey because of the occurrence of a persistent limestone 50 to 100 feet above it to the west of this quadrangle in Kentucky. It is also called the Parsons bed by the Virginia Coal & Iron Co.

The Pardee bed lies 385 feet above the Low Splint bed. It is 7 to 10 feet thick where unbroken by partings but differs greatly in short distances owing to the occurrence of partings of clay or shale which in places attain a thickness of several feet. It underlies only a small area near the top of Black Mountain. It is mined at the Pardee mine and has been very thoroughly prospected around the head of Roaring Fork by the Virginia Coal & Iron Co.

A section of the bed obtained on South Fork of Pound River, at location 83, is as follows:

Section of Pardee coal bed on South Fork of Pound River, at location 83.

	Ft.	in.
Coal	1	6
Clay		3½
Coal	1	7
Clay		½
Coal		7
Clay		3
Coal		½
Clay		½
Coal		4
Clay		1
Coal	1	1½
Clay		2
Coal		11
	6	11½

The following sections, measured at locations 84, 85, and 86, near the head of Roaring Fork, have been selected from those furnished by the Virginia Coal & Iron Co.:

Sections of Pardee coal bed near head of Roaring Fork.

[Furnished by the Virginia Coal & Iron Co.]

Location 84, between Roaring Fork and Powell River.

	Ft.	in.
Shale.		
Coal	2	
Shale	12	
Coal	1	2
Shale	20	
Coal	1	2
	36	4

Location 85, near head of Straight Fork.

	Ft.	in.
Shale.		
Coal	6	6
Shale.		

Location 86, near head of Straight Fork.

	Ft.	in.
Shale.		
Coal	4	6
Shale		7
Coal	2	7
Shale		½
Coal	1	6
Shale		3
Coal	1	9
	11	2½

The Pardee coal is rather hard and its composition is that common to the Virginia and eastern Kentucky coals, as shown by analysis No. 15099 in the table on page 218, which represents the entire bed, 9 feet 7 inches thick.

HIGH SPLINT COAL.

Practically 400 feet above the Pardee bed lies the High Splint bed, well known to the west of this region in Kentucky. It is a genuine splint coal 4 to 5 feet thick, underlying a small area near the top of Black Mountain. On the north side of the mountain at the head of South Fork of Pound River, at location 87, the following section was obtained:

Section of High Splint coal bed at head of South Fork of Pound River, at location 87.

	Ft.	in.
Sandstone.		
Coal	3	4
Bone		1
Coal	1	
	4	5

The following sections, measured at locations 88 and 89, are taken from those furnished by the Virginia Coal & Iron Co. They were obtained in the course of extensive prospecting around the head of Roaring Fork of Powell River.

Section of High Splint coal at location 88, on point of ridge between Powell and Roaring forks.

	Ft.	in.
Shale.		
Coal	2	4
Shale		2
Coal		6
	3	

At the head of the right fork of Roaring Fork (location 89) three sections measured within a distance of 1,000 feet are of interest on account of the irregularity which they exhibit.

Section of High Splint coal at location 89, head of right fork of Roaring Fork.

Section No. 1.

	Ft.	in.
Shale.		
Coal	1	2
Shale	1	2
Coal		2
Shale		9½
Coal	1	10
Shale.		
	5	1½

Section No. 2.

	Ft.	in.
Shale.		
Coal	1	10
Shale	4	9
Coal	1	2
Shale.		
	7	9

Section No. 3.

	Ft.	in.
Shale.		
Coal	4	5

The condition shown by these sections is exceptional.

This coal appears to be of excellent quality and is said to burn very freely. No samples of unweathered coal could be obtained for analysis. Except for the local irregularity shown by the three sections at location 89 the bed is uniform in thickness and character, maintaining a general thickness of 4 to 4½ feet all around the head of Roaring Fork. At only one place does its thickness fall as low as 3 feet 4 inches, except at its extreme southeastern part, where it is thin and much parted, as shown by the section at location 88.

COAL BEDS ABOVE THE HIGH SPLINT BED.

On Black Mountain, at two places at least, coal was seen above the High Splint bed, but the beds were not well exposed and no information was obtained about their thickness or character.

COAL IN THE KENTUCKY AREA.

The number and sequence of coal beds exposed in the part of the Pound quadrangle that lies in Kentucky are shown in the columnar section for Kentucky on Plate XI. The Bingham, Lower Elkhorn, Upper Elkhorn, and Hyden (Fire Clay) beds are the only beds that are named, but several unnamed beds of some value are associated with those that are named.

Bingham coal.—The lowest coal bed exposed in the Kentucky part of the Pound quadrangle, identified as the Bingham bed,[1] is seen at location 124 along the railroad on Shelby Creek, 1 mile south of the north edge of the quadrangle. The bed is here composed of solid coal 2½ feet thick. It is not exposed elsewhere in the quadrangle.

Thin coal beds below the Lower Elkhorn bed.—Along the new railroad to Jenkins, between Shelby Gap and McPeak Branch, two coal beds within 50 feet below the Lower Elkhorn bed are exposed at a few places. The first coal is 10 to 25 feet below the Lower Elkhorn and is 12 to 14 inches thick; the second is about 50 feet below the Lower Elkhorn and, at the place observed (location 125), is 18 inches thick. They were not seen elsewhere.

Lower Elkhorn coal.—The Lower Elkhorn bed is best known along Elkhorn Creek and its western tributaries in the country northeast of McPeak Branch. It dips southwestward under the bed of Elkhorn Creek at the mouth of McPeak Branch and under Middle or Straight Branch of Beefhide Creek 1 mile above the mouth of the branch. It does not outcrop west of a line connecting the points described unless a bed which outcrops on Kentucky River between Holbrook Branch and Laurel Fork is the Lower Elkhorn.

Throughout most of the territory in which the Lower Elkhorn coal outcrops it is 3 to 3½ feet thick and has in the middle a highly characteristic bench of bright, soft, flaky coal of impure composition. On Pigeon Branch, near the north edge of the quadrangle, at location

[1] Stone, R. W., Coal resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull. 348, 1908.

126, the bed is 2 feet 8 inches thick, contains the layer of flaky coal, and is shaly in the middle. At location 127, on Big Branch, 1½ miles southwest of Pigeon Branch, and at location 128, at the mouth of a branch one-half mile south of location 127, the following sections were measured:

Sections of Lower Elkhorn coal bed at locations 127 and 128.

Location 127, on Big Branch.

	Ft.	in.
Sandstone.		
Coal, one-fourth inch layers with "rash" partings		2
Coal		4
Parting		½
Coal	1	3½
Coal, bony		10
Shale, coaly	1	6
	4	2

Location 128, near Elkhorn Creek, 3 miles southwest of northeast corner of quadrangle.

	Ft.	in.
Sandstone.		
Coal		6
Coal, shaly	2	
Coal, bottom not seen		11+
	3	5+

At location 129, on Shelby Creek 2 miles south of the quadrangle edge, the bed is 2 feet 4 inches thick, and at Ratliff's bank on Elkhorn Creek, 5 miles northeast of Jenkins (location 130), the bed is 3 feet thick. The sections at locations 129 and 130 are as follows:

Sections of the Lower Elkhorn coal bed at locations 129 and 130.

Location 129, on Shelby Creek 2 miles south of the quadrangle edge.

	Ft.	in.
Sandstone.		
Coal, laminated	1	3
Coal, irregularly jointed	1	1
	2	4

Location 130, at Ratliff's bank on Elkhorn Creek, 5 miles northeast of Jenkins.

	Ft.	in.
Sandstone.		
Coal [1]		8
Coal, laminated [2]	1	
Coal [1]	1	4½
	3	½

The coal was sampled at this mine, the laminated part and the remainder being sampled separately. At location 132, on Johns Fork 1½ miles south of the quadrangle edge, the Lower Elkhorn bed is 2 feet 9 inches thick and has a 2-inch laminated layer near the middle. On Kentucky River, between Holbrook Branch and Laurel Fork, a bed 2 feet thick and 250 feet below the Upper Elkhorn bed outcrops along the road. This may be the Lower Elkhorn, although its characteristic laminated bench was not observed. A coal, apparently thin and of no value, which shows at water level on Kentucky River and on Boone Fork near its mouth, is possibly also the Lower Elkhorn.

On Straight or Middle Fork of Beefhide Creek, at location 131, a bed 2 feet 8 inches thick lies 220 feet below the Upper Elkhorn coal and apparently has not the laminated bench. This bed may be the

[1] Analysis No. 14970, p. 219. [2] Analysis No. 14971, p. 219.

Lower Elkhorn, but the shorter distance below the Upper Elkhorn and the absence of the laminated bench are features that suggest that it may be the bed 60 feet above the Lower Elkhorn on Elkhorn Creek described below.

Coal bed 60 feet above the Lower Elkhorn coal.—On Elkhorn Creek one-fourth of a mile west of Shelby Gap, at location 133, a thin coal bed 60 feet above the Lower Elkhorn coal is exposed at the top of a railroad cut. A bed about 1 foot thick and about 220 feet below the Upper Elkhorn bed, which shows on Long Fork of Shelby Creek just off the north edge of the quadrangle, and a bed 1 foot thick and about 185 feet below the Upper Elkhorn bed, which outcrops in the bed of Potter Fork, about 1 mile above Boone Fork, at location 134, are referred to the same horizon.

Coal bed 120 feet below the Upper Elkhorn bed.—In a railroad cut at the tipple of Consolidation No. 201 mine a coal 2 feet thick and about 120 feet below the Upper Elkhorn bed is exposed. On Bens Branch, near Consolidation No. 202 mine, at location 135, the same bed has the following character:

Section of coal bed on Bens Branch at location 135.

	Ft.	in.
Sandstone.		
Coal	1	3
Bone		1
Coal, hard		6
Coal		6
Sandstone.		
	2	4

At location 136, on Little Laurel or Fishpond Branch of Kentucky River, this bed outcrops in the same position relatively to the Upper Elkhorn bed and appears to be fairly thick, but more definite knowledge of the bed at that point was not obtainable. On Kentucky River one-half mile below the mouth of Boone Fork, at location 137, a bed 15 inches thick is referred to this horizon, and a 2-foot bed that outcrops on Millstone Creek just east of the edge of the quadrangle is probably the same.

On Pigeon Branch, near location 126 on the Lower Elkhorn bed, a bed of clean coal 4½ feet thick occurs about 150 feet above the Lower Elkhorn bed. This bed appears also to be the same as that 120 feet below the Upper Elkhorn. It is a valuable bed in the Pigeon Creek region and perhaps also westward toward Shelby Creek.

Coal beds 40 and 50 feet below the Upper Elkhorn bed.—On Elkhorn Creek, at the tipple of Consolidation No. 205 mine, and also in a railroad cut near McRoberts, at location 138, two coal beds are exposed below the Upper Elkhorn coal, as shown in the following sections:

Sections of coal beds 40 and 50 feet below the Upper Elkhorn bed.

Tipple of Consolidation No. 205 mine.

	Feet.
Coal, Upper Elkhorn.	
Shale	40
Coal	2
Shale	10
Coal	1
	53

Location 138, near McRoberts.

	Ft.	in.
Coal, Upper Elkhorn.		
Shale	40	
Coal	1	4
Shale	20	
Coal	2	4
Clay	4	
	67	8

The upper one of these beds appears to be 3 feet thick in a road cut on Elkhorn Creek a short distance above No. 205 mine. One of the beds is exposed in a railroad cut near Consolidation No. 204 mine and one has been opened at two places on Pine Creek near the west edge of the quadrangle, at location 139, where it is 28 inches thick and has a sandstone roof and clay floor.

Upper Elkhorn coal.—The Upper Elkhorn is the great coal bed in this part of Kentucky. It ranges from 6 to 8 feet thick over all that part of the area between Shelby Creek and Boone Fork of Kentucky River. West of Boone Fork it decreases in thickness to 4 feet or less on Rockhouse Creek. East of Boone Fork it is nearly everywhere divided near the middle by a soft flaky clay parting that has a maximum thickness of 1 foot. Exceptionally, as at No. 201 mine, this parting is a little more than 2 feet thick. On Rockhouse and Millstone creeks the parting is not present and the bed consists of a single bench.

The 4-foot bed on Rockhouse Creek was regarded by Hodge[1] as a different bed from the Upper Elkhorn, but thorough and continuous prospecting by the Consolidation Coal Co. has shown beyond question that the coal on Rockhouse Creek is the Upper Elkhorn.

A few selected sections given below exhibit the general range of thickness and character of the bed.

Sections of Upper Elkhorn coal bed at locations 140 and 141 and at Consolidation No. 201 mine.

Location 140, near Shelby Gap.

	Ft.	in.
Shale.		
Coal	1	1
Clay		4
Coal	2	9
Clay.		
	4	2

Location 141, at Haynes opening near head of left fork of Marshall Branch.

	Ft.	in.
Shale.		
Coal	1	1
"Rash"		3
Coal	2	6
Clay	1	
Coal	3	
	7	10

Consolidation No. 201 mine.

	Ft.	in.
Shale.		
Shale, cannel		3
Coal	3	4
Clay	1	3
Coal	3	8
	8	6

[1] Hodge J. M., Kentucky Geol. Survey Bull. 11, 1910.

Possibly there is another bench of coal in the section at location 140 below the lower clay, as in the section measured at the Haynes opening.

The lower 15 inches of the bed at the Consolidation No. 201 mine is partly hard splint coal. The occurrence of splint coal in the lower part of the Upper Elkhorn bed prevails widely in the region.

Sections of Upper Elkhorn coal bed in Consolidation No. 204 mine.

Section at mouth of mine.

Shale.	Ft.	in.
Coal	3	10
Clay, 5 to 7 inches, average		5½
Coal	4	3
	8	6½

Section at face of main east entry 1,700 feet from mouth of mine.

	Ft.	in.
Coal [1]	3	7
Clay		3
Coal [1]	3	8½
	7	6½

Section at face of main entry 1,700 feet from mouth of mine.

	Ft.	in.
Coal [2]	4	
Clay		5
Coal [2]	4	
	8	5

Sections of Upper Elkhorn coal bed at various locations.

Location 142, on Laurel Fork of Kentucky River 4½ miles southwest of Jenkins.

Shale.	Ft.	in.
Coal	2	4
Clay		4
Coal	3	4
	6	

Location 143, on bottom Fork of Kentucky River.

Shale.	Ft.	in.
Coal	2	
Clay		4½
Coal	1	2
Clay		3½
Coal	1	8
	5	6

Location 144, on Pine Creek near west edge of quadrangle.

Shale.	Ft.	in.
Coal	2	1
Clay		4
Coal	1	
	3	5

Location 145, on small branch of Millston Creek, 1 mile north of Kentucky River.

Shale.	Ft.	in.
Coal	1	10
Clay		1
Coal	4	9
	6	8

Location 146, at the Isaac Potter opening on Potter Fork.

Shale.	Ft.	in.
Coal	2	
Clay		2
Coal	2	7
Clay		3½
Coal	4	5½
	9	6

At Consolidation No. 214 mine at McRoberts.

Shale.	Ft.	in.
Coal	3	8
Clay		2
Coal	3	4
	7	2

[1] Included in sample for analysis No. 14904, p. 219.

[2] Included in sample for analysis No. 14905, p. 219.

Section of Upper Elkhorn coal bed at various locations—Continued.

Location 147, on west side of Beefhide Creek near quadrangle edge.

	Ft.	in.
Shale.		
Coal	1	6
Clay		5
Coal	3	6
	5	5

Location 148, on Long Fork near north edge of quadrangle.

	Ft.	in.
Shale.		
Coal	3	5
Clay		3½
Coal	2	3
	5	11½

Location 149, on Boone Fork.

	Ft.	in.
Shale.		
Coal	2	1
Clay		2
Coal	3	10
	6	1

Location 150, on Rockhouse Creek at edge of quadrangle.

	Ft.	in.
Sandstone.		
Coal	3	5

Location 151, on Meadow Branch of Millstone Creek.

	Ft.	in.
Shale.		
Coal, clean	4	9

The thickness at the Isaac Potter opening (location 146) seems to be the maximum for the bed in this region.

The Upper Elkhorn is a very high grade bituminous coal, especially adapted to the manufacture of gas. On Elkhorn Creek, according to the analyses of the Consolidation Coal Co., it is uncommonly low in ash. Analyses 14904 and 14905, though numerically inadequate, indicate its probable range of composition. The composition shown in analysis 14904 probably more nearly represents its prevailing character than that shown in analysis 14905.

The principal defect of the bed in this vicinity is its weak roof. Immediately over the coal lies a few feet of soft shale which is very likely to fall with the top coal and which on account of its crumbling character can not be economically separated from the coal. This feature makes it necessary to leave 1 foot to 15 inches of the top coal for roof. It is hoped that a large part of this roof coal may be recovered on the abandonment of the worked-out parts of the mines.

The coal is mined extensively at Jenkins and McRoberts by the Consolidation Coal Co., and most of the output is shipped to Michigan for consumption in by-product coke ovens. It seems to be excellently adapted to such use.

Coal bed 20 feet above the Upper Elkhorn coal.—Near location 149, on Boone Fork; at location 150, on Rockhouse Creek; and at location 151, on Millstone Creek, an 18-inch coal lies 20 feet above the Upper Elkhorn bed.

Coal bed 60 feet above the Upper Elkhorn coal.—On the new road between Elkhorn Creek and McRoberts a coal bed 60 feet above the Upper Elkhorn bed has been exposed. Above Consolidation No. 207 mine it is 1 foot thick and above No. 214 mine it is 8 inches thick.

Coal bed 175 feet above the Upper Elkhorn coal.—On the new road just mentioned a coal bed 175 feet above the Upper Elkhorn bed at

No. 207 mine has been exposed. At that place it is worthless, as shown by the section below.

Section of coal bed 175 feet above the Upper Elkhorn coal, on new road above No. 207 mine.

	Ft.	in.
Sandstone.		
Coal		2½
Clay		2½
Coal		1
Clay	1	
Coal		11
Clay	2	5
	4	10

Near the head of Elkhorn Creek, at location 152, this bed shows the following section:

Section of coal bed near head of Elkhorn Creek, at location 152.

	Ft.	in.
Sandstone.		
Coal		2
Clay		2
Coal		4
Clay		4
Coal	1	4
	2	4

At this place the bed is about 160 feet above the Upper Elkhorn.

Coal bed 200 feet above the Upper Elkhorn coal.—At No. 207 mine in the new road to McRoberts a bed that contains 3 feet 4 inches of clean coal is exposed 200 feet above the Upper Elkhorn coal. A bed near this horizon appears to be persistent in the region.

On the west side of the ridge above No. 214 mine the bed also shows 3 feet 4 inches of coal. A bed opened at the head of Wrights Fork (location 153) and reported to be 2 to 2½ feet thick may be this bed or the one discussed under the next heading. A bed opened on the head of Rockhouse Creek just beyond the north boundary of the quadrangle, near location 154, is regarded as this bed. At this place 25 inches of clean coal was seen and the thickness may be greater. Fossil ferns collected from the bed at this point indicate the horizon of the Clintwood coal of Virginia.

Coal bed 240 feet above the Upper Elkhorn coal.—A bed containing 2 feet 2 inches of clean coal is exposed on the new road to McRoberts, about 240 feet above the Upper Elkhorn at No. 207 mine. This bed has not been recognized elsewhere.

Coal bed 340 feet above the Upper Elkhorn coal.—On the new road to McRoberts a bed 340 feet above the Upper Elkhorn and almost 30 inches thick, apparently clean coal, shows on both sides of the summit and about 120 feet below it.

Hyden (Fire Clay) coal bed.—A thick coal bed lies 400 feet above the Upper Elkhorn bed, as determined at widely separated points in the region. This bed is characterized by a parting of flint clay, from which it has been named the Fire Clay bed in reports of the Kentucky Geological Survey.[1] It is also called the Hyden bed, and that name is adopted here.

The best exposure of the Hyden bed in this area is at the opening of M. B. Tolliver on Meadow Branch near the west side of the quadrangle, at location 155. On the new road to McRoberts the bed is exposed at location 156 on the west side of the summit and 71 feet below it. The sections at locations 155 and 156 are as follows:

Sections of Hyden coal bed at locations 155 and 156.

Location 155, at M. B. Tolliver's bank on Meadow Branch.

	Ft.	in.
Shale.		
Shale, black, fissile (1 foot).		
Coal	3	5
Clay, flint		4
Coal, splint at top	1	5
Coal, cannel		3
Clay		1
Coal, splint		9
	6	3

Location 156, on west side of summit on new road to McRoberts.

	Ft.	in.
Shale.		
Coal	3	2
Clay, flint		5
Coal	1	1
	4	8

At the opening of W. M. Yonts, one-half mile northwest of Baker post office, at location 157, and near the head of Long Fork, at location 158, the bed is made up as follows:

Sections of Hyden coal bed at locations 157 and 158.

Location 157, opening of W. M. Yonts, one-half mile northwest of Baker post office.

	Ft.	in.
Shale, black (4 inches).		
Coal	1	
Pyrite		1
Coal	1	6
Coal, with streaks of clay and bone		8
Clay, flint		1½
Coal, splint, thin clay partings and bony; thickness, 6 to 10 inches, average		8
	4	½

Location 158, near the head of Long Fork.

	Ft.	in.
Coal	2	6
Clay, flint		4
Coal	1	6
	4	4

A coal bed high on the hill at the head of Big Branch in the northeast corner of the quadrangle, at location 159, reported to be 4 feet thick is certainly the Hyden bed. Reports are current of a bed at this horizon at other places in the area and leave no doubt of its persistence, probably as a workable bed.

[1] Kentucky Geol. Survey Bull. 11, 1910.

Coal beds above the Hyden.—On the new road to McRoberts, just below the summit on the east side, at location 160, a coal is exposed 50 feet above the Hyden bed. Its section is as follows:

Section of coal bed 50 feet above the Hyden bed on new road to McRoberts, at location 160.

	Ft.	in.
Shale.		
Bone		1
Coal		3
Bone		3
Clay		5
Coal	2	
	3	

Mr. M. B. Tolliver reports a coal 6 feet thick above the Hyden bed at his opening, at location 155, and the presence of a bed in that position is indicated by a bloom above the opening. On the high ridges in the northwest corner of the quadrangle 500 feet of strata overlie the Hyden bed. According to Bulletin 11 of the Kentucky Geological Survey, at least three coal beds occur in this interval, but no exposures of any of these beds were discovered by the writer although the beds are probably present.

QUANTITY OF ULTIMATELY AVAILABLE COAL.

The quantity of ultimately available coal in the Pound quadrangle has been computed with the results shown in the following table:

Tonnage of available coal in the Pound quadrangle.

Bed.	Thickness. Ft.	Thickness. in.	Area. Sq. mi.	Tonnage.[a]
VIRGINIA.				
High Splint	3	10	1.60	7,060,000
Pardee	7	6	4.80	41,470,000
First coal below Pardee	2		6.57	15,130,000
Second coal below Pardee	1		8.17	9,520,000
Phillips	2		9.62	22,160,000
Low Splint	3	2	13.92	50,830,000
Taggart	4		17.19	79,210,000
Upper Standiford	3		20.15	69,640,000
Lower Standiford	2	6	20.15	58,000,000
Upper Bolling	3	4	39.19	150,300,000
Lower Bolling	2	4	39.19	105,200,000
First coal above Clintwood	2		75.92	174,900,000
Clintwood (thick)	7	3	17.91	149,580,000
Clintwood (thin)	3	8	58.00	245,200,000
Blair	2	8	91.29	279,750,000
Coal 70 feet above Glamorgan	2	6	99.61	285,700,000
Glamorgan (thick)	2	7	59.80	179,100,000
Glamorgan (thin)	2		49.20	113,350,000
Total Wise formation				2,136,080,000
Norton formation	7	2	137.72	1,137,550,000
Lee formation	7	4	137.72	1,162,920,000
Total coal in Virginia				4,436,550,000

[a] Estimated on the basis of 1,152,000 tons to the square mile for each foot in thickness of coal.

Tonnage of available coal in the Pound quadrangle—Continued.

Bed.	Thickness.		Area.	Tonnage.
KENTUCKY.	*Ft.*	*in.*	*Sq. mi.*	
Hyden	4	5	13.13	66,820,000
Two beds	4		39.20	180,630,000
Upper Elkhorn [a]	6	1½	42.98	303,380,000
Do. [a]	4		6.77	31,200,000
One bed	1		49.75	57,310,000
Do	4	10	3.18	14,650,000
Between the Lee and Lower Elkhorn	11		68.11	842,110,000
Lee	7		68.11	549,240,000
Total coal in Kentucky				2,304,640,000
Grand total				6,741,190,000

[a] Computed for separate areas containing different thicknesses of coal.

In the above table the results are given to the nearest 10,000 tons. The minimum thickness of a coal bed considered in a commercial sense as ultimately minable is 14 inches, and the maximum depth for that thickness is taken as 1,700 feet. On this basis the comparatively meager data for the Norton and Lee formations in Virginia indicate a total thickness of 7 feet 2 inches of coal in the Norton and 7 feet 4 inches in the Lee. That is, the amount of coal fulfilling the conditions of depth and thickness stated above equals a single bed 7 feet 2 inches thick in the Norton and another 7 feet 4 inches thick in the Lee, the areal extent of these beds being considered as equal to the area underlain by the Norton formation. In the Kentucky area the coals of the Lee and of the strata between the Lower Elkhorn coal and the top of the Lee approximately equivalent to the Norton of Virginia have not been tested.

In Bulletin 12 of the Kentucky Geological Survey coals that aggregate about 10 feet in thickness are described in the Lee where it outcrops on the western border of the eastern coal field in Kentucky, and on the basis of this fact, together with the known occurrence of about 7 feet of workable coal in the Lee of Virginia, it is assumed that the Lee in the Kentucky part of the Pound quadrangle contains at least 7½ feet of workable coal. Stone[1] describes four coal beds aggregating 11 feet in thickness in the rocks between the Lee formation and the Lower Elkhorn coal in the Big Sandy drainage area, 10 miles northeast of the Pound quadrangle. The occurrence of these beds in that area forms the basis of the assumption of a total thickness of 11 feet of coal in these rocks in the part of the Pound quadrangle in Kentucky.

In Virginia the average thickness of the High Splint, Pardee, Low Splint, Taggart, Bolling, Clintwood (where it is 7 feet 3 inches thick), and Glamorgan (where it is 2 feet 7 inches thick) is based on an

[1] Stone, R. W., Coal resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull 348, 1908.

adequate number of detailed measurements and can be accepted as reliable. The thickness of the other beds is less certain. In Kentucky the average thickness of only the Upper Elkhorn coal is adequately determined. The thickness of the Lower Elkhorn is based on a number of good measurements obtained northeast of Marshall Branch, and the thickness of each coal above the Upper Elkhorn is based on only a small number of accurate measurements.

In both Virginia and Kentucky, beds other than those included in this estimate were seen at one or a very few points, but of these so little is known that they were not considered. This fact, together with the fact that the beds included in the estimate are as likely to average somewhat thicker as they are to average thinner, supports the belief that the total estimated tonnage, enormous though it be, does not exceed the actual amount of ultimately minable coal in the Pound quadrangle.

CHEMICAL COMPOSITION OF THE COALS.

The chemical composition of some of the coals of the region is shown in the table of analyses (pp. 218–219). Only a small number of samples were taken because, as deep mines are few, opportunities for obtaining fresh unweathered coal are rare. Most of the samples from local mines are probably somewhat affected by weathering. However, the composition of such samples approximates that of fresh coal closely enough for rough comparisons.

The samples were collected as follows: From the fresh face of the bed, or as nearly fresh as could be obtained, a uniform cut was made from top to bottom of sufficient size to yield 5 pounds to the foot after rejecting all partings that would not be included in the coal as marketed. This coal was pulverized and quartered in the mine until there was left sufficient coal of a size that would pass through a half-inch mesh to fill a 2-quart galvanized-iron can. This was sealed with adhesive tape and mailed to the laboratory of the Bureau of Mines for analysis.

The coals of this quadrangle are all bituminous and in composition resemble the coals of the eastern side of the Appalachian field from Russell County, Va., to Alabama, except those of Lookout Mountain. Analyses show that samples from Russell, Dickenson, Wise, and Lee counties, Va., and from eastern Kentucky are much alike in average composition. All the samples from the Pound quadrangle are low in sulphur and moisture, and all but those from the Pardee and Bolling beds are notably low in ash. Samples from a larger number of localities are, however, needed in order to obtain more satisfactory data. It should be added that the calorific determinations that are based on samples from country banks, or on weathered samples, do not show the full heat value of the fuels.

The coals of this quadrangle all differ from the coals of the Pocahontas region in respect to content of volatile hydrocarbons and fixed carbon. The coals of that region which generally have less than 20 per cent volatile and more than 70 per cent fixed carbon are classed with the semibituminous coals, like those of the Clearfield district of Pennsylvania. On the other hand, the coals described in this report contain more than 30 per cent of volatile matter. The high volatile content of the coals of the Pound quadrangle invites consideration of by-product processes in coking.

With the exception of the semibituminous coal of Lookout Mountain in Georgia and Alabama, the coals of this region are suitable for any of the uses to which the coals south of the Pocahontas region are put. For domestic use, including the grate, for the generation of steam and for coke and gas they will probably compare favorably with most of the coal mined for such uses in the southern Appalachian field.

Their coking qualities are mostly unknown. The Imboden bed at Stonega, southwest of the quadrangle, is regarded as one of the best coking coals of the country. This bed is supposed to be the same as the Edwards bed in the Norton formation. The Glamorgan coal mined at Glamorgan makes good coke and the output of the mine is largely utilized in this way. It is quite probable that some of the other Norton coals also possess good coking qualities.

Analyses of coals from the Pound and Clintwood quadrangles in Virginia and Kentucky.

[Made by the Bureau of Mines, A. C. Fieldner, chemist in charge.]

Virginia.

Laboratory No.	Name of mine and location.	Collector.	Coal bed.	Air-drying loss.	Form of analysis.[1]	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heating value. Calories.	Heating value. British thermal units.	Page.
14766	Mine of John A. Yeates, 1 mile southwest of Clintwood.	W. A. Nelson	Clintwood	1.2	A	2.2	34.2	60.4	3.2	0.85					8,110	14,590	196
					B	1.0	34.6	61.2	3.2	.86					8,205	14,770	
					C		34.9	61.8	3.3	.87					8,290	14,920	
					D		36.1	63.9		.90					8,570	15,420	
14767	Mine of Elbert Powers, 3 miles southeast of Clintwood.	do	do	3.3	A	4.3	29.4	62.1	4.2	1.02							196
					B	1.0	30.4	64.2	4.4	1.05							
					C		30.7	64.9	4.4	1.07							
					D		32.1	67.9		1.12							
15099	Pardee No. 1 mine of Blackwood Coal & Coke Co., Pardee.	Chas. Butts	Pardee	1.0	A	2.3	33.8	54.7	9.21	1.56	4.99	74.46	1.57	8.21	7,420	13,360	205
					B	1.3	34.2	55.2	9.30	1.58	4.93	75.21	1.59	7.39	7,495	13,490	
					C		34.6	56.0	9.43	1.60	4.85	76.20	1.61	6.31	7,595	13,670	
					D		38.2	61.8		1.77	5.35	84.13	1.78	6.97	8,385	15,100	
15100	Glamorgan No. 3 mine of Stone Gap Colliery Co., Glamorgan.	do	Glamorgan	1.6	A	2.6	33.1	59.3	5.0	1.37					7,895	14,220	189
					B	1.1	33.6	60.2	5.1	1.39					8,025	14,450	
					C		34.0	60.9	5.1	1.41					8,115	14,600	
					D		35.8	64.2		1.49					8,550	15,390	
15101	do	do	do	2.0	A	3.2	31.3	59.1	6.37	.87	5.27	78.02	1.65	7.82	7,730	13,910	189
					B	1.3	31.9	60.3	6.50	.89	5.15	79.61	1.68	6.17	7,885	14,200	
					C		32.3	61.1	6.58	.90	5.08	80.65	1.71	5.08	7,990	14,380	
					D		34.6	65.4		.96	5.44	86.33	1.83	5.44	8,550	15,390	
15174	Mine of Reuben Bolling, 2 miles east of Flat Gap.	do	Upper Bolling.	5.8	A	6.9	30.4	54.6	8.1	.95					7,210	12,980	
					B	1.2	32.3	57.9	8.6	1.01					7,655	13,780	
					C		32.6	58.6	8.8	1.02					7,745	13,940	
					D		35.8	64.2		1.12					8,485	15,280	

Kentucky.

14904	Jenkins No. 4 mine of Consolidation Coal Co., Jenkins.	Chas. Butts	Upper Elkhorn.	1.9	A	3.9	33.8	54.8	7.5	0.51	......	......	......	......	7,460	13,430	210
					B	2.1	34.5	55.8	7.6	.52	......	......	......	......	7,605	13,690	
					C	......	35.2	57.0	7.8	.53	......	......	......	......	7,765	13,970	
					D	......	38.2	61.8	......	.57	......	......	......	......	8,420	15,150	
14905	....do	....do	....do	1.7	A	3.6	35.8	58.0	2.59	.51	5.39	80.06	1.52	9.93	7,910	14,240	210
					B	2.0	36.4	59.0	2.63	.52	5.29	81.44	1.55	8.57	8,050	14,490	
					C	......	37.2	60.1	2.69	.53	5.18	83.09	1.58	6.93	8,210	14,780	
					D	......	38.2	61.8	......	.54	5.32	85.38	1.62	7.14	8,440	15,190	
14970	Mine of Joel Ratliff, 5 miles northeast of Jenkins.	....do	Lower Elkhorn.	3.1	A	4.8	33.7	57.8	3.7	.82	......	......	......	......	7,690	13,840	207
					B	1.8	34.8	59.6	3.8	.85	......	......	......	......	7,935	14,290	
					C	......	35.4	60.7	3.9	.86	......	......	......	......	8,080	14,550	
					D	......	36.9	63.1	......	.90	......	......	......	......	8,410	15,140	
14971	....do	....do	....do	3.6	A	5.1	28.8	48.2	17.9	.68	......	......	......	......	6,365	11,450	207
					B	1.6	29.9	50.0	18.5	.71	......	......	......	......	6,600	11,880	
					C	......	30.3	50.8	18.9	.72	......	......	......	......	6,710	12,080	
					D	......	37.4	62.6	......	.89	......	......	......	......	8,270	14,880	
15172	Mine of David Sturgill, 1½ miles south of Flat Gap.	....do	Lower Standiford.	2.8	A	4.1	35.2	55.7	5.0	1.74	......	......	......	......	7,725	13,910	199
					B	1.3	36.2	57.3	5.2	1.79	......	......	......	......	7,950	14,310	
					C	......	36.7	58.1	5.2	1.81	......	......	......	......	8,055	14,500	
					D	......	38.7	61.3	......	1.91	......	......	......	......	8,500	15,300	
15173	Mine of J. H. Mullin, 3 miles southwest of Flat Gap.	....do	Lower Bolling.	2.6	A	4.0	31.8	53.0	11.2	.97	......	......	......	......	7,140	12,850	199
					B	1.4	32.6	54.5	11.5	1.00	......	......	......	......	7,330	13,200	
					C	......	33.1	55.3	11.6	1.01	......	......	......	......	7,435	13,380	
					D	......	37.4	62.6	......	1.14	......	......	......	......	8,415	15,150	

[a] A, Analysis of the coal as received; B, analysis of the coal after drying at a temperature a little above the normal; C, Theoretical composition of the coal after all moisture has been eliminated; D, Coal substance after all ash and moisture have been theoretically removed. This is supposed to represent the true coal substance after the most significant impurities have been removed. Forms C and D are obtained from the others by recalculation.

MINING CONDITIONS.

The coal beds of the region are nearly flat or gently inclined. Level haulways are possible throughout most of the field, permitting the use of electric haulage. It seems likely that all the beds of the Wise formation can be reached by drift mines, but it will be necessary to sink shafts to the coals of the Norton and Lee formations. As a rule the beds have a good roof, except the Upper Elkhorn bed in Kentucky, which has a weak roof, as described on page 211. The mines that have been opened appear to be free from gas or water in troublesome quantities.

The country has an abundant supply of mine-timber, and the water supply for making steam and other uses will probably always be ample. The construction of railroads will be the most expensive factor in mining enterprises. That subject has been discussed on pages 168–169.

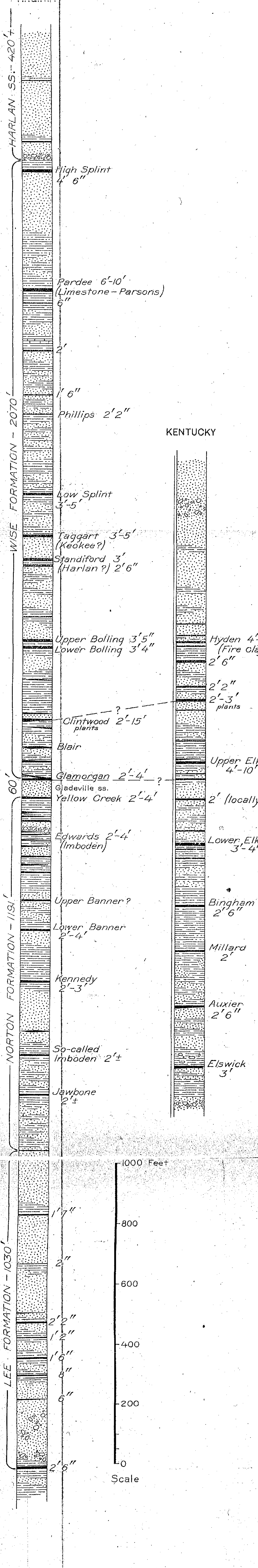
DEVELOPMENT.

The region until recently was entirely undeveloped. Within the past three years, however, developments on a large scale have been begun by the Consolidation Coal Co. on the Upper Elkhorn bed in Kentucky and 14 shipping mines are in operation, yielding a large output. In the Virginia area only the Glamorgan mine is operating, though here and there a local mine supplies the surrounding neighborhood. Most of the best coal land is in the possession of the large coal companies, who have ascertained the coal resources by thorough prospecting, and developments on a large scale may be expected in the near future.

SUMMARY.

It was ascertained by this survey that the maximum thickness of the coal-bearing rocks of the area is 4,800 feet. This thickness is attained in Black Mountain and is probably the maximum thickness for the coal measures of the Appalachian coal field outside the Coosa and Cahaba coal fields of Alabama.

The coal resources of the lower 2,000 feet of these rocks could not be thoroughly investigated, but it is known from borings and scattered exposures of coal beds on the outcrops of these rocks that there are about a dozen beds, 14 inches to 4 feet thick, at depths of less than 2,000 feet, and all this coal is considered to be ultimately available. In the upper 2,800 feet of rocks are 16 coal beds that range from 18 inches to 10 feet in thickness, all but one of which are known to be 2½ feet or more thick over large areas. The areal extent of the individual beds ranges from 2 or 3 square miles to more than 100 square miles, the extent depending on the irregularity in the thickness of the beds and their position in the hills. The coal of



LEGEND

Wise formation (Cw)
Sandstone and shale with many coal beds

Gladeville sandstone (Cg)

Norton formation (Cno)
Sandstone and shale with many coal beds, most of which are thin in this quadrangle

Lee formation (Cle)
Mostly coarse thick-bedded sandstone. Includes shale strata with thin coal beds. Sandstone conglomeratic in upper and lower parts

(In Kentucky the rocks above the Lee formation are probably equivalent to the Norton, Gladeville, and lower part of the Wise)

Undifferentiated Mississippian formations (Cpng)
Include Pennington shale, Cpn (red and green shale and sandstone, 800 feet thick), at top; Newman limestone, Cn (300 feet thick), in middle; and upper part of Grainger shale, Cgr (green clay shale and brown and red sandstone, 400 to 500 feet thick), at bottom

Undifferentiated Devonian formations, including perhaps some Mississippian beds at the top (Dgc)
Include lower part of Grainger shale and the Chattanooga shale of this region. Soft fissile shale, predominantly black but containing pale-brown layers and dark layers with very thin gray and yellow bands

Coal outcrop; line broken where outcrop is concealed. Number refers to measured section of bed

Shipping mine

Local mine

Prospect

Bore hole

Syncline

Anticline

Road and house

Triangulation station

NAMES OF COAL BEDS IN VIRGINIA

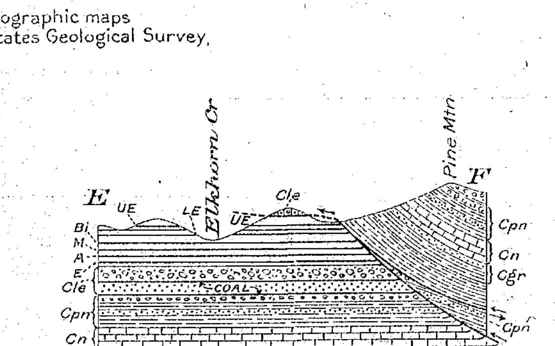
HS	High Splint
P	Pardee
Ph	Phillips
L Sp	Low Splint
T	Taggart
US	Upper Standiford
LS	Lower Standiford
UB	Upper Bolling
LB	Lower Bolling
C	Clintwood
B	Blair
G	Glamorgan
Y	Yellow Creek
Ed	Edwards
UBn	Upper Banner
L Bn	Lower Banner
K	Kennedy
SI	So-called Imboden
J	Jawbone

NAMES OF COAL BEDS IN KENTUCKY

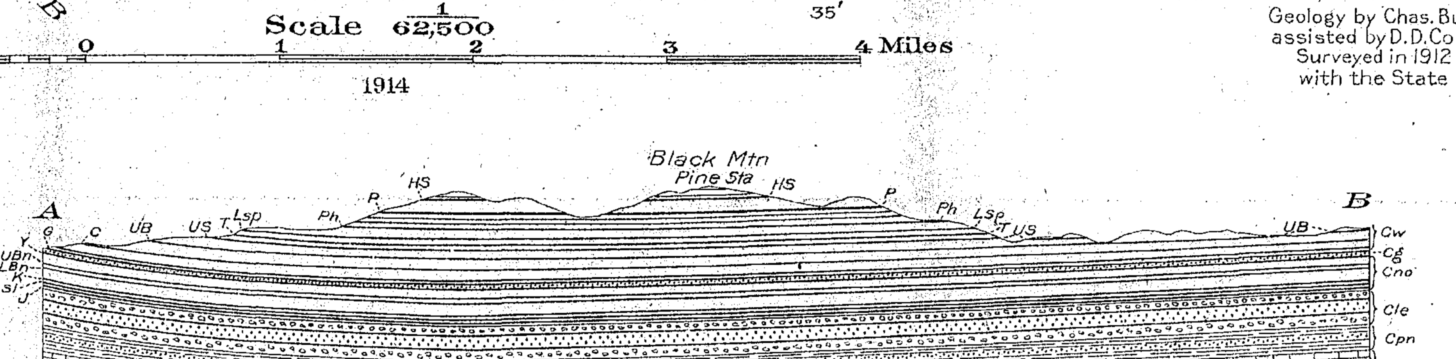
H	Hyden (Fire clay)
UE	Upper Elkhorn
LE	Lower Elkhorn
Bi	Bingham
M	Millard
A	Auxier
E	Elswick

NAMES OF COAL MINES IN KENTUCKY

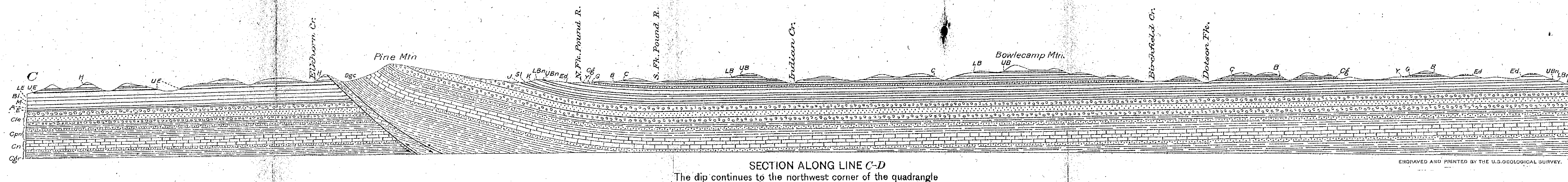
No. 1	Consolidation	No. 201
No. 2	"	" 202
No. 3	"	" 203
No. 4	"	" 204
No. 5	"	" 205
No. 6	"	" 206
No. 7	"	" 207
No. 11	"	" 211
No. 13	"	" 213
No. 14	"	" 214
No. 15	"	" 215



SECTION ALONG LINE *E-F*



SECTION ALONG LINE *A-B*



SECTION ALONG LINE *C-D*
The dip continues to the northwest corner of the quadrangle the same as shown in the section

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY.

GEOLOGIC MAP AND SECTIONS OF THE POUND QUADRANGLE, KENTUCKY AND VIRGINIA

the region is all bituminous, has the same range of composition, and is suitable for the same uses as the coal of the Appalachian field south of the Pocahontas region, except that of Lookout Mountain in Georgia and Alabama. The part of the quadrangle that lies in Virginia is as yet without adequate railroad facilities, but the area in Kentucky has recently been provided with railroads and 14 large mines have been put into operation.

The rocks lie generally nearly flat and all coal beds that outcrop can be exploited by drift mines. The beds generally have a strong roof and stable floor. There is no reason to expect trouble from gas or water. Timber and water for mining uses are abundant. Mining conditions, therefore, seem highly favorable and the region should with development become one of the principal coal-producing centers of the central Appalachian coal field.

THE COAL RESOURCES OF A PART OF NORTHEASTERN MISSOURI.[1]

By F. C. Greene.

INTRODUCTION.

The district here considered is situated near the eastern border of the western interior coal field which lies in the Mississippi Valley.

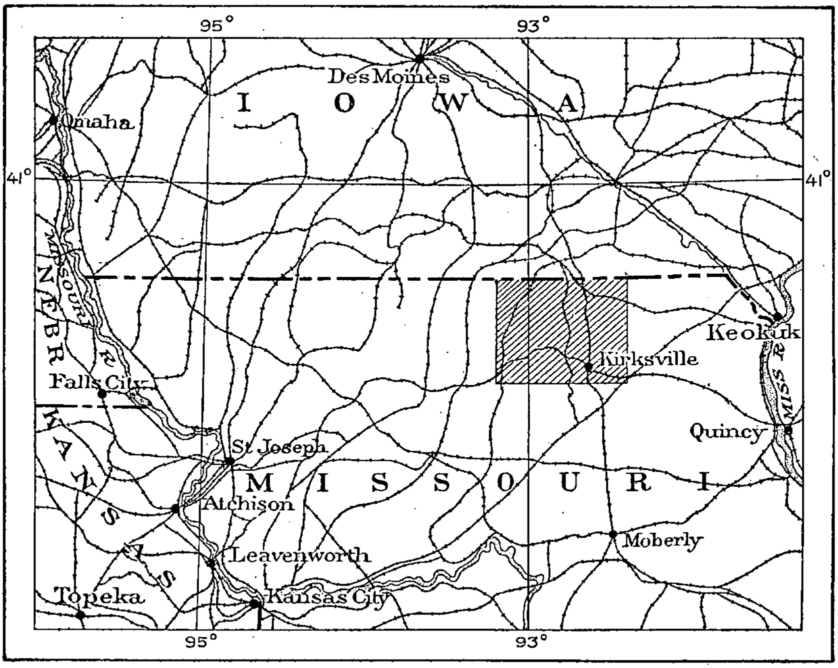


Figure 7.—Index map showing location of part of coal field of northeastern Missouri.

(See fig. 7.) The four counties in the northeastern part of Missouri in which the district is situated contain an estimated total original tonnage of nearly 10,000,000,000 short tons of bituminous coal in beds 2 to 6 feet thick and mostly less than 350 feet below the surface. Six lines of railroad cross or touch the area and furnish good shipping facilities.

[1] The field work for this report was done in cooperation with the Missouri Bureau of Geology and Mines, by which this paper is contributed.

The coal is of the bituminous grade, but can not be considered a coking coal. Most of the beds are of uniform thickness and character over large areas. Some of the beds outcrop at the surface and most of the remainder can be reached by shafts not over 200 or 300 feet deep.

This district, which borders the Iowa State line, includes the Novinger coal field, in which the Bevier is the chief producing coal bed, and the Mendota coal field, in which the production comes from other beds. Geographically the two fields are not sharply divided, and in fact to some extent overlap. For this reason and because the district is separated from the other Missouri coal fields by areas in which little or no mining is being done, it will here be described as a unit rather than as two separate fields.

A reconnaissance survey of the region was made in 1910 and 1911 by Henry Hinds and the writer, and in 1912 the outcrops of the coal beds were mapped by the writer, assisted by Maurice Albertson. This paper is based on this field work.

The stratigraphy of the general region is given in the reports of the Missouri and Iowa geological surveys [1] and in more detail in a later report by Hinds.[2] The geologic section of Putnam County given by Hinds is substantially the same as that used in this paper. Several correlations suggested by Hinds can now be made with certainty.

GEOGRAPHY AND TOPOGRAPHY.

Northeastern Missouri is a dissected plain. It is traversed in a north-south direction by the Grand Divide, east of which the drainage is southeast to the Mississippi and west of which it is in general south to Missouri River. The upland surface ranges in altitude from 900 feet along the eastern margin of the area to nearly 1,100 feet near the western edge. Chariton River, the largest stream in this part of the State, occupies a valley 1 to 3 miles wide and about 200 feet below the upland on the east.[3]

The Des Moines branch of the Wabash Railroad follows the Grand Divide across the area, the Iowa & St. Louis Railway extends through the Chariton Valley, and the Keokuk, Laclede & Carrollton branch of the Chicago, Burlington & Quincy Railroad traverses the western edge of the area. These three north-south lines are intersected by the Quincy, Omaha & Kansas City Railroad and the Keokuk & Western Railroad.

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[1] See especially Missouri Geol. Survey Rept. for 1873-74, pp. 222-302, 1874, and Iowa Geol. Survey, vol. 5, pp. 360-438, 1896, and vol. 19, pp. 254-284, 1909.

[2] Hinds, Henry, The coal deposits of Missouri: Missouri Bur. Geology and Mines, vol. 11, 2d ser., 1912. Matter published in that report is used here without further acknowledgment.

[3] The topography of part of the area is shown on the Edina, Queen City, and Green City sheets of the United States Geological Survey.

GEOLOGY.

STRATIGRAPHY.

FORMATIONS PRESENT.

The geologic formations at or near the surface in this district are presented in the following table:

Geologic formations in northeastern Missouri.

System.	Series.	Group.	Formation.	Thickness.	Description.
Quaternary.	Recent.			*Feet.*	Alluvium.
	Pleistocene.			10-300	Glacial drift; bowlder clay, sand, pebbles, and bowlders.
	-Unconformity-				
Carboniferous.	Pennsylvanian.	Missouri.	Kansas City formation.	45+	Limestone and shale.
		Des Moines.	Pleasanton formation.	100-150	Shale and sandstone containing thin coal beds.
			Henrietta formation.	30-50	Limestone and shale.
			Cherokee shale.	200-410	Shale and sandstone with coal and some limestone.
	-Unconformity-				
	Mississippian.			(a)	Limestone with some shale and sandstone.

a Not exposed.

Only the upper 125 feet of the Cherokee shale is exposed, the remainder being known from drill records. The Mississippian is nowhere exposed in the area here considered, but along the east border in places it possibly lies immediately below the glacial drift.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

The entire area with the exception of parts of the deeper valleys is covered by an irregular thickness of glacial clay, sand, bowlders, and gravel, which in places is overlain by 1 or 2 feet of gray loess. The glacial materials were spread over the country by a sheet of ice during Pleistocene time. These materials filled up the old valleys and covered the old hills, leaving the surface a nearly level plain. The present cycle of erosion has destroyed much of the plain, though remnants of it have been left along the Grand Divide and in the other high parts of the area.

At most places the upper 30 or 40 feet of the drift consists of yellow clay and the lower part of an irregular thickness of blue clay, with sand or gravel at the base. A line drawn from a point near Kirksville northwest to Lemons approximately separates the area covered by thick drift from that in which the drift is thin. Southwest of that line sandstone and limestone outcrop nearly to the ridge tops, although a few channels filled with thick drift are probably present. Northeast of that line the drift under the uplands is 150 to 300 feet thick, owing apparently to the existence of a preglacial lowland. In certain parts of the area the preglacial channels are especially numerous and seriously interfere with the mining of the higher coal beds; in places the coal gives way to drift. The thickness of the drift on or near the upland is shown in the following drill records:

Depth of drift in a part of northeastern Missouri as shown by drill records.

	Feet.
Four and one-half miles northwest of Connelsville (sec. 19, T. 64 N., R. 16 W.)	110
Green Top	300
One-fourth mile southwest of Green Top (sec. 27, T. 64 N., R. 16 W.)	201
Three miles west of Harris (sec. 30, T. 64 N., R. 22 W.)	215
Howland	164
Kirksville	170
Six miles north of Kirksville (sec. 9, T. 63 N., R. 15 W.)	175
One-half mile west of Kirksville (sec. 8, T. 62 N., R. 15 W.)	140
One and one-half miles northwest of Kirksville (sec. 5, T. 62 N., R. 15 W.)	190
Lancaster	240
Six and one-half miles northeast of Lancaster (sec. 14, T. 67 N., R. 14 W.)	199
Lucerne	185
Memphis and vicinity	67–234
Omaha	115
Queen City	295
Two and one-half miles west of Queen City (sec. 19, T. 65 N., R. 15 W.)	165±
Unionville	220
One mile south of Unionville (sec. 3, T. 65 N., R. 19 W.)	116
Two and one-half miles northwest of Worthington (sec. 19, T. 65 N., R. 16 W.)	95+

In valleys the drift is commonly thinner than shown in the records given.

The great thickness of drift not only impairs the accuracy with which the outcrop of any particular coal bed may be traced, but in the eastern part of the area it completely obscures the boundary of the Pennsylvanian series.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

Thickness and character.—Except for the surficial Pleistocene material all the rocks that outcrop belong to the Pennsylvanian series. An aggregate of about 350 feet of Pennsylvanian rocks is exposed and, as shown by drilling in the northern part of the area, these rocks are underlain by a maximum of about 275 feet more of the same series, which rests unconformably upon strata of Mississippian age. The following table shows the depths at which the Mississippian has been reached, or, in other words, the thickness of the overlying Pennsylvanian and the glacial drift:

Depth to Mississippian rocks in northeastern Missouri as shown by drill records.

	Feet.
Connelsville, on hillside	258
5 miles northwest of Hurdland, on upland	130
Kirksville, on upland	244–450(?)
Memphis, various situations	150–287
Mendota, in valley	296–332
Moulton, Iowa, on upland	463
Sedan, Iowa, on alluvial plain of Chariton River	377
Unionville, on upland	545

Most of the variation in these depths is due to the differences in the altitude of the surface, but some of it is due to the variation in the thickness of the Pennsylvanian itself, the contact of which with the Mississippian is rather irregular because of an unconformity.

The Pennsylvanian series is divided into the Kansas City formation, Pleasanton formation, Henrietta formation, and Cherokee shale. The coal beds, however, are confined chiefly to the Cherokee shale. The following is a generalized section of the Pennsylvanian series of the region:

Generalized section of Pennsylvanian series in northeastern Missouri.

	Ft.	in.
Kansas City formation:		
Bethany Falls limestone member:		
Limestone, in nodules	3	
Limestone, gray; heavy bedded above, thin bedded below; has a few shale partings	12	4
Ladore shale member:		
Shale, blue	1	10
Shale, black, "slaty"	1	6
Limestone, gray		4
Shale, drab	5	
Sandstone, yellow; even and thick bedded	4	9
Shale, light drab; sandy	10	4
Hertha limestone member:		
Limestone, gray; in two beds at Milan, but to the east contains several shale partings	5	

	Ft.	In.
Pleasanton formation:		
Shale, variable; lower part is commonly black and "slaty" and bears large spherical concretions	15	
Coal (Ovid), very irregular, ranges from a film to 2 feet in thickness		3
Clay and shale	5	
Sandstone, blue when fresh, yellow or brown when weathered; in places calcareous; cross-bedded at top and locally contains 1 to 20 feet of conglomerate and coarse sandstone at base; unconformable on underlying beds; thickness of sandstone irregular, 15 to 88 feet, averaging about	50	
Shale, drab; thickness, 5 to 55 feet where present; replaced by the preceding sandstone in some areas; average probably	20	
Limestone, dark and shaly to blue and siliceous; interbedded with fossiliferous shale	2	
Shale, generally red at base; blue, drab, and red above; argillaceous, or in places sandy, and locally containing one or two thin coal beds accompanied by black "slaty" shale; average	20	
Henrietta formation:		
Limestone (Pawnee limestone member), gray, massive to nodular; apparently lacking in places but generally present and average thickness about	3	
Shale, red and green near top; about 10 feet thick and calcareous in southern part of area; contains a layer of sandstone in upper part and is 22 feet thick in northern part; average	15	
Limestone, in several thin layers with shale partings; locally called the "water rock"	2	
Shale, variable, drab to dark; argillaceous, calcareous, or bituminous	10	
Limestone, gray; even bedded ("10-inch cap rock")	1	
Shale, gray, blue, or green	2	
Limestone, blue; argillaceous; weathers to a buff earthy material; the "cap rock"	2	
Cherokee shale:		
Shale, black, "slaty"	1	2
Coal (Lexington) with two or three clay partings; absent in many places	3	3
Clay, 2 to 7 feet, average	3	
Limestone, blue to drab; upper surface uneven; in places conglomeratic; 2 to 6 feet, average	3	
Shale and sandstone, whitish at top	23	
Limestone, dark, impure; 2 to 12 inches		3
Shale, dark and soft at top, black and "slaty" below ("slate vein")	5	6
Shale, dark; calcareous, with abundant shells		6
Coal (Summit)		1
Clay, shaly at base; 5 to 10 feet, average	7	
Limestone, blue, weathers buff; nodular on top	2	
Shale, clayey	3	

	Ft.	In.
Cherokee shale—Continued.		
Limestone, blue, even bedded, weathers to buff-colored blocks; absent in much of area	1	
Shale, light at top, black and "slaty" below; generally absent but in places 6 feet thick; average		6
Coal (Mulky), in one place 21 inches thick; generally absent		1
Shale, sandstone, and clay, 36 to 55 feet; clay at top, dark shale or sandstone at base; average	47	
Coal (Bevier); replaced by sandstone at a few places near Kirksville; north and west of Connelsville and Novinger the thickness is irregular, as the lower clay parting thickens to 20 feet and locally contains sandstone; total coal content of bed commonly about	3	
Clay, locally containing calcareous nodules at base; 1 to 7 feet; average	3	6
Limestone, generally in two beds separated by shale	4	
Shale, clayey and sandy (lowest stratum that outcrops); contains locally a 12-inch coal bed near middle; 40 to 60 feet; average	50	
Coal (Lower Ardmore)	2	
Shale, sandstone, and several irregular coal beds; lower portion absent in southern part of area	160	
Coal (Cainesville?) Upper and lower benches thin where parting thickens; absent in southern part of area; average	6	
Shale, sandstone, and clay; absent in southern part of area	40	
Limestone (Mississippian).		
	560	2

Kansas City formation.—The Kansas City is the highest indurated formation exposed and contains the thickest limestone beds in the area. In this locality the formation is only 45 feet thick, as all but the three lower members have been removed by preglacial erosion. It outcrops in a few small areas, the largest being in the vicinity of Milan, where there are good exposures of both the Hertha and Bethany Falls limestone members; the Bethany Falls is quarried for rough stone.

Pleasanton formation.—Beneath the Kansas City lies 100 to 150 feet of shale and sandstone belonging to the Pleasanton formation. The sandstone is most conspicuously developed southwest of a line extending from Millard to Pennville. It is massive and forms overhanging cliffs and caves along Spring Creek in Sullivan County and in the southern part of Adair County. In northern Putnam County the Pleasanton is represented by a few feet of variegated shale lying between the top of the Henrietta formation and the glacial drift. In the vicinity of Mapleton and Worthington the conglomerate which generally occurs near the middle of the formation rests on beds belonging to the Cherokee shale, indicating the erosion of 100 feet of strata.

Henrietta formation.—Below the Pleasanton lies the limestone and shale of the Henrietta, 30 to 50 feet thick. This formation outcrops throughout the area, wherever erosion has reached its horizon, except along the Chariton River drainage between Novinger and a point about 3 miles south of the Iowa-Missouri State line. In this area and directly east of it the Henrietta formation and probably much of the Cherokee shale have been removed by preglacial erosion. The Henrietta, though not coal bearing, is important as a guide to the depth of the coal beds of the underlying Cherokee.

Cherokee shale.—The Cherokee, which is the chief coal-bearing formation of the area and of the State, lies low with respect to drainage and, therefore, only a comparatively small portion of it is exposed. The upper part outcrops in several localities and contains some of the most persistent strata in Missouri which, like those of the Henrietta formation, furnish important clues to the depth of the underlying coal beds. The lower beds are apparently more irregular. The formation was deposited in an epoch of transgressing seas, so that beds reported in deep drillings in northern Putnam County and in Appanoose County, Iowa, disappear to the south. This is shown in the following drill records:

Log of core drill from boring at Sedan, Iowa.[a]

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Quaternary:				
Soil and drift	74		74	
Cherokee shale:				
Coal (upper bench of Bevier)	2	5	76	5
Fire clay	2		78	5
"Soapstone" shale	21		99	5
Coal (lower bench of Bevier)		5	99	10
Fire clay	3		102	10
Shale, dark, with limestones	16		118	10
"Slate," black	10		128	10
Shale, clayey, white	29		157	10
Coal (Lower Ardmore)	1	10	159	8
Shale, black	3		162	8
"Soapstone" shale	30		192	8
Coal	1	10	194	6
Sandstone	7		201	6
Shale, blue	5		206	6
Coal		9	207	3
Shale, gray	9		216	3
Shale, sandy	16		232	3
Shale, black	4		236	3
Coal		7	236	10
Shale, clayey, blue	2		238	10
Cherokee shale—Continued.				
Coal	2	3	241	1
Shale, blue	5		246	1
"Conglomerate"	1		247	1
Coal	2	10	249	11
"Soapstone" shale	7		256	11
Shale, gray	4		260	11
Shale, blue	2		262	11
Coal	1	3	264	2
Shale, gray	5		269	2
Shale, blue	20		289	2
Sandstone	14		303	2
Shale, blue	18		321	2
(Cainesville coal?) Coal	2	10	324	
(Cainesville coal?) Fire clay		8	324	8
(Cainesville coal?) Coal	2	1	326	9
Shale, blue	9		335	9
Coal	2	4	338	1
Fire clay	7		345	1
Shale, gray	13		358	1
Shale, blue	2		360	1
"Soapstone" shale, white	17		377	1
Limestone (probably Mississippian)	5		382	1

[a] Iowa Geol. Survey, vol. 19, pp. 266-267, 1909.

Log of core drill near Star shaft, Kirksville, Mo.

	Thickness.		Depth.			Thickness.		Depth.	
Quaternary:	*Ft.*	*in.*	*Ft.*	*in.*	Cherokee shale—Contd.	*Ft.*	*in.*	*Ft.*	*in.*
Soil, black	1		1		Clay	3	4	168	6
Clay, yellow	10		11		Shale, light	2		170	6
Sand	8		19		Limestone		9	171	3
Clay, blue, mixed with sand	51		70		Shale, blue	1	2	172	5
Cherokee shale:					Limestone		7	173	
Limestone, broken	2		72		Shale, sandy	32		205	
Shale, sandy	30		102		Shale, light	9	10	214	10
Shale, black, "slaty" (Summit coal horizon)	5		107		Coal (Lower Ardmore)	2		216	10
Shale, calcareous	6		113		Clay	2		218	10
Limestone	2		115		Shale, calcareous	25	2	244	
Shale, dark	2	6	117	6	Sandstone	8		252	
Shale, light	7	6	125		Shale, calcareous	10		262	
Sandstone	37	10	162	10	Limestone	2		264	
Bevier coal: Coal	1	3	164	1	Shale, calcareous	10		274	
Bevier coal: Shale		1	164	2	Limestone (probably Mississippian)	2		276	
Bevier coal: Coal	1		165	2					

MISSISSIPPIAN SERIES.

The Pennsylvanian series throughout northeastern Missouri rests on beds of Mississippian age that contain no coal in this State. These beds outcrop nowhere in the area described in this report but have been found in a number of drillings. The Mississippian rocks consist chiefly of limestone, though at a number of places in Putnam and Adair counties the uppermost beds are thin, alternating layers of limestone, shale, and sandstone that are distinguished with difficulty from the Cherokee shale. Drilling for coal should therefore be carried sufficiently deep to insure reaching the thick and easily recognized limestone that forms the lower and major portion of the Mississippian.

STRUCTURE.

The strata in the area lie nearly horizontal but dip gently to the southwest. The general dip is interrupted by a series of low folds whose axes trend northwest and southeast. The most pronounced fold is the arch that causes the Bevier coal to outcrop near Connelsville.

THE COAL BEDS.

DISTRIBUTION AND STRATIGRAPHIC RELATIONS.

The principal coal beds of the area are the Ovid, Lexington, Mulky, Bevier, Lower Ardmore, and Cainesville (?). Of these, all except the Mulky and Cainesville (?) are utilized, though only two beds, the Lexington and Bevier, are mined for shipment. Coal underlies most of the region shown in Plate XII (p. 234), but there are probably many small barren areas near the eastern margin of the district.

Ovid coal bed.—The Ovid, the highest coal bed in the area, is now mined only for local use. It is probable that for a long time it will not be used in any other way, owing to its small areal extent and thinness and to the absence of "mining clay" in many places. It has been found thick enough to mine 2 or 3 miles north of Milan (secs. 32 and 27, T. 63 N., R. 20 W.), where it is 14 to 30 inches thick but contains clay partings (Pl. XII, sections 1 and 2). It is mined by drifts about 6 miles north of Green City (sec. 18, T. 64 N., R. 11 W.) where it ranges from 20 to 30 inches (Pl. XII, sections 3 and 4). It is overlain by black laminated ("slaty") shale and rests directly on firm sandstone. It was formerly mined about 2 miles southeast of Youngstown and will probably be found in other small areas in southwestern Adair County. No samples of the Ovid coal were collected in this area for analysis.

Lexington coal bed.—Though important as a source of fuel for local consumption, the Lexington coal of the Mendota district furnished in 1911 but 1 per cent of the State's production. The bed is remarkably uniform over its entire area (Pl. XII, sections 5 to 11) but contains many "slips" (true faults of small throw) and "faults." The "faults" are places in which the coal is lacking, either because it was never deposited there or because of removal by preglacial erosion due to the relatively high position of the bed with regard to drainage. The presence of these abrupt channels detracts greatly from the commercial value of the bed. The Lexington bed outcrops in many places on Spring, Shuteye, Blackbird, and Shoal creeks. The following shows the average section in eastern Putnam County, near the center of the field:

Average section of Lexington coal bed in eastern Putnam County.

	Ft.	in.
Limestone (cap rock)	3	
Clay (clod)	1	2
Shale, black, laminated (slate)		11
Coal (upper bench)	1	9
Clay (mud band)		2
Coal (lower bench)	1	
Clay		1
Coal (Dutchman)		3
Clay	4	6
Limestone (bottom rock)	4	

West of Unionville and north of Milan the "Dutchman" bench disappears. The coal has been mined near Powerville and also in the SW. ¼ SW. ¼ sec. 27, T. 64 N., R. 19 W. It is reported in drillings near Princeton but is irregular in thickness at this place. South of T. 63 N. the Lexington coal is generally absent, though the limestones associated with it are persistent. On Missouri River the coal bed is present and is being mined. Chariton River marks the general eastern boundary of the Lexington bed, but in the northwestern corner of Schuyler County it outcrops in T. 67 N. and is said to have been traced to Guinn station by drillings. To the north, in Appanoose County, Iowa, the Lexington, or Centerville (Mystic) coal as this bed is there known, is mined extensively.

Mulky coal bed.—The Mulky coal bed has been found of workable thickness at only one place in the area (Pl. XII, section 12), but it may occur at others. The following section was measured on the south side of Shoal Creek near old Glendale post office (NW. ¼ NW. ¼ sec. 35, T. 66 N., R. 17 W.):

Section of Mulky coal bed near old Glendale post office.

	Ft.	in.
Limestone, gray, weathers deep buff	1	5
Shale, banded gray, blue, and black	6	
Coal; contains white partings that weather red	1	9
Shale, gray, streaked with black, soft	1	8

At other places in the Chariton Valley the Mulky coal occurs as a thin bed below its limestone cap rock and roof shale, or as a black streak a few feet below the horizon of the Summit coal bed.

Bevier coal bed.—The coal so extensively mined in the Novinger district and sold under the name "Novinger" is correlated with that in the Bevier field, and in the interests of uniformity the name Bevier, which has priority, is here used. The Bevier bed is 90 to 100 feet below the Lexington. In 1911 the mines operating on the Bevier bed in this locality yielded approximately 10 per cent of the State's production. At Novinger and Connelsville the bed is of uniform thickness (Pl. XII, sections 13 and 14), but at Kirksville and Youngstown (Pl. XII, sections 15 and 16), sandstone replaces the upper bench or the whole bed. The following is the average section in the vicinity of Novinger:

Average section of Bevier coal bed near Novinger.

	Ft.	in.
Coal	2	1
Clay		½
Coal		4
Clay		1
Coal	1	
	3	6½

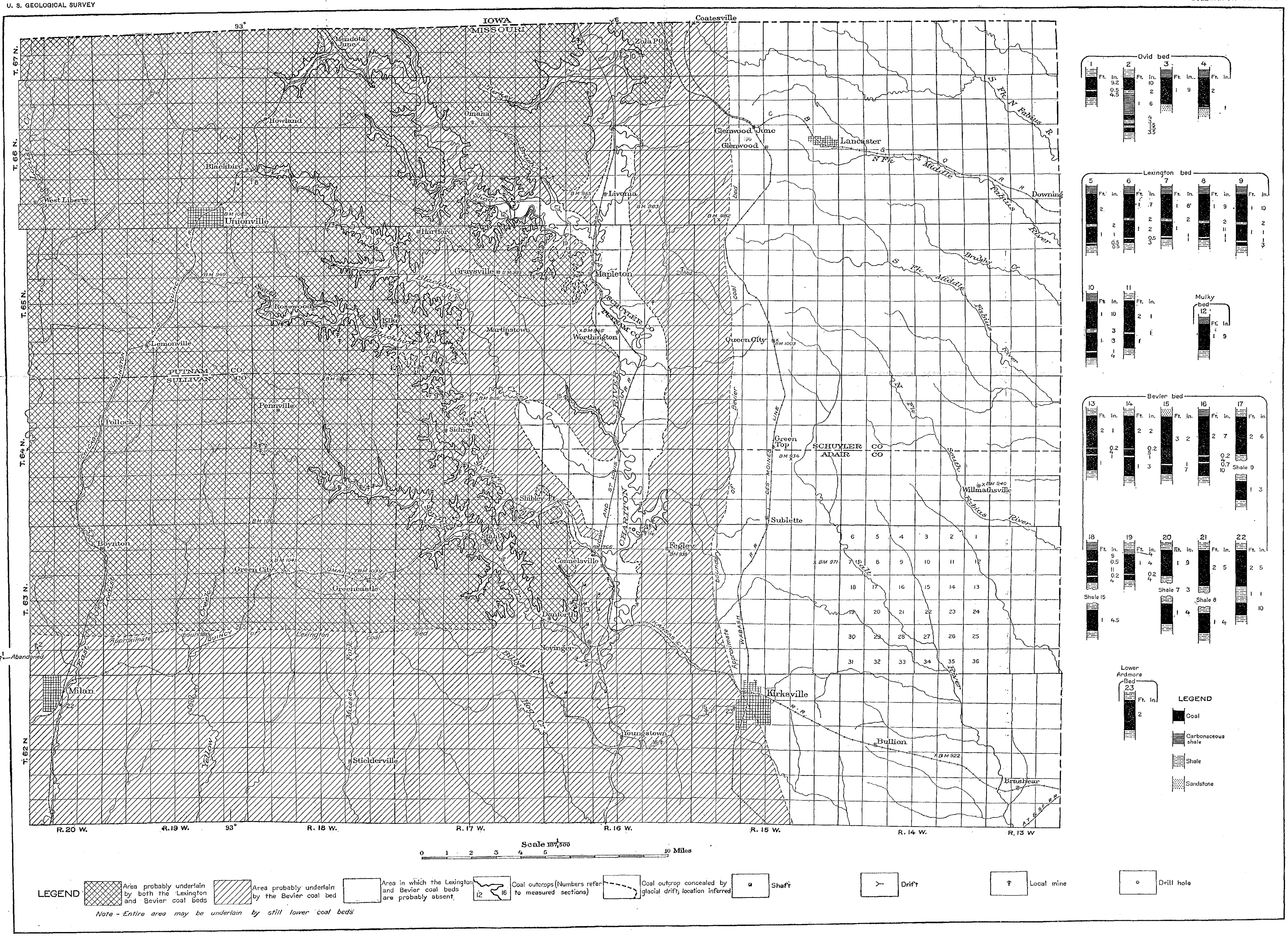
At Danforth, Stahl (Pl. XII, section 17), Duey, and Milan (Pl. XII, section 22) the lower clay parting is irregular. It is 9 feet thick at Stahl, 14 feet thick at Duey, and ranges from a thin film to 27 inches at Milan. North of Connelsville and Hazel Creek in Putnam (Pl. XII, sections 18 and 20), and Schuyler (Pl. XII, section 21) counties, the lower clay parting is as much as 20 feet thick and contains sandstone. The Bevier coal outcrops on Chariton River near Connelsville, at Slate Ford near Worthington, and on the lower courses of Shuteye, Wildcat, and Shoal creeks. Drillings at Princeton and Trenton, Mo., show the two benches of the coal to be irregular and to include more or less clay and shale between them. Drillings near Pure Air and Yarrow, in southwestern Adair County, show nearly or quite the normal thickness of the coal and the clay parting and it is probable that future development will be toward this locality. Drillings along the Wabash Railroad indicate the absence of the Bevier bed under the Grand Divide, north of Kirksville. However, a boring for water in the SW. ¼ SE. ¼ sec. 19, T. 65 N., R. 15 W., is reported to have encountered 56 inches of coal (probably in part shale) at a depth of 245 feet, an altitude which corresponds closely with that of the Bevier coal at the old Rawson shaft about 2 miles distant (SW. ¼ SE. ¼ sec. 12, T. 65 N., R. 16 W.). The reported coal may therefore be the Bevier, but this is the easternmost locality at which there is any evidence of it in the northern part of the area. At all outcrops and as reported in all reliable drill records in northern Putnam and Schuyler counties and in Appanoose County, Iowa, the Bevier bed is split by a clay, shale, or sandstone parting, but both benches are, as a rule, over 14 inches thick.

The material overlying the Bevier bed is variable. At Novinger, Connelsville, and near Hazel Creek it is a light or dark shale which, does not, however, approach a "slaty" shale like that over the Lexington bed. Near Kirksville and east of Youngstown the roof is a massive sandstone whose base is characterized by "rolls," which in places cut down into the coal, thus rendering mining difficult. The coal is underlain by clay and that in turn by limestone.

Lower Ardmore coal bed.—About 50 feet below the Bevier lies the Lower Ardmore coal, a bed that does not outcrop in the area but is well known in drillings. At present it is mined only by the Star Coal Co., near Kirksville (Pl. XII, section 23). It is reported in drillings to range from 14 to 36 inches in thickness, but is usually close to the average of 24 inches.

The western boundary of the Lower Ardmore bed is not known, but the bed has been found at Princeton and is probably the one mined at Trenton. It extends south to Linn and Macon counties, but little is known of it between those counties and the Novinger district. Drillings at Green Top, Queen City, and Lancaster indicate that it is replaced by glacial drift under the Grand Divide. To the north, in Appanoose County, Iowa, it appears to be persistent but is slightly thinner.

Lower beds.—In Davis County, Iowa, 6½ miles northeast of Lancaster (SE. ¼ sec. 14, T. 67 N., R. 14 W.), a 38-inch coal bed with a 4 to 6 inch clay parting was mined, and the same bed is reported to have been found one-half mile south of the Missouri line. The thick coal bed at Sedan, Iowa, is shown in the drill log given on page 230.



MAP SHOWING COAL RESOURCES OF A PART OF NORTHEASTERN MISSOURI, WITH SECTIONS OF THE COAL.

By F. C. Greene.

It is possible that deep drilling may show the presence of this or other thick coal beds in northeastern Putnam and in northern Schuyler counties. At Mendota no thick coal was found at the Cainesville horizon, but between Mendota and Princeton a wide stretch of territory has not been explored. The existence of thick coal below the Lower Ardmore coal bed near Connelsville, Kirksville, and Novinger or for some distance to the south is thought to be improbable.

QUALITY OF THE COAL.

PHYSICAL CHARACTER.

The coal of this district, like that of the surrounding region, is bituminous. It is capable of forming a low-grade coke, but can not be properly considered a coking coal. The average quality of the coal of the district is slightly lower than that of the coal of southwestern Missouri, but compares very favorably with that of the near-by districts in Iowa and Illinois.

In physical properties the coal of the different beds is similar, varying but slightly. White scale (gypsum and calcite) is usually present but is probably more abundant in the Lexington than in the lower beds. The "sulphur" (iron sulphide) concretions are easily detected and may be thrown out by the miner. The luster of the Lexington coal is commonly brighter than that of the lower beds, and the coal is also distinguished by the fact that the larger lumps come from the mine in a roughly cubical shape that has given rise to the name "block coal," which is often used in Iowa. It is this property that gives it good shipping quality and causes it to be favored as a domestic fuel. One of the beds, the Bevier, is somewhat dirty at the top and bottom, but is hard and is an excellent steam coal.

CHEMICAL ANALYSES.

Analyses of samples of the three principal coal beds of the district are given herewith. The Lexington and Bevier beds are represented by four and six analyses, respectively, but the Lower Ardmore bed by only one. Conclusions must be made with this fact in mind.

Analyses of coal samples from northeastern Missouri.

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

Adair County.

Laboratory No.	Locality.	Collector.	Name of bed.	No. on Pl. XII.	Air-drying loss.	Form of analysis.[a]	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heating value. Calories.	Heating value. British thermal units.
10088[b]	1½ miles south of Connelsville..	J. M. Webb...	Bevier............	13	11.4	A	16.1	32.1	39.1	12.65	3.31	5.70	55.76	1.00	21.58	5,685	10,240
						B	5.3	36.2	44.2	14.28	3.74	5.00	62.93	1.13	12.92	6,420	11,550
						C	......	38.3	46.6	15.07	3.94	4.66	66.44	1.19	8.70	6,775	12,190
						D	......	45.1	54.9	....	4.64	5.49	78.23	1.40	10.24	7,980	14,360
10106[c]	½ mile west of Kirksville........	.....do........	.....do...........	15	11.1	A	14.6	32.0	39.5	13.91	3.69	5.56	56.12	.93	19.79	5,700	10,260
						B	3.9	36.1	44.4	15.65	4.15	4.87	63.13	1.05	11.15	6,410	11,540
						C	......	37.5	46.2	16.29	4.32	4.61	65.71	1.09	7.98	6,675	12,010
						D	......	44.8	55.2	....	5.16	5.51	78.50	1.30	9.53	7,975	14,350
10442[c]	.....do........................	.....do........	.....do...........	15	9.8	A	14.4	32.3	40.2	13.14	5.29	5.56	56.43	1.00	18.58	5,720	10,300
						B	5.1	35.8	44.5	14.57	5.86	4.95	62.56	1.11	10.95	6,345	11,420
						C	......	37.7	46.9	15.35	6.18	4.63	65.93	1.17	6.74	6,685	12,030
						D	......	44.6	55.4	....	7.30	5.47	77.88	1.38	7.97	7,895	14,210
10090[b]	2½ miles southwest of Novinger.	V. H. Hughes.	.....do...........	13	9.5	A	15.1	32.7	41.9	10.26	3.52	5.68	58.41	.98	21.15	5,950	10,710
						B	6.2	36.1	46.4	11.34	3.89	5.11	64.54	1.08	14.04	6,575	11,840
						C	......	38.5	49.4	12.09	4.15	4.71	68.82	1.15	9.08	7,010	12,620
						D	......	43.8	56.2	....	4.72	5.36	78.28	1.31	10.33	7,975	14,360
10089[b]	2½ miles north of Novinger......	.....do........	.....do...........	13	10.4	A	15.7	33.5	38.9	11.89	3.02	5.69	57.72	.99	20.69	5,785	10,410
						B	6.0	37.3	43.4	13.27	3.37	5.06	64.43	1.10	12.77	6,455	11,620
						C	......	39.7	46.2	14.11	3.58	4.68	68.50	1.17	7.96	6,865	12,350
						D	......	46.2	53.8	....	4.17	5.45	79.77	1.36	9.25	7,990	14,380
10081[b]	1 mile northwest of Stahl.......	J. M. Webb...	Lexington	5	9.5	A	15.4	34.8	38.8	10.99	3.57	5.88	57.09	.95	21.52	5,810	10,460
						B	6.5	38.5	42.9	12.14	3.95	5.33	63.08	1.05	14.45	6,420	11,560
						C	......	41.1	45.9	12.98	4.22	4.93	67.45	1.12	9.30	6,865	12,360
						D	......	47.3	52.7	....	4.85	5.67	77.51	1.29	10.68	7,890	14,200
14799	½ mile west of Kirksville........	M. Albertson..	Lower Ardmore...	23	11.0	A	16.0	38.1	37.2	8.69	4.12	5.90	59.09	.94	21.26	6,000	10,800
						B	5.6	42.9	41.7	9.76	4.63	5.26	66.39	1.06	12.90	6,740	12,130
						C	......	45.4	44.3	10.34	4.90	4.90	70.33	1.12	8.41	7,140	12,850
						D	......	50.6	49.4	....	5.46	5.46	78.44	1.25	9.39	7,965	14,330

[a] A, Analyses of the coal as received; B, air-dried coal; C, moisture-free coal; D, moisture and ash free coal.
[b] Composite of three samples.
[c] Composite of two samples.

Putnam County.

Laboratory No.	Locality.	Collector.	Name of bed.	No. on Pl. XII.	Air-drying loss.	Form of analysis.[a]	Proximate.				Ultimate.					Heating value.	
							Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
11401[b]	1 mile southeast of Mendota....	J. M. Webb (?)	Lexington.........	7	15.2	A	18.5	32.6	39.0	9.90	4.09	5.76	55.71	0.91	23.63	5,580	10,040
						B	3.8	38.5	46.0	11.67	4.82	4.80	65.69	1.07	11.95	6,580	11,840
						C	......	40.0	47.9	12.14	5.02	4.55	68.31	1.12	8.86	6,840	12,310
						D	......	45.5	54.5	....	5.71	5.18	77.75	1.27	10.09	7,785	14,010
14880	2½ miles northeast of Unionville.	M. Albertson..	.....do...........	8	12.8	A	16.5	34.4	37.3	11.8	3.39	......	....	......	....	5,600	10,080
						B	4.3	39.4	42.8	13.5	3.89	......	....	......	....	6,420	11,560
						C	......	41.2	44.7	14.1	4.06	......	....	......	....	6,705	12,070
						D	......	47.9	52.1	....	4.73	......	....	......	....	7,810	14,050
14881	.....do.........................	.....do.......	.....do...........	8	12.8	A	16.5	34.8	37.4	11.3	2.88	......	....	......	....	5,565	10,010
						B	4.3	39.8	42.9	13.0	3.30	......	....	......	....	6,380	11,430
						C	......	41.6	44.8	13.6	3.45	......	....	......	....	6,665	11,990
						D	......	48.2	51.8	....	3.99	......	....	......	....	7,710	13,880

Sullivan County.

Laboratory No.	Locality.	Collector.	Name of bed.	No. on Pl. XII.	Air-drying loss.	Form of analysis.[a]	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
10143[b]	1 mile south of Milan...........	J. M. Webb...	Bevier............	22	8.4	A	13.1	32.3	37.5	17.12	5.93	5.40	53.38	0.92	17.25	5,500	9,900
						B	5.1	35.2	41.0	18.69	6.47	4.88	58.28	1.00	10.68	6,000	10,800
						C	......	37.1	43.2	19.70	6.82	4.53	61.44	1.06	6.45	6,330	11,390
						D	......	46.2	53.8	....	8.49	5.64	76.51	1.32	8.04	7,880	14,180

[a] A, Analyses of the coal as received; B, air-dried coal; C, moisture-free coal; D, moisture and ash free coal.

[b] Composite of three samples.

All the samples were selected from freshly cleaned faces of coal in active workings of the mines in accordance with the regulations prescribed by the Bureau of Mines. The analyses were made by this bureau or by the technologic branch of the United States Geological Survey before it was organized as the Bureau of Mines.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. 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 probably represents the coal in its most stable condition and approaching most closely its condition as it reaches the market. Analysis C represents the theoretical condition of the coal after all its moisture has been eliminated. Analysis D represents the coal after all moisture and ash have been theoretically removed. Forms C and D, which are obtained from the others by recalculation, represent theoretical substances that do not exist. In the proximate analysis the coal is broken up into certain conventional constituents, representing approximately those found in the process of coking. In other words, the proximate analysis shows what portion of the sample passes away in coking (the moisture and volatile matter) and what part remains (the fixed carbon and ash). The ultimate analysis shows the chemical elements of the coal. For general comparisons, however, the heating value of the sample in the air-dried condition presents a more succinct means than the amounts of the various constituents determined by the proximate or ultimate analyses.

COMPARISON OF ANALYSES OF THE DIFFERENT BEDS.

The samples as received from the mine show the Lexington coal to contain on the average the most moisture and the Bevier the least, but in the air-dried condition the Lexington contains the least and the Lower Ardmore the most moisture. On an air-dried basis the Bevier bed ranks highest and the Lower Ardmore lowest as regards the amount of fixed carbon in the average sample. According to these analyses, the Lower Ardmore contains the least ash and the Bevier contains the most. The amount of sulphur in the average of the Bevier samples and in the one sample of the Lower Ardmore is practically the same, and is more than in the Lexington. In the number of British thermal units, the Lower Ardmore seems to rank highest, but the Lexington and Bevier appear to be close seconds.

The following table of average analyses shows in concise form the statements of the foregoing paragraph:

Average analyses of coal beds of a part of northeastern Missouri.

Name of bed.	Condition of samples.	Moisture.	Fixed carbon.	Ash.	Sulphur.	British thermal units.
Lexington	Air dried	4.71	43.66	12.57	3.99	11,605
	As received	16.71	38.15	11.00	3.48	10,148
Bevier	Air dried	5.27	43.97	14.63	4.56	11,451
	As received	14.84	39.52	13.16	4.16	10,300
Lower Ardmore	Air dried	5.60	41.77	9.76	4.63	12,132
	As received	15.98	37.18	8.69	4.12	10,798

QUANTITY.

As little is known of the coal resources in many places in the district, only an approximate estimate of the total original tonnage can be made. The following estimate for the four counties in the district, made on the basis of 1,800 tons of coal to the acre-foot, includes only beds 14 inches or more in thickness and is very conservative. Of the total original tonnage of 9,865,000,000 tons, less than one-fifth of 1 per cent has been mined.

Estimated original tonnage of coal.

County.	Coal beds.	Short tons.
Adair	Lexington, Bevier, and Lower Ardmore	2,260,000,000
Putnam	Lexington, Bevier, Lower Ardmore, and lower beds	4,295,000,000
Schuyler	do	340,000,000
Sullivan	Ovid, Lexington, Bevier, and Lower Ardmore	2,970,000,000
		9,865,000,000

DEVELOPMENT.

At present three districts in the area have shipping mines. These districts are, in productive rank, the Novinger-Connelsville, the Coal City, and the Mendota-Unionville. Besides the shipping mines a large number of local mines, chiefly drifts and slopes, operate during the threshing season and the colder months of the year and sell to a wagon trade. Few of these mines penetrate more than 100 feet from the outcrop and are abandoned in the spring, as it is easier to open a new mine than to clean out the old entries when work is resumed in the fall.

HISTORY.

The date of the first mining probably coincides with the settlement of the country. At the Snake Den mine, in northwestern Schuyler County, operations have been in progress more or less continuously for about 50 years. The first shipping mines were those at Mendota, which have been operated for a quarter of a century or more. The drift mines at Stahl and one of the shafts at Danforth were producing in 1890. The first shaft at Milan was sunk in 1890 and the Blackbird Block Coal Co., after purchasing the mine of Castello & Sunderland, at Blackbird, Putnam County, began operations in September of the same year. The Emporia shaft was sunk in 1894 in the same district. Stroup Bros. began in that year to sink a shaft 1 mile west of Novinger in hope of reaching the bed worked at Danforth. The attempt was successful, and as a result the O. K. Coal Co. was organized and began producing in October, 1894. About the same time the camp at Duey was started and work in both the Lexington and Bevier beds was begun but proved a failure. Before 1897 prospecting at Stahl showed a lower bed and in 1897 a shaft was sunk to it but was soon abandoned.

Although mining began at Novinger in 1894 it was six or seven years before that district began to attract much attention. The Rombauer Coal Co. bought the O. K. property in 1898 and in 1901 began to sink shaft No. 2. In the same year the Kansas City Midland Coal Co. commenced business at Novinger, the Manufacturers Coal & Coke Co. opened a number of mines near Ninevah, changing the name of that village to Connelsville, and C. B. Havens bought the Danforth property. In 1901 also the Iowa & St. Louis Railroad was built, and the district surrounding Novinger was rapidly transformed from a wilderness to a thriving mining community. The next year the Manufacturers Coal & Coke Co. opened a slope in northwestern Schuyler County and the Bevier bed was reached at Kirksville. In 1903 the Great Northern Fuel Co. entered the Novinger field and the next year the second Milan shaft was sunk. Two years later a second shaft was sunk at Kirksville, and in 1912 the Lower Ardmore bed was opened at that place. At present the Danforth, Duey, Stahl, and Milan mines have nearly or quite ceased operations, so far as shipping is concerned, as they are unable to compete with other mines because of the parting in the coal bed.

EQUIPMENT.

The coal is mined by stripping, drifts, and slopes or shafts, though most of the larger mines have shafts. The 236-foot shaft of the Star Coal Co. at Kirksville is the deepest. Most of the larger mines are well equipped with top works and one mine has an electric hoist. The other large mines have steam hoists. The common type of horse gin or handpower hoist is used at the smaller shaft mines. The hauling is done with mules or burros in all mines of any size, though the Consolidated Stahl Coal Co., which formerly operated a drift at Stahl, used motor haulage to advantage.

The mines at Novinger, Connelsville, Milan, Mendota, and Coal City are connected with the main lines of the railroads by spurs, one being under construction at the shaft near Unionville when the field work was done. The mines in eastern Putnam County would undoubtedly be greatly benefited by spurs that could be easily built up Shoal and Blackbird creeks.

MINING METHODS.

Lexington coal bed.—In most of the area under discussion, the Lexington coal is mined by the room-and-pillar system, owing to the presence of "slips" and preglacial channels ("faults") and to the tendency of the underclay to "heave." The limestone cap rock about 2 feet above the coal forms a good roof, however, and would probably permit long-wall work where there are no "slips" and "faults" and where the underclay is thin.

Bevier coal bed.—At present the room-and-pillar method is usually followed in mining the Bevier coal bed, but the long-wall method has been introduced with good results. The hydraulic cartridge is being used in connection with long-wall work and in the opinion of operators in the Novinger field is a success in reducing the amount of slack coal. By the room-and-pillar method approximately two-thirds of the coal is recovered.

Lower Ardmore coal bed.—As the Lower Ardmore coal bed has just been opened, nothing is known of the conditions under which it may best be mined, but it is the intention to use the long-wall system if on trial it proves to be successful. Although not equal in importance at the present time to the Bevier coal, it will probably become a valuable bed when the Bevier is exhausted, and should prove of value at present in the localities in which the Bevier is absent or irregular in thickness.

PRODUCTION.

The production and value of the coal mined in the parts of the four counties lying in the region under discussion for 1910 and 1911 are shown in the following table:

Production and value of coal mined in a part of northeastern Missouri, 1910–11.

County.	Production (short tons).		Value.	
	1910	1911	1910	1911
Adair	250,230	352,486	$412,621	$553,848
Putnam	60,645	21,259	119,896	37,442
Schuyler	1,943	21,950	3,936	40,675
Sullivan	7,200	1,000	21,600	2,750
	320,018	396,695	558,053	634,715

FUTURE OF THE DISTRICT.

Under present conditions the future outlook for the district is not particularly bright, chiefly because of its location, which limits the market. On the south lies the Bevier field and on the north the Iowa field, so that the output in this district is largely used locally or in near-by sections of northern Missouri by railroads and for domestic fuel. Direct communication by rail with northwestern Missouri and eastern Nebraska would furnish a new outlet and would undoubtedly be a great advantage. Manufacturing in the district has been commenced by the location of a shoe factory at Kirksville, and other enterprises might be started at this and other near-by points to the mutual advantage of manufacturer and mine operator.

THE CANNONBALL RIVER LIGNITE FIELD, MORTON, ADAMS, AND HETTINGER COUNTIES, NORTH DAKOTA.

By E. Russell Lloyd.

INTRODUCTION.

LOCATION AND EXTENT.

During the summers of 1912 and 1913 the writer undertook to determine as nearly as possible the southeastern limits of the North Dakota lignite region. Previous to that time the presence of lignite in this part of the State was known in only a general way and it was

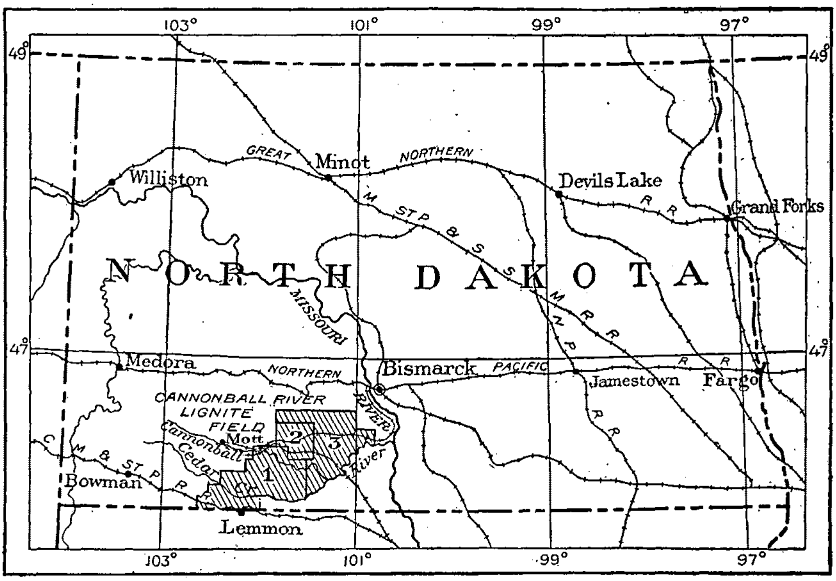


FIGURE 8.—Map of North Dakota, showing location of Cannonball River lignite field. 1, Area shown on Plate XIII; 2, area shown on Plate XIV; 3, area examined but not shown on maps.

necessary to examine a large area wherein lignite occurs only locally and in thin beds. The limits of the region of the more important beds lie partly within the area examined and partly northwest of it, and the term "Cannonball River lignite field" is used to embrace a few small districts wherein lignite is being or may be mined on a large scale and a large area wherein lignite is absent or occurs in beds so thin that it will never be of importance except for local use.

The field has a total area of about 2,170 square miles (fig. 8), of which only about one-fifth, or approximately 420 square miles, is underlain by beds of lignite more than 2½ feet in thickness. A large area in the eastern part of the district examined contains only thin beds of lignite; for that reason it is not included in the area represented on the accompanying maps (Pls. XIII, p. 282, and XIV, p. 290) and will be only briefly described in this report. In another paper the writer proposes to present more fully the scientific data obtained in this and adjoining fields.

The Cannonball River field lies between longitude 100° 40′ and 102° 40′ west (fig. 8). Its southern boundary west of the one hundred and second meridian is the North Dakota-South Dakota State line. East of that meridian it adjoins the old Standing Rock Indian Reservation, the northern boundary of which is formed by Cedar Creek and that part of Cannonball River east of the mouth of this creek. On the northeast the field adjoins the Bismarck quadrangle, which is bounded on the south by latitude 46° 30′ and on the west by longitude 101°. The boundary of the Cannonball River field on the west and north is irregular and was determined by the desirability of immediate classification of this land with regard to its coal or noncoal character and by the time available for examination.

FIELD WORK.

The field examination upon which this report is based was made by parties in charge of the writer during the summers of 1912 and 1913. The writer was assisted in 1912 by B. W. Clark, W. T. Thom, jr., and L. M. Neumann; in 1913 by W. C. Mansfield, A. C. Dennis, and L. M. Neumann. The work was done under the direct supervision of M. R. Campbell and E. G. Woodruff, to both of whom the writer is indebted for many valuable suggestions. The field work was materially assisted by the ever-ready hospitality of residents of the field and by much valuable information contributed by them. It is impracticable to make special mention of these courtesies, and acknowledgments can be made only in this general way.

The area examined in 1912 is shown on the larger map (Pl. XIII) and embraces an area of about 970 square miles. In 1913 an adjoining area of nearly 1,200 square miles was examined in the valleys of Cannonball and Heart rivers, of which eight townships, comprising the more important lignite district, are shown in Plate XIV.

The geologic examination was made primarily for the purpose of classifying the land with regard to the amount of lignite it contains. In conducting such an examination an attempt was made to determine the extent and thickness of the lignite beds from a study of their outcrops, supplemented by such data as could be obtained concerning lignite discovered in wells. Exposures of lignite more than 2 feet thick were carefully measured, and the locations and altitudes determined with plane table, telescopic alidade, and stadia rod. The outcrops of lignite beds were mapped accurately wherever exposed, and where not exposed they were mapped approximately by reference to adjacent strata or from topographic features alone. Where lignite was not found, the geology and topography were mapped with plane table and alidade.

The Land Office surveys of the region embraced in this report were made between the years 1890 and 1902. The corners are, as a general rule, well marked, and no discrepancy was observed between the position of the stones in the field and that shown on the official plats. Township plats of the General Land Office were used as base maps for the field work and for the construction of Plates XIII and XIV.

PREVIOUS PUBLICATIONS.

The portion of western North Dakota drained by Cannonball River and its tributaries has long been known to be a part of the great lignite area of the Dakotas and eastern Montana. The explorations of the Lewis and Clark expedition, 1804–1806, established the existence of what was supposed to be "stone coal" (lignite) in the Mandan country. Nearly every succeeding expedition added something of interest, but it was not until the exploration of F. V. Hayden, under the direction of Lieut. G. K. Warren, United States Topographical Engineers, that any attempt was made to publish a geologic map of the region.[1] In 1874 an expedition under the command of Gens. Custer and Ludlow, accompanied by N. H. Winchell, as geologist, made a reconnaissance trip to the Black Hills, crossing the Cannonball River field on the way.[2] In recent years the Geological Survey of North Dakota has published several articles dealing with the lignite beds of the State, but particular attention was given to the more fully developed territory to the north and west, and the Cannonball River field received scant attention. A. G. Leonard, State geologist, has recently published an article[3] in which he records and discusses several sections exposed along Cannonball and Heart rivers in Morton County. Some of these sections have been reexamined by the writer and will be described later.

GEOGRAPHY.

COMMERCIAL RELATIONS.

The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southwestern border of the field in an east-west direction. The Cannonball branch of the same road, which extends from McLaughlin, S. Dak., to New England, N. Dak., crosses the central part of the area

[1] Hayden, F. V., Notes explanatory of a map and section illustrating the geologic structure of the country bordering on the Missouri River from the mouth of the Platte River to Fort Benton: Acad. Nat. Sci. Philadelphia Proc., vol. 9, pp. 109–116, 1858.

[2] Winchell, N. H., Report of a reconnaissance of the Black Hills of Dakota made in the summer of 1874 by William Ludlow, pp. 22 and following, and map, 1875.

[3] Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, pp. 507–547, 1911.

examined in 1913 and the north border of the area examined in 1912. A branch of the Northern Pacific Railway which leaves the main line at Mandan and extends to Mott, N. Dak., also crosses the central part of the area examined in 1913. Wagon roads throughout the field are in general located on section lines, except locally where the land is so rough as to render this impracticable. These roads are numerous and render all parts of the field easily accessible.

The construction of the two branch railway lines has promoted the development of a rich agricultural district. On each line are located a number of towns, all of which have shown a steady growth. Solen, Timmer, Flasher, Lark, Carson, Heil, and Odessa on the Northern Pacific, and Shields, Freda, Raleigh, Brisbane, Leith, and Kaiser on the Cannonball branch of the Chicago, Milwaukee & St. Paul lie within the Cannonball field; Elgin, New Leipzig, and Bentley are only a few miles beyond its limits. Haynes and Petrel lie within the field on the main line of the Chicago, Milwaukee & St. Paul. Lemmon, S. Dak., at the State line, is the center of a large agricultural district and Hettinger, N. Dak., half a mile west of the west boundary of the field, is scarcely less important. The entire region is well settled and is supplied with adequate postal facilities.

TOPOGRAPHY.

The Cannonball River field lies in the Great Plains province, which extends from the Rocky Mountain region eastward and merges gradually with the Glaciated Plains east of Missouri River. The greater part of the field is a rolling prairie, interrupted, however, at many places by high bowlder-covered ridges and buttes or by steep-sided valleys. There are also large badland areas in the eastern part of the field. The central and southern parts are drained by Cannonball River and by its principal tributary, Cedar Creek, both of which have wide valleys cut from 200 to 500 feet below the surrounding plateau. Heart River crosses the northern part of the area examined in 1913. The principal smaller tributaries of Cannonball River in the field are Louse Creek with its branches, Chanta Peta and Dogtooth creeks, Three Buttes Creek, Sixmile Creek, and Snake Creek. Crooked, Timber, and Duck creeks flow into Cedar Creek. The only important southern tributary of Heart River is Antelope Creek.

All these streams and many of their smaller tributaries contain either running water or water holes throughout the year. Springs are fairly common throughout the whole area but are most abundant at the outcrops of the principal lignite beds. In most places water can be reached by wells at comparatively shallow depths, and it is from such wells that the principal supply is obtained for domestic use. The water in this area is in general comparatively free from sulphates, calcium, and sodium, the ordinary impurities which render much of the water of the Great Plains region unfit for use.

From a point about a dozen miles above the mouth of Cedar Creek and thence eastward to Missouri River, the valleys of Cannonball River and its principal tributaries are characterized by bad lands which in the eastern part of the field extend locally several miles back from the streams. Within the badland area are wide stretches which appear nearly level but which are cut by numerous small coulees and are only locally sufficiently level for cultivation.

West of the badland areas the valleys of Cannonball River and of Cedar Creek have in general broadly terraced slopes, due chiefly to the erosion of alternating beds of sandstone and shale. The valley of the Cannonball is in general narrower and more rugged than that of Cedar Creek, but both streams have at many places cut steep bluffs in which the strata are well exposed. The general upland part of the field is gently rolling or nearly level, except for numerous high ridges which are practically covered with large quartzitic bowlders.

AGRICULTURE.

The Cannonball River field is located in what is known as the semi-arid region of the Great Plains, where the rainfall is only moderate in amount and often comes at seasons when least needed. With the exception of the rocky hills and some rough country along the streams, nearly all of the land can be cultivated, the soil constituents being such that only a small amount of moisture is sufficient to insure good crops. Wheat is by far the most important crop, but flax, oats, rye, barley, potatoes, and other grains and vegetables are raised extensively. Except for a limited growth of small timber along the principal streams and in steep coulees, the region is open prairie, destitute of trees.

GEOLOGY.

STRATIGRAPHY.

GENERAL CHARACTER OF THE ROCKS.

The Fort Union formation, of the lower part of the Tertiary system (Eocene), which contains the greater part of the valuable lignite in the Dakotas and eastern Montana, embraces the surface rocks in the western and northwestern parts of the Cannonball River field. Underneath the Fort Union is a series of beds which are now tentatively classified as probably of early Tertiary age and which have been referred to the Lance formation. The upper 250 or 300 feet of this formation is in the field markedly different in lithologic character from the underlying more typical Lance, and has been found at numerous places to contain the remains of a marine fauna, which has not previously been known in this part of the stratigraphic section. These beds have been mapped separately and are herein designated the Cannonball marine member of the Lance formation.[1] The under-

[1] The Cannonball marine member of the Lance formation is described only briefly in this report. It will be described in detail in a forthcoming paper, which is now in course of preparation.

lying lower part of the Lance is of fresh-water origin and is composed of alternating beds of shale and sandstone which on erosion give rise to the badlands described above. Its thickness is approximately 400 feet. In the extreme eastern part of the field the top of the Fox Hills sandstone, which underlies the Lance formation, is exposed in the bluffs of Cannonball River.

The tops of a few high buttes are capped with sandstone and fresh-water limestone belonging to the White River (Oligocene) formation. Beds of sand and gravel on the tops of some of the higher buttes belong to either the latest Tertiary or to the early part of the Quaternary period, and the Quaternary is also represented by high-terrace river gravel and by glacial bowlders.

The general character and relations of the formation exposed in this field are shown in the following table:

Stratigraphy of the Cannonball River lignite field.

System.	Series.	Formation.	Character.	Thickness.
Quaternary.			Glacial bowlders and river terrace gravel.	*Feet.* (a)
Tertiary or Quaternary.			Sand and gravel on tops of high buttes.	(a)
Tertiary.	Oligocene.	White River formation.	Cross-bedded sandstone and fresh-water limestone.	(a)
	Eocene.	Fort Union formation.	Yellow sandstone, shale, clay, and lignite.	300-400
Tertiary (?).	Eocene(?).	Lance formation.	Cannonball marine member (dark sandy shale, dark shaly sandstone and yellow sandstone, containing marine shells).	250-300
			Somber-colored shale, yellow sandstone, and thin lignite beds.	400-450
Cretaceous.	Upper Cretaceous.	Fox Hills sandstone.	Sandstone, yellow or brown, friable.	(a)

[a] Not determined.

CRETACEOUS SYSTEM.

FOX HILLS SANDSTONE.

The Fox Hills sandstone is exposed in the bluffs of Cannonball River in the extreme eastern part of the area examined in 1913, about 25 miles east of the area shown on the maps accompanying this report. The rock is a fine-grained friable sandstone, yellow or brown in color, and locally contains a rich marine fauna.[1]

[1] For more complete description of the Fox Hills sandstone in this region see: Stanton, T. W., Fox Hills sandstone and Lance formation ("Ceratops beds") in South Dakota, North Dakota, and eastern Wyoming: Am. Jour. Sci., 4th ser., vol. 30, pp. 172–188, 1910 Knowlton, F. H., Further data on the stratigraphic position of the Lance formation (Ceratops beds): Jour. Geology, vol. 19, pp. 358–376, 1911. Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, p. 511, 1911; The geological map of North Dakota: Univ. of North Dakota Quart. Jour., vol. 4, No. 1, Oct., 1913. Calvert, W. R., and others, Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota: U. S. Geol. Survey Bull. 575, pp. 11-16, 1914.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

Lower part of the Lance formation.—The lower part of the Lance formation outcrops in the valleys of Cannonball River and its tributaries in the eastern part of the field. Within the region shown on the accompanying maps it outcrops only in small areas on Cannonball River and Cedar Creek. This part of the formation consists of alternating beds of shale and sandstone with thin beds of lignite. The total thickness is approximately 400 feet. The shale is predominantly somber in color, commonly gray or black. The sandstone is yellow or buff. Locally, brown carbonaceous layers and lenticular beds of bog iron are present and form conspicuous outcrops. Where the Lance formation is exposed, the surface is characterized by wide and nearly flat valleys bordered by steep and picturesque badland bluffs.

Fossil leaves collected near the top of the lower part of the Lance have been identified by Mr. Knowlton as belonging to the Fort Union flora. Only fragmentary vertebrate remains were found in this portion of the Lance in the Cannonball River field, but in the examination of the Standing Rock Indian Reservation[1] in 1909 abundant remains of dinosaur and turtle bones were found in several places, and a few collections of dinosaur bones have been made near the mouth of Cannonball River.[2]

The lignite beds of the lower part of the Lance formation have been found nearly everywhere in the Dakotas to be thin and lenticular. The thin beds occurring in this field are no exception to the rule. They are most abundant from 50 to 75 feet below the top of the lower part of the formation and one or more beds are exposed in nearly all parts of the field where that portion of the formation appears at the surface.

Cannonball marine member.[3]—The Cannonball marine member comprises the upper 250 or 300 feet of the Lance formation. It is typically represented in the bluffs of Cannonball River, in Tps. 132 and 133 N., R. 88 W., where the member is well exposed. The following vertical section, measured in this type area, shows the general character of the beds:

Section of Cannonball marine member of Lance formation in river bluff in NW. ¼ sec. 11, T. 132 N., R. 88 W.

	Ft.	in.
(Soil.)		
Sandstone, calcareous		6
Sandstone, gray, partly consolidated, containing numerous layers cemented with iron	10	6

[1] Calvert, W. R., and others, Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota: U. S. Geol. Survey Bull. 575, pp. 21-22, 1914.

[2] Stanton, T. W., Washington Acad. Sci. Proc., vol. 11, No. 3, p. 250, 1909. Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, p. 524, 1911.

[3] A more complete description of the Cannonball member is in course of preparation and will soon be published.

	Ft.	in.
Sandstone, yellow, consolidated	5	
Sandstone, red, hard		6
Shale, dark gray, with "cannonball" concretions	25	
Shale, very dark gray, very sandy, with a layer of marine shells 20 feet from base and with "cannonball" concretions	103	
Base concealed.		
	144	6

The top of the above section lies approximately 50 feet below the top of the member. Although not complete, the section is fairly representative and shows that the Cannonball member in the type locality is composed predominantly of dark sandy shale or shaly sandstone, with a subordinate amount of dark-yellow and gray sandstone commonly occurring in lenticular beds. Similar sections are exposed at other places along Cannonball River and in the bluffs of Cedar Creek and Heart River. Some of the beds of sandstone near the top of the member are very calcareous and contain also a considerable amount of feldspar, biotite, and pyroxene. Over the greater part of the area where the Cannonball member comes near the surface it is concealed by a heavy soil mantle, and in such places the sandstone appears relatively more prominent owing to its greater resistance to erosion.

In the Cannonball River field several collections of marine invertebrate fossils, made from the Cannonball member during the field seasons of 1912 and 1913, have been identified by T. W. Stanton as belonging to a modified Fox Hills fauna.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The Fort Union formation is exposed in the western and northwestern parts of the Cannonball River field. The thickness of that part of the formation which outcrops in the field is about 350 feet, but this is only a part of the original thickness of the lignite-bearing rocks of this age which at one time covered the entire region. The lower 100 feet of the formation is made up almost wholly of unconsolidated and partly consolidated yellow and gray sandstone and has previously been included in the Lance formation.[1] The material appears to be of fresh-water origin, however, and for that reason should be included in the Fort Union rather than in the underlying member of the Lance, which is of marine origin.

The higher strata of the Fort Union consist of massive yellow and white sandstone, clay shale, brown and black carbonaceous shale, and lignite. The sandstone is most prominent because of its greater resistance to erosion, but clay shale and carbonaceous shale probably make up more than half of the formation. The sandstone is for the most part unconsolidated, but locally cementation has produced

[1] Leonard, A. G., The Cretaceous formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, pp. 507–547, 1911.

resistant ledges which support the flat-topped buttes and plateaus or stand out as rugged hills on an otherwise smooth prairie. In most places the cementation of the sandstone proceeds outward from a center in disklike form with the short axis vertical. Where the process is not far advanced, the individuals appear in a section as lenticular concretions arranged along more or less definite horizons. At a later stage these individuals coalesce to form a ledge of hard sandstone.

A peculiar surface feature of the Fort Union, and to some extent of the underlying Lance formation, is the abundance of angular and wind-worn blocks or bowlders of a very hard quartzitic rock. These bowlders are in general confined to the higher buttes, over many of which they are strewn so thickly as to make the surface almost impassable for a horse. In general, the bowlders on the lower buttes are neither so large nor so numerous, but they are scattered over small hillocks far down in the Lance formation. They are commonly absent over the greater part of the flat prairies and in the valleys. All these bowlders are residual remnants from two or more comparatively thin beds in the Fort Union which have been found in place near the tops of several high buttes. The material is very fine grained, composed chiefly of angular or slightly rounded quartz grains, and contains an abundance of silicified plant stems of various sizes, which have in many places weathered out, leaving the rock full of holes.

The age of the Fort Union is attested by three collections of fossil leaves, all of which are typical Fort Union species.

WHITE RIVER FORMATION.

The outcrop of the White River formation in this field is limited to the tops of three high buttes in the northern part of T. 131 N., R. 90 W., and the southern part of T. 132 N., R. 90 W. The formation consists of about 50 feet of calcareous arkosic sandstone overlying a marly limestone, both of which are referred to the formation on faunal and lithologic evidence.

STRUCTURE.

A comparison of the altitudes of the lignite beds at various places, determined during the field work of 1912, shows that the strata have a general but very slight dip to the north or northeast in the northern and western parts of the field and to the north and northwest in the southern and eastern parts. This dip averages about 15 feet to the mile, which is nearly one-sixth of 1°. There is little evidence at hand on which to base a general conclusion concerning the attitude of the beds in the part of the field examined in 1913. In that portion which is shown on Plate XIV (p. 290), the general dip is probably to the north and northwest. The region has apparently not been disturbed by any orogenic movements, with the exception of a probable slight tilting to the northeast and an uplift relative to sea level which has brought it under the influence of erosional rather than of depositional agencies.

THE LIGNITE.

DISTRIBUTION.

The beds of lignite at the top of the lower portion of the Lance formation are so thin that they will probably never be of value except to a slight extent for local use. In the Cannonball River field no lignite beds are known in the Cannonball marine member of the Lance formation. The valuable beds are confined to the upper 250 feet of that part of the Fort Union formation which is exposed in the field. Owing to the heavy mantle of soil which obscures the strata over the greater part of the area, conclusive correlations of the lignite beds exposed at widely separated points can not be made.

After the deposition of the lower sandstone of the Fort Union in this region it seems evident that marsh conditions set in over wide areas, and that in these independent or semi-independent swamps vegetal matter was accumulating throughout the field during approximately the same period of time. This condition led to the formation of lignite on this surface, possibly as one continuous bed throughout the field, but more probably as a series of isolated lenses which are at or very near the same horizon. In the following discussions the lowest important lignite bed in all parts of the field, except in the valley of Cannonball River in T. 133 N., R. 30 W., is called the Haynes lignite bed, although it is possible that beds are thus included under one name which are not continuous with one another or which were not even deposited synchronously. All the evidence in hand, however, indicates that the bed, although varying greatly in thickness, was once practically continuous over at least the greater part of the field. It is therefore believed to be probably present under all the area from which it has not been removed by erosion.

The Haynes lignite bed reaches its greatest known thickness under a range of high buttes north of the town of Haynes in T. 129 N., R. 94 W. In this locality the bed is 11 to 13 feet thick and is being mined extensively for local use. Farther north and east, between Duck and Cedar creeks, in T. 130 N., R. 94 W., the bed outcrops near the tops of a number of high buttes, where it has been burned extensively along the outcrop. There the thickness is from 10 to 12 feet. Between Cedar and Timber creeks the bed outcrops for the most part where the surface has a gentle slope, and consequently exposures of the bed are practically confined to the places at which it has been mined. The greatest known thickness, 10 feet, in this part of the area is at the Merry mine, in T. 132 N., R. 93 W., half a mile north of the border of the field. From this place southeastward the thickness gradually decreases to less than 2 feet in the southeastern part of T. 131 N., R. 92 W. In this township another lignite bed, about 50 feet higher than the Haynes, is exposed at a few places only. The very meager data in hand indicate that it is from 4 to 6 feet thick.

North of Timber Creek, in the northern part of T. 131 N. and the southern part of T. 132 N., R. 91 W., there are two beds of lignite more than 2½ feet thick. The lower of these, which is correlated with the Haynes bed, is 5 to 7 feet thick. The upper bed, approximately 50 feet higher, is about 5 feet thick. In the northern part of T. 132 N., R. 91 W., and the southeastern part of T. 133 N., R. 90 W., is a group of small mines or strip pits on a bed which is 4 to 6 feet thick and which is presumably the Haynes bed.

South of Coffin Butte, in T. 131 N., R. 90 W., very little information concerning the lignite could be obtained. It seems that there are in this locality two beds from 3 to 6 feet thick, the lower of which is doubtfully correlated with the Haynes bed. It is probable that two beds which are exposed on the south face of Pretty Rock Butte, in T. 131 N., R. 89 W., are the same. The lower of these beds is 4 feet 2 inches and the upper 2 feet 5 inches thick. Farther north in the same township the lower bed underlies a group of small hills, but is only from 2½ to 3 feet thick.

In the valley of Sheep Creek, in T. 132 N., R. 90 W., and in portions of adjoining townships, three important beds are exposed. The lowest of these, which is doubtfully correlated with the Haynes bed, outcrops in the valley of Sheep Creek and has been mined at numerous places. The thickness in this vicinity ranges approximately from 2 to 6 feet. The second bed, which is about 50 feet higher, is worked in three large stripping mines in the southern part of T. 132 N., R. 90 W. The thickness of the bed in each of these mines is over 6 feet but its value is considerably impaired by thin partings of shale and bone (sections 95, 96, and 97, Pl. XIII, p. 282). The uppermost bed is exposed high up on the north side of Coffin Butte in the same township in an abandoned strip pit, where it is 4 feet 8 inches thick but contains a parting of shale over a foot in thickness (section 98, Pl. XIII). In the southwestern part of T. 133 N., R. 89 W., and the southeastern part of T. 133 N., R. 90 W., a group of high buttes is underlain by a bed of lignite, probably the same as that exposed in Coffin Butte. The bed has been burned extensively along the outcrop and the resulting red clinker forms a conspicuous topographic feature. A single measurement of the bed obtained in this vicinity (section 138, Pl. XIII) shows a thickness of 7 feet 8 inches with an 8-inch parting of sandstone 2 feet from the top.

In the valley of a branch of Cannonball River, in the eastern part of T. 133 N., R. 90 W., there are several exposures of a bed of lignite which is probably the Haynes bed. Its thickness ranges from 3½ to 5 feet. Another bed which is thought to be somewhat lower stratigraphically than the Haynes bed is exposed in the bluffs of Cannonball River in the same township. Its thickness ranges from 1 foot 11 inches to over 6 feet in a distance of about a mile.

North of Cannonball River, in the neighborhood of the towns of Leith, Heil, and Kaiser, there are two lignite beds, the lower and more important of which is being mined near Leith in shaft and drift mines and at other places in strip pits. The thickness averages about 8 feet in the mines west of Leith but decreases both to the east and west. The upper bed averages 4 or 5 feet in thickness. The vertical distance between the beds is approximately 40 feet. In the northwestern part of T. 135 N., R. 88 W., two beds, separated by about 30 feet of shale and sandstone, are being mined in small strip pits. Each bed is about 3 feet thick.

In addition to the lignite beds mentioned above, a few other beds less than 2½ feet thick outcrop in various parts of the field. These will be mentioned in the individual township descriptions given on pages 263–291.

PHYSICAL PROPERTIES.

The lignite of the Cannonball River field is similar in general character to that from other parts of North Dakota. It is very dark brown, almost black, but the powder is brown. Most of the fresh lignite has a dull luster, and much of it a tough woody texture. Detailed examination of the more woody parts shows some variations in texture, color, and luster. Small lenses of bright black lignite, ranging in thickness from a thin film up to an inch or more, alternate with the dark-brown material, which has not nearly so bright a luster. Both these varieties retain in places the fibrous character of the wood from which they were derived. In other varieties the luster is duller, the woody texture is lacking and the lignite contains a large percentage of noncombustible material or ash. Some of the lignite is of a hard black variety with well-developed cleavage similar to the subbituminous coals of eastern Wyoming and Montana.

On exposure to the air lignite loses a considerable part of its moisture, shrinks, and soon falls to pieces, a characteristic which makes shipping in open cars to distant markets almost impossible and which is proving a serious handicap in the development of the mining industry. The breaking up or checking begins almost immediately when fresh lignite is exposed to the air. The cracks on the surface are nearly at right angles, so that the small blocks which scale off are roughly cubical in form. In the best quality of lignite the weathered surfaces are black and have a bright vitreous luster, even though in the unweathered condition the lignite is brown and has a dull luster. Where the woody texture is not developed much of the lignite weathers into thin laminæ parallel to the bedding plane. The weathering of different varieties of lignite is so characteristic that often an examination of the weathered face of an exposed section will afford a better conception of the variations in character within the bed than will an examination of the fresh material itself.

CHEMICAL COMPOSITION.

In order to ascertain the chemical composition of coal or lignite, it is necessary that samples taken for analysis be as fresh as possible. For this reason the samples from the Cannonball River field were taken only in drift and shaft mines and not from strip pits. Four such samples were collected in accordance with the regulations of the United States Geological Survey, which in brief are as follows: In a clean, fresh face a channel is cut perpendicularly from roof to floor, discarding partings which are thrown out in mining. The material thus obtained is broken to pass through a half-inch screen and the sample is reduced by quartering to about 1 quart, which is placed in a galvanized can, sealed, and sent immediately to the laboratory. The samples were analyzed in the chemical laboratory of the Bureau of Mines at Pittsburgh.

The analyses of these samples are presented in the accompanying table. With them are included for comparison the analyses of three samples collected by A. L. Beekly in 1909 from small strip pits in the valley of Cedar Creek in T. 129 N., R. 88 W., and also the analyses of four representative samples of lignite from producing mines in widely separated parts of North Dakota.

In the table 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 of analysis is not well suited for the comparison of one coal with another because the amount of moisture in the sample as it comes from the mine is largely a matter of accident, and consequently analyses of different samples 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 to the general purposes of comparisons. Analysis C represents 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 are obtained from the others by recalculation.

In the analytical work chemists generally recognize that 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. In an ultimate analysis the ash, sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. It is also understood that calorific determinations to individual units are 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 ten (the value of a British thermal unit being about one-half that of a calorie).

Analyses of lignite samples from the Cannonball River and neighboring fields, North Dakota.

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

Laboratory No.	Name.	Location.				No. on map (Pl. XIII).	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
		Quarter.	Sec.	T. N.	R. W.				Moisture.	Volatile matter.[a]	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
14542	Nipper & Monroe mine, near Haynes, N. Dak.	NW.	16	129	94	4	14.5	A	32.6	30.6	28.5	8.3	1.53	......	......	......	......	4,085	7,360
								B	21.2	35.8	33.3	9.7	1.79	......	......	......	......	4,780	8,600
								C	......	45.4	42.3	12.3	2.27	......	......	......	......	6,070	10,920
								D	......	51.8	48.2	......	2.59	......	......	......	......	6,920	12,460
14544	Pinkham mine, 9 miles northeast of Haynes, N. Dak.	NW.	36	130	94	8	15.3	A	32.4	30.9	28.1	8.6	1.49	......	......	......	......	4,070	7,330
								B	20.2	36.5	33.2	10.1	1.76	......	......	......	......	4,805	8,650
								C	......	45.7	41.6	12.7	2.21	......	......	......	......	6,025	10,850
								D	......	52.4	47.6	......	2.53	......	......	......	......	6,900	12,420
14729	Jones mine, near Leith, N. Dak.	SE.	12	133	88	152	27.1	A	36.2	29.8	25.3	8.70	.68	6.76	39.45	0.59	43.82	3,720	6,700
								B	12.5	40.8	34.8	11.93	.93	5.15	54.11	.81	27.07	5,105	9,190
								C	......	46.7	39.7	13.63	1.07	4.29	61.81	.92	18.28	5,830	10,500
								D	......	54.0	46.0	......	1.24	4.97	71.56	1.07	21.16	6,750	12,150
17537F	Kolbank mine, near Leith, N. Dak.	NE.	7	133	87	188	16.6	A	34.7	29.9	24.9	10.5	1.50	......	......	......	......	3,775	6,800
								B	21.7	35.8	29.9	12.6	1.80	......	......	......	......	4,530	8,150
								C	......	45.7	38.2	16.1	2.30	......	......	......	......	5,785	10,410
								D	......	54.5	45.5	......	2.74	......	......	......	......	6,895	12,410
7341	Mine of A. L. McCord, on Cedar Creek, N. Dak.	NE.	5	129	88	139	19.3	A	32.1	25.6	31.7	10.6	1.19	......	......	......	......	3,790	6,820
								B	15.8	31.8	39.2	13.2	1.48	......	......	......	......	4,695	8,460
								C	......	37.8	46.6	15.6	1.75	......	......	......	......	5,580	10,040
								D	......	44.8	55.2	......	2.07	......	......	......	......	6,615	11,910
7839	Surface prospect on Cedar Creek, N. Dak.	SW.	1	129	88	......	21.1	A	33.1	25.5	36.1	5.3	.69	......	......	......	......	4,150	7,470
								B	15.2	32.4	45.7	6.7	.87	......	......	......	......	5,255	9,460
								C	......	38.2	53.9	7.9	1.03	......	......	......	......	6,200	11,160
								D	......	41.5	58.5	......	1.12	......	......	......	......	6,735	12,120
7842	Surface prospect on Cedar Creek, N. Dak.	SE.	4	129	88	......	23.1	A	32.5	27.1	34.6	5.8	.37	......	......	......	......	4,030	7,250
								B	12.2	35.3	45.0	7.5	.48	......	......	......	......	5,240	9,430
								C	......	40.1	51.3	8.6	.55	......	......	......	......	5,965	10,740
								D	......	43.9	56.1	......	.59	......	......	......	......	6,525	11,750

1935	Mine of Washburn Lignite Coal Co., Wilton, N. Dak.	......	1	142	80	......	32.3	A	40.5	27.1	27.4	5.0	.76	......	......	......	......	3,690	6,640
								B	12.2	39.9	40.4	7.5	1.12	......	......	......	......	5,450	9,810
								C	......	45.5	46.0	8.5	1.28	......	......	......	......	6,205	11,170
								D	......	49.7	50.3	......	1.40	......	......	......	......	6,780	12,210
1971	Mine of Consolidated Coal Co., Lehigh, N. Dak.	......	8	139	95	......	35.6	A	42.1	24.5	25.7	7.7	1.13	......	......	......	......	3,420	6,160
								B	10.0	38.1	40.0	11.9	1.75	......	......	......	......	5,310	9,560
								C	......	42.4	44.4	13.2	1.95	......	......	......	......	5,905	10,630
								D	......	48.8	51.2	......	2.25	......	......	......	......	6,805	12,250
12533	Mine of United States Reclamation Service, 3 miles northeast of Williston, N. Dak.	......	7	154	100	......	33.2	A	43.9	24.9	25.4	5.8	.49	......	......	......	......	3,300	5,940
								B	16.0	37.2	38.1	8.7	.73	......	......	......	......	4,940	8,890
								C	......	44.3	45.3	10.4	.87	......	......	......	......	5,875	10,580
								D	......	49.5	50.5	......	.97	......	......	......	......	6,555	11,800
14485	Scranton mine of Charles Liddell, Scranton, N. Dak.	SW.	24	131	100	......	22.5	A	34.8	31.1	26.0	8.1	.66	......	......	......	......	3,840	6,920
								B	15.9	40.1	33.5	10.5	.85	......	......	......	......	4,960	8,920
								C	......	47.7	39.8	12.5	1.01	......	......	......	......	5,890	10,610
								D	......	54.5	45.5	......	1.15	......	......	......	......	6,730	12,120

[a] Volatile matter in analyses 14542, 14544, 14729, 17537F, 12533, and 14485 was determined by the modified official method. See Bu. Mines Bull. 22, p. 2, 1913.

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Laboratory No. 14542.—Sample from the Haynes lignite bed, Fort Union formation, in the Nipper & Monroe mine, 3½ miles northeast of Haynes, collected in regular manner by E. R. Lloyd on July 30, 1912. Sample taken in entry about 630 feet nearly due east from the mine mouth. The thickness of the bed at this point is about 12 feet, of which the lower 8 feet 3 inches is being mined and was sampled.

Laboratory No. 14544.—Sample from the Haynes lignite bed, Fort Union formation, in mine of William Pinkham, about 9 miles northeast of Haynes, collected in regular manner by E. R. Lloyd on July 30, 1912. Sample taken in main entry about 225 feet south from the mine mouth. The thickness of the bed is about 12 feet, of which the lower 8 feet 10 inches is being mined and was sampled (section 8, Pl. XIII, p. 282.)

Laboratory No. 14729.—Sample from the Haynes (?) lignite bed in the Jones mine of J. T. Dunn, about 2 miles west of Leith, collected in the regular manner by E. R. Lloyd on September 7, 1912. Sample taken in a room about 75 feet southwest from the mine shaft. The thickness of the bed is about 8 feet 6 inches, of which the lower 5 feet 6 inches is being mined and was sampled (section 152, Pl. XIII).

Laboratory No. 17537F.—Sample from the Haynes (?) lignite bed in the Kolbank mine of Simon Pederson, about 1½ miles southwest of Leith, collected in regular manner by E. R. Lloyd on July 10, 1913. Sample taken in room about 70 feet south of the mine mouth. The thickness of the bed at the mouth is 7 feet 9 inches, of which the lower 4 feet 10 inches is being mined and was sampled (section 188, Pl. XIV, p. 290.)

Laboratory No. 7481.—Sample from a bed of lignite in the Lance formation, in the McCord mine (strip pit) on the north side of Cedar Creek, in the NE. ¼ sec. 5, T. 129 N., R. 88 W., about 8 miles northeast of Morristown, S. Dak., collected in regular manner by A. L. Beekly in 1909. The bed has a thickness of 2 feet 2 inches, all of which was sampled. The sample was necessarily somewhat weathered, but represents fairly well the character of the lignite.

Laboratory Nos. 7839 and 7842.—Samples collected in regular manner by A. L. Beekly in 1909 from prospect pits on the south side of Cedar Creek, T. 129 N., R. 88 W. They are from the same bed as sample No. 7481 and are also slightly weathered.

Laboratory No. 1935.—Sample from a lignite bed in the Fort Union formation from mine of Washburn Lignite Coal Co., Wilton, McLean County, N. Dak., collected in regular manner by M. R. Campbell on August 3, 1905, at a distance of 1,750 feet from shaft. The thickness of the bed at this point is 9 feet 6 inches, of which the lower 6 feet 6 inches was sampled.

Laboratory No. 1971.—Sample from a lignite bed in Fort Union formation in mine of Consolidated Coal Co., at Lehigh, Stark County, N. Dak., collected in regular manner by M. R. Campbell on August 5, 1905, at a distance of 1,900 feet from the mine mouth. The thickness of the bed at this point is 6 feet 4 inches, of which the lower 5 feet was sampled.

Laboratory No. 12533.—Sample from a lignite bed in Fort Union formation, from mine of United States Reclamation Service, 3 miles northeast of Williston, Williams County, N. Dak., collected in regular manner by F. A. Herald on August 16, 1911, at a distance of 1,225 feet east from the mine mouth. The thickness of the bed at this point is 10 feet 3 inches, of which the lower 8 feet was sampled.

Laboratory No. 14485.—Sample from Harmon (?) lignite bed, Fort Union formation, from the Scranton mine of Charles Liddell, Scranton, Bowman County, N. Dak., collected in regular manner by C. J. Hares on June 30, 1912, from face of east entry 1,000 feet from mine mouth. The total thickness of the bed is 20 feet 3½ inches. The sample represents 6 feet near the middle of the bed.

In a general way the comparative values of the lignite from different mines and different beds can be obtained from the heating values of the air-dried sample (form B of analysis). In the analyses from the Cannonball River field, however, this criterion is at fault. In three of these analyses, the first, second, and fourth given in the above table, the air-drying loss is comparatively small, which is probably due to the slightly weathered condition of the lignite sampled. As a result, the other sample—the third in the table—gave a much higher heating value in the air-dried form of analysis, although it has a lower heating value in all the other forms. The results of the three analyses of lignite beds in the Lance formation must be considered as of comparatively little value on account of the weathered condition of the samples. They suggest, however, that the Lance lignite is probably of a little higher grade than that from the Fort Union.

In all lignites the percentage of moisture is very high. On exposure to air a considerable part of this moisture is evaporated and a resultant shrinkage takes place, causing the lignite to check or break up into small pieces. The percentage of sulphur represented in the analyses is higher than in the lignites of some portions of the plains basins, but it is not so high as in other regions. It occurs in the form of nodules or balls of pyrite or marcasite distributed along both joint and bedding planes.

In the analyses of samples from the Cannonball River field, and in some of the others given in the above table, the volatile matter was determined by a new or modified method. This method involved a preliminary heating of the lignite before subjecting it to a temperature high enough to drive off the volatile matter. In the standard method the higher heat is applied at once, a process which when applied to lignite is apt to cause sputtering with attendant mechanical loss of particles of the sample. This loss affects chiefly the fixed carbon, so that when the modified method is used the determined percentage of that constituent is generally higher, in some analyses as much as 20 per cent.

In addition to the careful analyses made by the Bureau of Mines a number of supplementary chemical tests were made with a small portable outfit during the progress of field work. These tests were made in order to determine in a number of samples the percentage of moisture set free on air drying and the percentage of noncombustible material or ash. This work was done by C. E. Lesher, of the United States Geological Survey, in September, 1912. The samples were all taken in the west-central part of the field. The most important results of these tests are presented in tabular form on page 260:

Tests on lignite samples from the Cannonball River lignite field.

[Made by C. E. Lesher, September, 1912.]

No.	Name.	Location.			Location on map (Pl. XIII).	Air-drying loss.	Form of analysis.[a]	Proximate.				Color of ash.	Luster, weathering, and other characters.
		Sec.	T. N.	R. W.				Moisture.	Volatile matter.	Fixed carbon.	Ash.		
1	Kelch's strip pit	4	132	91	93	21	B	10	34	40	16		Total thickness of bed, 64 inches. Lignite, partly weathered.
2	Compton's strip pit	10	133	90	111		A				16.5	Yellow	Dull, platy, from fresh surface 18 inches back from face.
3	do	10	133	90	111		A				10	Red	Dull, platy, from weathered surface.
4	do	10	133	90	111		A				4.5	Yellow	Bright, massive, conchoidal, from fresh surface 18 inches back from face.
5	do	10	133	90	111		A				5	White	Bright, massive, conchoidal, from weathered surface.
6	do	10	133	90	111		B				12		Hard to burn off. Mineral charcoal.
7	Delebar's strip pit	15	133	90	107		A				3	White	Woody, fibrous material.
8	do	15	133	90	107		A				23.5		Dirty parting, dull, dry.
9	do	15	133	90	107	33	B				14	Gray	Soft black material, weathered.
10	Well	32	133	90	99	29	B	3.5	46	36	14		From well under water.
11	Coffin Butte strip pit	34	132	90	98	21	B				7.5		Upper bench of bed. Good lignite.
12	do	34	132	90	98	21	B				14		Lower bench of bed. Lignite 2 feet 3 inches, shale 1 inch.
13	do	34	132	90	98	32	B				2.5	Red	Good lignite.
14	do	34	132	90	98	11	B				54.5		Parting, sandy.
15	Strip pit	26	133	90	104	32	B				6		Weathered top of bed appears very dirty.
16	do	26	132	91	65	38	B				23		Carbonaceous material with thin streaks of good lignite, weathered.
17	do	27	132	90	97	44	B				23	Red	Very soft, weathered at top of bed.
18	do	33	132	91	55	15	B				50	White	Parting, bone.
19	Jones mine	12	133	88	152	11	B				33		Bone.
20	do	12	133	88	152	23	B				32.5		Lignite (?).
21	do	12	133	88	152	33	B				13		Standard sample. Chemical Laboratory No. 14729.

[a] A indicates sample as taken from mine; B indicates air-dried sample.

The results of these tests, which were purposely made on material of all grades of purity, are particularly important for reference during the course of field work, as the most variable element in the North Dakota lignites is the amount of ash. For purposes of land classification it is assumed arbitrarily that lignite or coal does not contain over 33 per cent ash. If the percentage is higher and the material otherwise similar, it is called bone. The work carried on by Mr. Lesher was particularly efficacious in determining the character of material which lies near this border line. For example, Nos. 8, 9, 16, and 17 represent finely divided material the value of which could not be told owing to the much weathered state in which it was found. The tests, however, showed that the ash content of all four samples is below 33 per cent and that in one, No. 9, it is sufficiently low to class the material as high-grade lignite. Nos. 19 and 20 represent a parting which in the mine examination was classed as bone. The analyses showed it to be at the dividing line. Two samples, Nos. 7 and 13, were selected fragments of the best quality of lignite and show that the minimum amount of ash in lignite is about 2.5 per cent.

MINING DEVELOPMENT.

At the times of the examination (1912 and 1913) there were only two important mining districts in the Cannonball field, one in T. 129 N., R. 94 W., north of Haynes, and the other in T. 133 N., Rs. 87 and 88 W. Strip pits have also been opened and lignite taken out for local use in nearly all parts of the field. In the Haynes district, T. 129 N., R. 94 W., the lignite underlies a high narrow ridge and is 11 to 13 feet thick. Five drift mines have been opened and supply the local trade for 15 or 20 miles to the east and south. A small quantity of lignite is hauled in wagons to Haynes and shipped on the railroad. The two largest mines are the Nipper & Monroe mine in sec. 16 and the Brown mine of the Haynes Coal & Mining Co. in sec. 8, both of which are shipping mines. Two other mines, the Stephenson & Gunderson, in sec. 15, and the mine of the Claremont Coal Co., in sec. 16, depend chiefly on the local demand. At the Farmers mine of the Haynes Coal Association, in sec. 9, mining has been done both by stripping and by drifting, but the mine was not in operation at the time of examination in August, 1912. In the vicinity of Leith there are two important mines, one a drift mine, in sec. 7, T. 133 N., R. 87 W., which is owned by Simon Pederson, and the other a shaft mine, in sec. 12, T. 133 N., R. 88 W., owned by John T. Dunn. Although neither of these is a shipping mine, they supply a large local demand. The main lignite bed in this locality varies considerably in thickness, reaching a maximum of about 8 feet 6 inches.

In sec. 36, T. 130 N., R. 94 W., a small drift mine, operated by William Pinkham, supplies the local demand. All these mines, except that of Simon Pederson, are dry, but the lignite on analysis shows the characteristically high moisture content. At all of these places only the lower part of the bed is mined, as the shale or clay shale overlying the lignite is too weak to serve as a roof, and 2 or 2½ feet of lignite must be left for that purpose.

The lignite in nearly all the mines is shot from the solid, a very wasteful method, in which nearly a third of the lignite is broken in small fragments and left in the mine. This method of mining is particularly inexcusable in the Haynes district, where the supply of lignite is very limited. The writer estimated that over one-half of the bed was being wasted or rendered useless by this practice.

In all parts of the field lignite is obtained for local use by stripping off the surface material near the outcrop. Although the labor involved in this process is comparatively great it seems to be at present the most economical method of supplying the local demand, except where the bed is 6 or 7 feet thick. The bottoms of most of these strip pits are filled with water, which is one of the most serious obstacles to this method of mining.

The most extensive stripping examined is the Merry mine in sec. 34, T. 132 N., R. 93 W., half a mile north of the boundary of the field. Here the lignite bed has a thickness of 10 feet, and the pit is easily drained. Mining at this point, however, could be carried on more profitably by a drift.

Some of the difficulties affecting mining have already been mentioned. Many of the lignite beds, which are commonly inclosed by beds of relatively impervious shale, form channels for underground water, which issue at the outcrop as springs. It will in general, therefore, be necessary that drift mines be opened on north or northeast slopes so that the entries follow the slight but general rise of the beds, which is to the southwest, and which it is believed will be sufficient to furnish natural drainage.

The most serious drawback to mining in this field is the character of the overlying shale or clay shale, which is so weak that it can not be used as a roof, so that part of the top of the bed must be left for this purpose. For this reason only the thicker beds can at present be mined, except by surface stripping.

The lignite is at present used generally for domestic purposes and to some extent for steaming. The low grade of the fuel and its extremely poor stocking qualities render it unfit for shipping in open cars, so that development for some years at least will be governed by the local demand. Experiments made by the Bureau of Mines at Pittsburgh[1] and by the experiment station of the North Dakota School of Mines[2] have proved that the North Dakota lignites can be

[1] Wright, C. L., Briquetting tests of lignite at Pittsburgh, Pa., 1908-9, Bu. Mines Bull. 14, 1911.

[2] Babcock, E. J., Investigations of lignite coal relative to the production of gas and briquets: Rept. School of Mines and Experimental Station of North Dakota, 1911.

made into briquets at a cost which would place them on the market in favorable competition with high-grade coals.

DESCRIPTION BY TOWNSHIPS.

The following description of the Cannonball lignite field deals with township units, beginning with T. 129 N., R. 95 W. The ranges are described in order from west to east and in each range the townships are considered from south to north. The townships shown on Plate XIII (p. 282) are described first.

The lignite beds in each township are described in order, beginning with the lowest. All places where examination of the lignite was made and many places where it was reported to be present were accurately located, and their positions are shown on the maps by location numbers. The lignite sections measured at these places are numbered correspondingly, and reference from the text to the maps and graphic sections is made by means of these numbers.

T. 129 N., R. 95 W.

The surface of T. 129 N., R. 95 W., is a broad rolling prairie interrupted by a few prominent sandstone-capped buttes. Flat Creek flows eastward across the central part of the township and drains the greater part of its area. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the central part of the township in an east-west direction. Hettinger is situated on that road in sec. 13 of the township adjoining on the west. All the rocks exposed in the township belong to the Fort Union formation. The highest land is in the northeastern part, in secs. 1 and 2, where a high rounded ridge strewn with quartzitic bowlders extends westward from T. 129 N., R. 94 W.

The principal lignite bed of the region, to which the name Haynes lignite bed is applied, underlies the ridge in secs. 1 and 2, its presence being shown at a few points by mounds of red clinker and by black dust or "blossom" at the surface. Otherwise it is concealed, and no measurement of its thickness could be made nearer than the mine of the Haynes Coal Co., in sec. 8, T. 129 N., R. 94 W., where it is 13 feet thick. A thin bed of lignite at a lower horizon underlies some of the buttes in the southern part of the township and was measured at locations 1 and 2 in secs. 25 and 28, where thicknesses of 1 foot 7 inches and 1 foot 4 inches, respectively, were found.

T. 129 N., R. 94 W.

The most prominent topographic feature of T. 129 N., R. 94 W., is a high rounded ridge extending from sec. 6 southeast into sec. 22. The surface slopes gradually away from this divide to the valleys of Duck Creek on the north and Flat Creek on the south. South of Flat Creek, along the southern border of the township, there is a series of prominent buttes capped with 30 to 40 feet of resistant sandstone. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southern part of the township in a southeast-northwest direction. The town of Haynes is located on that road in sec. 29.

The rocks that outcrop in the township belong to the Fort Union formation except in a part of the valley of Flat Creek, where the upper part of the Cannonball marine member of the Lance formation appears at the surface.

The most important bed of lignite in the Cannonball River field, the Haynes bed, underlies the high ridge in the northwest-central part of the township. It is being mined in four drift mines in secs. 8 (location 3), 15 (location 6), and 16 (locations 4 and 5). A fifth mine in sec. 9 (location 7) was not in operation in the summer of 1912. Except for a few small mounds of reddened clinker there is no surface indication of this bed, and it was first found in a well in the SW. ¼ sec. 9. All five of the mines lie within a radius of less than a mile and show little variation in the character of the lignite or the thickness of the bed, which ranges from 10 feet in the Stephenson & Gunderson mine (location 6, Pl. XIII, p. 282) to 13 feet in the Brown mine (location 3). The tops of the hills south of the village of Haynes are at about the altitude of this bed, but owing to the dip of the strata are stratigraphically lower, and the bed is therefore not present in that locality. A sample for chemical analysis was obtained from the Nipper & Monroe mine (location 4), the results of which are shown in the table on page 16. Sections measured in two of the mines are shown in Plate XIII (locations 5 and 6).

T. 130 N., R. 94 W.

The surface of T. 130 N., R. 94 W., is for the most part rolling prairie, interrupted by a number of prominent buttes in the eastern and central parts of the township. All the outcropping strata belong to the lower 200 feet of the Fort Union formation. The high buttes are underlain by the Haynes lignite bed, but the lignite has been burned extensively and much of the neighboring surface is strewn with blocks of reddened clinker or with small mounds of the same material. In only a few of the larger buttes is the lignite preserved unburned.

Two mines are in operation in the township, one a strip pit in sec. 3 (section 9, Pl. XIII), now partly filled with water, and the other a drift mine operated by William Pinkham, in the NW. ¼ sec. 36 (section 8, Pl. XIII). The lower part of the bed in the strip pit at location 9 could not be examined, but the thickness is reported to be 13 feet; it is separated by 2 feet 4 inches of shale from a 2-foot bed of impure lignite above. At location 8 the main bed is reported to be 12 feet thick and the upper bed 1 foot 6 inches thick. A sample of the lower 8 feet 10 inches of the bed was obtained from this mine, the analysis of which is given in the table on page 256.

T. 129 N., R. 93 W.

The greater part of T. 129 N., R. 93 W., is drained by Duck Creek, which flows eastward across the north-central part. The rolling prairie, which is characteristic of most of the township, is interrupted by numerous prominent buttes, many of which are capped by a resistant sandstone. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southern part of the township in an east-west direction. The town of Petrel lies in sec. 35, and White Butte post office, S. Dak., is a few hundred feet south of the south line of sec. 31. The rocks belong to the lower 200 feet of the Fort Union formation and to the upper part of the Cannonball marine member of the Lance formation. The tops of the highest buttes in secs. 4 and 25 are capped with reddened clinker, showing the former presence of a bed of lignite, which is now entirely burned out. This bed was presumably the Haynes lignite bed.

T. 130 N., R. 93 W.

Cedar Creek flows southeast across the central part of T. 130 N., R. 93 W., and drains the entire area of the township. All the rocks belong to the Fort Union formation except those in a small area in the creek valley in the southeastern part of the township, where the upper beds of the Cannonball marine member of the Lance formation are exposed.

The Haynes lignite bed outcrops near the tops of a few high rocky buttes in secs. 30, 31, and 32. In this locality it has been extensively burned, however, and probably only a very small quantity of lignite remains. A bed of lignite, presumably also the Haynes, underlies the low hills in the northeastern corner of the township. It is for the most part concealed at the outcrop, and surface indications were found at only two places. At the Maire mine, in the SE. ¼ sec. 1 (location 11), some lignite has been removed by stripping the overlying surface material. The bed at this place has a thickness of about 7 feet, part of which is under water. At the other locality, in the SE. ¼ sec. 2 (location 10), only some weathered lignite and ashes are exposed on the surface.

T. 131 N., R. 93 W.

A series of high rocky buttes, the divide between Cedar Creek and Timber Creek, extends across T. 131 N., R. 93 W., in a general northwest-southeast direction. On either side of this divide the surface slopes gently downward toward the valleys of the two streams. The higher buttes are strewn with large quartzitic bowlders, and practically the whole area is grass covered. All the rocks belong to the Fort Union formation, but exposures are in general poor.

At least one bed of lignite underlies the central part of the township and is correlated with the Haynes bed. Its outcrop, as shown on the map (Pl. XIII), is located as accurately as the available data would permit. Farther east, in T. 131 N., R. 92 W., two other beds have been found, one about 50 feet and the other nearly 150 feet higher in the section. As the hills in T. 131 N., R. 93 W., rise nearly 200 feet above the level of the Haynes coal, it is probable that one or both of these higher beds are present in the township but are concealed.

The Haynes bed was examined at a few places in this township and surface indications were found at several other places. In the SW. ¼ sec. 5 (location 12) a strong spring issues from a bed of lignite, which is probably the Haynes bed. No measurement, however, was made and no evidence was obtained with regard to the bed from that place to the southeast as far as sec. 28, where, on the west side of the hill, there is a small but prominent mound of clinker. At the south end of the same hill a section was measured (location 13), but only 1 foot 4 inches of weathered lignite and ash was found. Two other sections were measured south of the ridge, one in the SW. ¼ sec. 27 (location 14) and the other near the west quarter corner of sec. 35 (section 15, Pl. XIII, p. 282). The thicknesses measured at these places were 5 feet 6 inches and 5 feet 5 inches, respectively, but at both places the top of the bed was slightly burned. Small mounds of clinker at a few places in sec. 34 show where the bed has been burned at the outcrop. North of the divide, in the SE. ¼ sec. 12 (location 16) weathered lignite was reported in a well, and on a small stream near the center of sec. 13 (location 17) 1 foot 2 inches of the base of the bed was found, but the upper part had been eroded away. At Olsen's mine, in the SW. ¼ sec. 11 (location 18), the greater part of the bed is under water. Mr. Olsen reports that there is 3 feet of good lignite, and the writer has estimated that the weathered and burned material above represents at least 2 feet more. The bed was found in a well in the NW. ¼ sec. 2 (location 19), but the thickness is not known. Half a mile north of the township line, at Merry's mine, in sec. 34, T. 132 N., R. 93 W. (section 20, Pl. XIII), the bed has a thickness of 10 feet, all of which is good lignite. A considerable amount of lignite has been removed for local use.

T. 129 N., R. 92 W.

The most prominent topographic feature in T. 129 N., R. 92 W., is a series of high rocky buttes in the east-central part of the area, which were known to the early explorers in the region as Les Belles Pierres Hills from the abundance of colored pebbles scattered over their tops. North of the hills the slope is steep, but to the south it is comparatively gradual down to the rolling prairie country around

Lemmon, S. Dak. The drainage is to the north toward Cedar Creek. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southern part of the township in an east-west direction. Lemmon is located on that road at the State line south of sec. 35.

The rocks that outcrop in most of this township belong to the Fort Union formation, but in the valleys of Duck Creek and a small creek in sec. 2 the upper part of the Cannonball marine member of the Lance formation is exposed.

The horizon of the Haynes lignite bed lies from 75 to 100 feet below the tops of the higher hills, but no evidence of any bed of lignite more than a few inches in thickness could be found in the township.

T. 130 N., R. 92 W.

Cedar Creek flows eastward across the southern part of T. 130 N., R. 92 W., and drains its entire area. South of the stream the surface rises steeply toward Les Belles Pierres Hills, but to the north the slope is much more gradual. The rocks belong to the upper part of the Cannonball marine member of the Lance formation and to the Fort Union formation, the former outcropping only in the valley of Cedar Creek. The Cannonball member is well exposed in the bluffs of the creek, but the Fort Union is for the most part concealed by a heavy mantle of soil. The high hills along the north border of the township are almost covered with large residual blocks of quartzitic material, a bed of which, apparently in place, forms the top of Spring Butte in sec. 4.

A lignite bed, which is believed to be the Haynes bed, underlies the higher land in the northern part of the township, but its outcrop is for the most part concealed. On the southwest side of Spring Butte, in sec. 4 (location 21), the bed has been mined to some extent for local use, but the bottom of the pit is now under water. At this place 4 feet 5 inches of lignite is exposed. On the other side of Spring Butte, also in sec. 4, is the Spring Butte strip pit (location 22) in which 4 feet of lignite is exposed above the water in the bottom of the pit. The measurements obtained in strip pits in T. 131 N., R. 92 W., indicate that the bed is thinner toward the east.

Near the top of Spring Butte, in sec. 4 (location 23), a bed of lignite about 2 feet thick is exposed about 150 feet above the Haynes bed. A bed of lignite less than 2 feet thick was found at a corresponding altitude on a high butte near the north line of sec. 1.

T. 131 N., R. 92 W.

T. 131 N., R. 92 W., is an area of very broad fertile valleys separated by high rocky ridges. The greater part of the township is drained by small streams flowing toward the north and east into Timber Creek, which crosses its northeastern corner. The main divide extends across the southern part of the township, but two high spurs extend into the northwest and east-central parts. All the rocks belong to the Fort Union formation, but there are very few natural exposures.

At least two lignite beds outcrop in the township, but the data are so meager that correlations of the various exposures and well records are not invariably certain. The lower bed, which is supposed to be the same as the Haynes lignite bed, underlies the greater part of the township, except in parts of the valleys to the northeast and east. The upper bed is about 50 feet higher and underlies only the buttes. The outcrops of the beds as shown on the map were sketched largely from the topography and are only approximately correct.

On the south side of the divide between Cedar and Timber creeks the lower bed has been mined at two places, at Rogers's strip pit in the SE. ¼ sec. 31 (location 24) and at Cooper's strip pit near the west line of sec. 35 (section 25, Pl. XIII). The Rogers mine is not operated at present and is partly filled with water. The lignite exposed above water level has a thickness of 5 feet 8 inches. At Cooper's mine, however, where a considerable amount of lignite is being removed for local use, the total thickness of the bed is only 3 feet 8 inches. North of the main ridge, at Hubbard's mine, in the SE. ¼ sec. 25 (section 26, Pl. XIII), the bed is only 1 foot 2 inches thick. A bed of lignite, doubtfully correlated with the Haynes bed, outcrops in a steep bluff in the SE. ¼ sec. 24 (location 27), where it has a thickness of only 1 foot. At Sheep Creek mine, in sec. 23 (location 28), the bottom of the bed is covered with water, but 3 feet 2 inches of lignite is exposed above water level. The five localities mentioned above are the only places in the township where the bed could be examined. At a number of places, however, in the western part of the township, lignite at about the horizon of the Haynes bed is reported in wells. These reported sections are as follows:

Lignite sections, probably on Haynes bed, reported in T. 131 N., R. 92 W.

[In addition to sections described in text and shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	Ft.	in.	No. on map (Pl. XIII).	Location.	Section.	Feet.
29	NW. ¼ sec. 10..	Lignite in well.....	2	6	35	SW. ¼ sec. 29..	Lignite in spring..	(a)
30	SE. ¼ sec. 20...	Lignite in well.....	3		36	SE. ¼ sec. 30...	Lignite in well.....	(a)
31	NW. ¼ sec. 28..	Lignite in well.....	2		37	SE. ¼ sec. 18...	Lignite in well.....	2+
32	SE. ¼ sec. 28...	Lignite in well.....	(a)		38	SE. ¼ sec. 4....	Lignite in well.....	(a)
33	SW. ¼ sec. 27..	Lignite in well.....	7		39	NE. ¼ sec. 4....	Lignite in well.....	(a)
34	SW. ¼ sec. 28..	Lignite in well.....		6	40	SW. ¼ sec. 5....	Lignite in well.....	3

a Unknown.

The upper bed is exposed at only one place in the township, a prospect in the SE. ¼ sec. 11 (section 44, Pl. XIII, p. 282). At this place it has a thickness of 5 feet 5 inches. Lignite at about this horizon was reported to have been found in several wells in the township, indicating that the bed probably has a thickness of 3 to 6 feet, at least in the eastern part of the township.

Lignite sections reported on bed about 50 feet above Haynes lignite bed in T. 131 N., R. 92 W.

[In addition to section shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
		Ft. in.			Feet.
41	SW. ¼ sec. 26..	Lignite in well..... (a)	45	NW. ¼ sec. 22..	Lignite in well...... 2
42	NW. ¼ sec. 26..	Lignite in well..... (a)	46	NE. ¼ sec. 8...	Lignite dust brought up by prairie dogs.
43	SE. ¼ sec. 14...	Lignite in well..... 1 6			

a Unknown.

T. 129 N., R. 91 W.

Les Belles Pierres Hills extend from the west more than halfway across the north-central part of T. 129 N., R. 91 W. The northern slope of the hills is broken into a series of steep bluffs separated by wide benches. South of the hills is a smooth, gently rolling prairie. The drainage of the entire township is to the north toward Cedar Creek. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southern part of the township in an east-west direction. The Cannonball marine member of the Lance formation is exposed in the valleys of Plum Creek and other northward-flowing streams. Fort Union strata underlie all the higher portion of the township. Beds of resistant sandstone belonging to this formation form prominent escarpments on the sides of the higher hills, but over the greater part of the township rock exposures are very few. No lignite was found or reported within the township.

T. 130 N., R. 91 W.

Cedar Creek flows eastward across the southern part of T. 130 N., R. 91 W., and with its principal tributary, Timber Creek, drains the entire area. South of the creek the bluffs rise somewhat abruptly toward Les Belles Pierres Hills, but to the north there is a more gradual slope. Rocks belonging to the Cannonball marine member of the Lance formation outcrop in the valleys of Cedar and Timber creeks in the northeastern corner of the township. These rocks are well exposed in the creek bluff about a mile east of Stowers post office and at a few other points along the creek. They are overlain by the lower part of the Fort Union formation, which occupies only a small part of the area.

A lignite bed which is correlated with the Haynes bed underlies a high butte along the north line of secs. 5 and 6. No exposure of the bed was found in this township, but in a well in the NE. ¼ sec. 6 (location 48) 2 feet of weathered lignite was reported at a depth of 26 feet. No evidence of the higher beds was found in this township.

T. 131 N., R. 91 W.

Timber Creek flows southeastward across the central part of T. 131 N., R. 91 W., and drains the entire area. The surface is for the most part a rolling prairie, rising to a series of rough buttes in the northern part of the township, and to a high ridge in the southwestern corner. The outcropping rocks belong to the Fort Union formation except in the low, flat area along Timber Creek and its tributaries in the southeastern corner of the township, where the upper part of the Cannonball marine member of the Lance formation appears at the surface.

There is evidence that three beds of lignite outcrop within the township, but exposures are so few that correlations are very unsatisfactory. The lowest bed outcrops in the steep bluffs of a branch of Timber Creek in sec. 9 (location 49), where it has a thickness of 1 foot 9 inches. Lignite at about the same horizon was reported in two wells, one in the SW. ¼ sec. 10 (location 50), where the thickness is unknown, and the other in the NW. ¼ sec. 14 (location 51), where the thickness is 2 feet. The next higher bed of lignite, which is correlated with the Haynes bed, is not exposed within the township, but a well in the SE. ¼ sec. 2 (location 52) reached the top of a bed of lignite which is at about the horizon of that bed. Just north of the township line, in the SE. ¼ sec. 33, T. 132 N., R. 91 W. (section 55, Pl. XIII, p. 282), the bed has a thickness of 6 feet 6 inches.

In the SE. ¼ sec. 31 (section 53, Pl. XIII) a bed of lignite 4 feet 10 inches thick is exposed in an abandoned strip pit. This bed is about 50 feet above the Haynes bed. It is not exposed in the northern part of the township, but its horizon is indicated by mounds of clinker at a number of places.

T. 132 N., R. 91 W.

A high, irregular upland area extends across the central part of T. 132 N., R. 91 W., forming the divide between Cannonball River and Cedar Creek. The whole township is characterized by nearly flat-topped hills with moderately steep slopes. The rocks all belong to the Fort Union formation and, as in other parts of the field, are covered with a heavy mantle of soil.

Two beds of lignite outcrop within the township, the lower of which is doubtfully correlated with the Haynes bed. In the southern part of the township this bed has been mined by stripping at two places, in the NW. ¼ sec. 31 (location 54) and in the SE. ¼ sec. 33 (section 55, Pl. XIII). At location 54 the pit is partly filled with water, and only 2 feet 2 inches of lignite was exposed. At location 55 the bed is 6 feet 6 inches in thickness, but contains three thin partings of shale and bone. Half a mile west of the township line, in sec. 36, T. 132 N., R. 92 W. (location 47), there is a strip pit in which the bed is at least 6 feet 4 inches thick, the base being concealed by water in the bottom of the pit. In the northern part of the township a bed, which is probably the Haynes, is exposed in three strip pits, and was reported to be present in several wells. At Kelch's mine, in sec. 4 (section 63, Pl. XIII), the bed is 5 feet 4 inches thick, but there is a considerable diminution in thickness toward the east. The lignite sections on this bed in the northern part of the township are as follows:

Lignite sections probably on the Haynes bed in the northern part of T. 132 N., R. 91 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	Ft.	in.	No. on map (Pl. XIII).	Location.	Section.	Ft.	in.
56	NE. ¼ sec. 12.	Lignite in well....	1		60	SE. ¼ sec. 10 (strip pit).	Shale, gray.		
57	SE. ¼ sec. 12.	Lignite in abandoned prospect full of water....	2½–3				Lignite........	1	10
58	SW. ¼ sec. 12.	Lignite in well...	(a)				Bone..........		4
59	NW. ¼ sec. 12	Lignite in well...	(a)				Lignite........	2+	
							Base of bed below water.		
							Total lignite.	3	10+
					62	SE. ¼ sec. 9.	Lignite in well...	5	

a Unknown.

About 50 feet above the Haynes bed is a lignite bed which outcrops at the base of a flat-topped hill in the southeastern part of the township. This bed is mined by stripping at two places in sec. 26 (locations 65 and 66) and was reported in wells in sec. 28 (location 64) and sec. 26 (location 67). The section measured at location 66 is shown graphically on Plate XIII (p. 282). Both pits were partly filled with water and only the approximate thickness could be ascertained. The bed is probably 5 feet or more in thickness in the southern part of the township. The partial sections obtained are as follows:

Lignite sections on bed 50 feet above the Haynes lignite bed in T. 132 N., R. 91 W.

[In addition to section shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	Ft.	in.
64	NE. ¼ sec. 28	Lignite in well	(a)	
65	SW. ¼ sec. 26 (strip pit)	Shale.		
		Lignite		2
		Shale		3
		Lignite	5	
		Base of bed below water.		
67	NW. ¼ sec. 26	Lignite in well	(a)	

a Unknown

T. 130 N., R. 90 W.

Cedar Creek flows eastward in a wide valley through the southern portion of T. 130 N., R. 90 W., and is joined in the southeastern part by Timber Creek, its largest tributary. These valleys are separated from the general upland level by a series of steep scarps and wide benches. That part of the township lying south of Cedar Creek was examined [1] in 1909 and is not included in the Cannonball River field. The greater part of the township, with the exception of the bluffs of Cedar and Timber creeks, is grass covered and rock exposures are few. The rocks in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. Only the lower part of the Fort Union is exposed in the township and these strata are for the most part yellow sandstone. No lignite was found or reported within the township.

T. 131 N., R. 90 W.

The principal topographic feature in T. 131 N., R. 90 W., is a group of high rugged buttes in its northern and central parts. Elsewhere in the township the country is rolling prairie, covered with a heavy mantle of soil, and rock exposures are few. The rocks in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union and White River formations with surficial deposits of late Tertiary or Quaternary river gravels. The top of the Cannonball member appears in the valleys of two small streams in the southern part of the township. Fort Union rocks outcrop throughout the remainder of the area, except on the tops of the highest buttes, which are capped by white marly limestone and sandstone of White River age. The deposits of river sand and gravel are very conspicuous on the tops of some of the buttes which are a little lower than the base of the White River.

The lignite beds are not so well exposed in this township as in areas to the north and west. The lowest bed is thin, and its presence is shown only by a small mound of clinker in the SE. ¼ sec. 14 and by about a foot of lignite in two wells in the western part of the same section (locations 68 and 69).

The next higher bed, which is doubtfully correlated with the Haynes lignite bed, is reported to have a thickness of about 6 feet in an old well in sec. 8 (location 70). In sec. 22 (location 71), at about the same horizon, some lignite dust has been brought to the surface by badgers. In the NE. ¼ sec. 23 (location 72) 2 feet 9 inches of lignite is exposed, but the top of the bed is eroded away. The same bed was reached by a well in sec. 12 (location 73) and by two wells in sec. 4 (locations 74

[1] Calvert, W. R., and others, Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota: U. S. Geol. Survey Bull. 575, p. 43, 1914.

and 75). These data are insufficient for definite conclusions, but it seems probable that the bed has a thickness of 3 to 7 feet under all the high land in the northern part of the township.

A higher bed of lignite was found in a well in sec. 10 (location 76), where it was reported to have a thickness of 3 feet. In sec. 2 (location 78), however, the following section was measured:

Section at location 78, in the SE. ¼ SW. ¼ sec. 2, T. 131 N., R. 90 W.

	Ft.	in.
Shale, carbonaceous.		
Lignite		4
Shale	1	4
Lignite	1	6
Shale, carbonaceous.		
	3	2

At several places in secs. 10 and 15, high up on the sides of the buttes, a considerable amount of reddened clinker shows where this lignite bed has been burned. The thickness of the bed in this part of the township could not be determined. At a horizon possibly somewhat lower, in the SW. ¼ sec. 12 (location 77), some prospecting has been done, but the bed examined was only a few inches thick.

T. 132 N., R. 90 W.

The surface in T. 132 N., R. 90 W., is for the most part smoothly rolling prairie interrupted by a few high rounded hills. Sheep Creek, which flows northeast toward Cannonball River, drains the greater part of the township. The rocks are all Fort Union (Eocene) in age with the exception of 20 or 30 feet of fine-grained marly limestone of White River age (Oligocene) on the top of Coffin Butte in sec. 34. The beds dip to the northeast at about the same angle as the slope of the valley of Sheep Creek.

The lowest bed of lignite in the township, which is doubtfully correlated with the Haynes bed, outcrops in the valley of Sheep Creek not far above the water level. In the central and eastern parts of the township the bed has been mined by stripping at a number of places and is also reported to have been found in several wells. In a number of the strip pits the bottom of the bed is concealed by water, so that in only a few places could the complete thickness be measured. The minimum thickness is probably in sec. 1, where the bed contains over 4 feet of lignite (section 81, Pl. XIII). The thickness increases to the south and southwest. In the SE. ¼ sec. 16 (location 90) the thickness is over 5 feet. Thicknesses of 6 feet or more were reported at three places. All the data obtained concerning the bed in this township are given in Plate XIII (p. 282) or in the following table:

Lignite sections on Haynes (?) bed in T. 132 N., R. 90 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	Ft.	in.
79	NE. ¼ sec. 13	Shale.		
		Sandstone	3	6
		Lignite	2+	
		Base of bed below water.		
		Reported thickness	6	6
80	SE. ¼ sec. 12	Lignite in well (Horizon doubtful.)		8
82	NE. ¼ sec. 14	Weathered lignite on surface.		
83	SW. ¼ sec. 14 (strip pit).	Clay, bluish gray.		
		Lignite	3	9+
		Base of bed under water.		
84	NE. ¼ sec. 26	Lignite in well	(a)	
85	NE. ¼ sec. 26	Lignite in well	2+	
86	SE. ¼ sec. 26	Lignite in well	(a)	
87	Center sec. 26	Lignite in well	(a)	
89	NE. ¼ sec. 21	Lignite in spring.	(a)	
90	SE. ¼ sec. 16 (strip pit).	Shale, gray	3+	
		Clay, black		8
		Lignite	5	2+
		Base of bed under water.		
91	SW. ¼ sec. 10 (in well).	Lignite	4	
		Shale	2	
		Lignite	4	6±
92	SW. ¼ sec. 14	Lignite in well	(a)	
93	NE. ¼ sec. 11 (prospect pit).	Lignite	1	6+
		Base of bed below water.		
94	SE. ¼ sec. 2	Shale, sandy	7+	
		Lignite	2	10+
		Base of bed below water.		
		Reported thickness	6	

a Unknown.

About 50 feet above the Haynes lignite bed is another important bed which has been mined by stripping at three places in secs. 35 and 27 but which was not found elsewhere in the township. In each of these mines the thickness of the bed is over 6 feet, but a number of partings of shale and bone reduce the value to some extent. The three sections measured (sections 95, 96, and 97) are shown in Plate XIII.

A bed of lignite about 100 feet higher stratigraphically is exposed in an abandoned strip pit (section 98, Pl. XIII) on the north slope of Coffin Butte in sec. 34. The total thickness is 4 feet 7 inches, but a parting of shale 1 foot 11 inches thick makes the bed of little value.

T. 133 N., R. 90 W.

Cannonball River flows eastward across the northern part of T. 133 N., R. 90 W., in a comparatively narrow valley, which is separated from the upland by a series of steep bluffs and wide terraces. Branch lines of the Northern Pacific and the Chicago, Milwaukee & St. Paul railways cross the northwestern part of the township. Odessa, in sec. 5, is located on the Northern Pacific, and New Leipzig, in sec. 35 of the township to the north, is a connecting point for the two roads. The strata throughout the township belong to the Fort Union formation, the lower sandstones of which are well exposed in the bluffs of Cannonball River and of a creek which flows northward in the eastern part of the township. Back from these streams, however, exposures are poor and the correlation of beds is difficult. The general dip of the strata to the northeast is a little more pronounced in this township than in areas to the south and west.

The lowest bed of lignite outcrops in the river bluffs in the eastern part of the township but is of little importance. It was measured at locations 101 and 100, in secs. 12 and 14, respectively, and is 1 foot 8 inches in thickness at both places. Another bed of lignite 1 foot 4 inches in thickness is exposed in a shallow well in the NE. ¼ sec. 32 (location 99).

About 30 feet above the bed at locations 100 and 101 is an important bed of lignite, which has been mined by stripping at several places in the river bluffs, in secs. 9, 10, and 13, where the thickness ranges from 3 feet 9 inches to 7 feet 6 inches. (See sections 107, 108, 109, and 111, Pl. XIII, p. 282.) The section at location 110 is as follows:

Section of lignite bed at location 110, in the SE. ¼ sec. 10, T. 133 N., R. 90 W.

	Ft.	in.
Shale, sandy	10	
Lignite	3	6
Bone		½
Lignite		8
Bone		1
Lignite	1	5
Shale	6	
	21	8½

Farther east, in sec. 11, the bed is much thinner. (See sections 106 and 112, Pl. XIII.) This bed is probably at a somewhat lower horizon than the Haynes lignite bed. In the bluffs of a small steep-sided valley in the southeastern part of the township a lignite bed, probably the Haynes bed, is well exposed and is from 3 feet 10 inches to 4 feet 9 inches thick. (See sections 102, 103, 104, and 105, p. 36..) In sec. 22, however, two wells, one in the SE. ¼ and the other in the SW. ¼ (location 113), pass through the horizon of this bed, but are reported to have passed through no lignite. In a well in sec. 28 (location 114) a thickness of 2 feet was reported.

A bed exposed at a small strip pit in sec. 32 (location 115) is at least 3 feet 9 inches thick, but the base of the bed is concealed by water in the bottom of the pit. This bed is correlated with the bed described above because of the accordance in altitude, but this evidence is not at all conclusive.

Lignite sections on Haynes (?) lignite bed in T. 133 N., R. 90 W.

No. on map (Pl. XIII).	Location.	Section.	Ft.	in.	No. on map (Pl. XIII).	Location.	Section.	Ft.	in.
102	NW. ¼ sec. 25 (strip pit).	Shale	5+		105	SW. ¼ sec. 26.	Lignite in well	3	6
		Lignite		10	113	SW. ¼ sec. 22.	Well passing through lignite horizon. Bed reported to be absent.		
		Bone		1					
		Lignite	3	6+					
		Base of bed concealed below water.							
103	SE. ¼ sec. 23.	Shale, sandy	10+		114	SW. ¼ sec. 28.	Lignite in well	2	
		Shale, carbonaceous	1	4	115	SW. ¼ sec. 32 (strip pit).	Shale.		
		Lignite	3	5			Lignite	3	9+
		Shale		1			Base of bed below water.		
		Lignite		4					
		Shale.							
104	SE. ¼ sec. 26 (strip pit).	Shale, brown.							
		Lignite	4	9+					
		Base of bed below water.							

About 100 feet higher than the Haynes(?) bed is another bed of lignite which outcrops near the tops of the high buttes in sec. 21 (location 116) and in sec. 36, where it has been burned extensively. No exposures of the bed, however, could be found in this township. The horizon of the bed is below the tops of the group of high buttes in secs. 22 and 27, but as no evidence of the bed could be found there the conclusion was reached that it is either very thin or absent.

T. 130 N., R. 89 W.

Cedar Creek flows eastward across the southern part of T. 130 N., R. 89 W., and forms the southern boundary of the Cannonball River field. The valley is generally wide and open and is bordered in only a few places by vertical bluffs. North of the stream the surface rises gradually to the moderately rolling prairie land characteristic of the northern part of the township. The rocks that outcrop in the township belong to the lower part of the Lance formation, the Cannonball marine member of the Lance, and to the Fort Union formation. The Lance formation outcrops in the valley of Cedar Creek, where it is fairly well exposed in a few of the steeper bluffs. The Fort Union underlies the northern portion of the township, but is for the most part concealed by a heavy mantle of soil. With the exception of a thin bed near the top of the lower part of the Lance, no lignite was found or reported within the township.

T. 131 N., R. 89 W.

The surface of T. 131 N., R. 89 W., is for the most part rolling upland prairie, interrupted by numerous small rounded buttes and a few high rocky buttes. The most conspicuous feature is Pretty Rock Butte, which is a prominent landmark for all the surrounding region. The rocks belong to the Fort Union formation, with the exception of two small areas in the southwestern part of the township, where the streams have cut through to the top of the Cannonball marine member of the Lance formation. The rocks are for the most part concealed by the heavy mantle of soil, but the upper beds are well exposed on the south face of Pretty Rock Butte. The general dip of the strata in this part of the field is toward the northwest.

Two beds of lignite outcrop on the sides of Pretty Rock Butte, the lower of which is probably the Haynes bed. This bed also underlies a number of low hills to the north and northwest. It has a thickness of 4 feet 2 inches on the south side of Pretty Rock Butte (section 120, Pl. XIII), and is probably over 2½ feet thick throughout the township. The upper bed was examined at only one place in the NW. ¼ sec. 34 (section 122, Pl. XIII), where it is 2 feet 5 inches thick.

Lignite sections on the Haynes (?) lignite bed in T. 131 N., R. 89 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
		Ft. in.			Ft. in.
117	SW. ¼ sec. 6	Lignite in well...... 1 6	121	NW. ¼ sec. 34	Shale. Lignite, much weathered ...... 1 10 Shale.
118	SW. ¼ sec. 6	Lignite in well...... 5			

T. 132 N., R. 89 W.

The surface of T. 132 N., R. 89 W. is for the most part rolling upland prairie which is dissected by a few steep-sided valleys and is surmounted in the northwestern part by a group of rocky hills. The rocks in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The sandy shale of the Cannonball member outcrops in the narrow valleys in the eastern part of the township, but the Fort Union rocks are largely concealed by the heavy mantle of soil.

A bed of lignite, correlated with the Haynes bed, underlies the high buttes in the northwestern part of the township and has been mined or prospected at several places. The greatest known thickness in the township, 4 feet 7 inches, is found in a strip pit in sec. 19 (section 123, Pl. XIII). Evidence as to the thickness of this bed in other parts of the township is very unsatisfactory, but indicates that there is little variation. Two of the sections measured in the township (sections 123 and 128) are shown graphically in Plate XIII. The other data concerning the bed are as follows:

Lignite sections on Haynes (?) lignite bed in T. 132 N., R. 89 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.		No. on map (Pl. XIII).	Location.	Section.	
			Ft. in.				*Feet.*
124	NW. ¼ sec. 20	Lignite in well	3 6	129	SW. ¼ sec. 4	Lignite in well	3±
125	SE. ¼ sec. 18	Lignite in well	(a)	130	SW. ¼ sec. 4 (prospect pit).	Lignite under water	(a)
126	NW. ¼ sec. 10 (prospect pit).	Lignite (reported)	3±				

a Unknown.

At the north end of the ridge, about 100 feet north of the township line, in the SE. ¼ sec. 36, T. 133 N., R. 89 W. (location 127), is a prospect pit in which 1 foot 8 inches of weathered lignite and ash is exposed. This may also be the Haynes bed, but the section is probably not complete.

T. 133 N., R. 89 W.

Cannonball River flows eastward across the northern part of T. 133 N., R. 89 W., in a comparatively narrow valley which is separated from the upland prairie on either side by a series of steep bluffs and wide terraces. Except near the river valley, the surface is moderately rolling prairie interrupted by a few rocky buttes. In the southwestern part of the township is an especially prominent group of high hills. The rocks that outcrop in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The sandy shale of the upper part of the Cannonball member and the yellow and white sandstone of the lower part of the Fort Union formation are well exposed along the bluffs of Cannonball River and Sheep Creek, but in other parts of the township the exposures are few. A good section of the Fort Union strata exposed in sec. 5 (location 136) has been examined and described by A. G. Leonard.[1] The section exposed at this place is as follows:

Section of Fort Union formation in the NE. ¼ sec. 5, T. 133 N., R. 89 W.

[See also section 136 on Pl. XIII.]

	Ft.	in.
Shale, gray, yellow, and brown	40	
Lignite (Haynes bed)	3	10
Shale, gray	4	4
Lignite		11
Shale, gray	18	6
Lignite	1	11
Shale	1	2
Lignite	2	3
Shale, light gray, sandy	8	7
Lignite	1	6
Sandstone, light gray and yellow	75	
Water level.		
	158	

[1] Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, p. 519, 1911.

The lowest bed of lignite in the above section corresponds with the lowest bed exposed in the river bluff in the SW. ¼ sec. 7 (location 131), where the section is as follows:

Section of Fort Union formation in SW. ¼ sec. 7, T. 133 N., R. 89 W.

	Ft.	in.
Sandstone, gray, unconsolidated	5+	
Bone		4
Shale, brown		4
Lignite		4
Shale, brown		2
Lignite		2
Shale, gray to light brown	1	2
Lignite		2
Shale, gray, sandy	4	6
Lignite	1	2
Sandstone, gray, unconsolidated	5+	
	18	4

The uppermost bed of lignite in the first section above is correlated with the Haynes bed and with the bed which is being mined at two places in sec. 6 (sections 134 and 135, Pl. XIII). The same bed was examined in the NW. ¼ sec. 8 (section 133, Pl. XIII) and in lot 2, sec. 1 (section 137, Pl. XIII). The average thickness in this part of the township is about 4 feet. On the south side of the river this bed is very poorly exposed, but in an abandoned mine in sec. 20 (section 132, Pl. XIII) it has a thickness of 6 feet 7 inches.

Another bed outcrops high up on the sides of the hills in the southwestern part of the township, where it has been extensively burned. A single measurement was obtained on this bed in section 32 (section 138, Pl. XIII), where it has a total thickness of 7 feet 8 inches with an 8-inch parting of sandstone 2 feet from the top.

T. 129 N., R. 88 W.

Only the small part of T. 129 N., R. 88 W., which lies north of Cedar Creek, is included in this field. The rocks that outcrop in this part of the township belong to the lower part of the Lance formation and are fairly well exposed in the creek bluffs and in a few steep slopes.

A group of thin beds of lignite outcrops in the bluffs of the creek and the smaller tributary streams. Two measurements of the thickest bed have been made in this township on the north side of Cedar Creek, one at the McCord mine in sec. 5 (location 139), where the thickness is 2 feet 2 inches, and the other in sec. 3 (section 140, Pl. XIII), where the thickness is 2 feet 10½ inches with a half-inch parting of shale 1 foot from the top. Measurements made south of Cedar Creek show that the bed is very lenticular in character. Chemical analyses were made of three samples obtained by A. L. Beekly in 1909 from the McCord mine and from two strippings on the south side of Cedar Creek. The results of these analyses are given on page 256.

T. 130 N., R. 88 W.

The surface in T. 130 N., R. 88 W., is irregularly broken, rising from the level of Cedar Creek on the south to the upland prairie in the northwestern part. The rocks in the township belong to the lower part of the Lance formation, to the Cannonball member of the Lance, and to the Fort Union formation. The Lance formation is fairly well exposed in the bluffs of Cedar Creek and some of its large tributaries, but elsewhere in the township exposures are few. A group of thin beds of lignite occurs near the top of the lower part of the Lance, the thickest of which has been mined by stripping at several localities in sec. 35. At all of the places examined the bed is less than 2½ feet in thickness. Two of the sections measured (sections 142 and 143) are shown graphically on Plate XIII (p. 282). The third, at location 141, is as follows:

Section of lignite bed in the lower part of the Lance formation at location 141, NW. ¼ sec. 30, T. 130 N., R. 88 W.

	Ft.	in.
Shale.		
Lignite	1	6
Shale		1
Lignite		9
Shale, brown.		
	2	4

T. 131 N., R. 88 W.

The surface of T. 131 N., R. 88 W., is a rolling upland interrupted by the steep-sided valleys of Snake Creek and its tributaries. The rocks belong to the Cannonball marine member of the Lance formation and to the lower part of the Fort Union formation, but the surface is covered with a heavy mantle of soil and exposures are very few. No lignite was found in this township nor does lignite appear anywhere in the Cannonball River field in this part of the stratigraphic section.

T. 132 N., R. 88 W.

Cannonball River flows eastward across the northern part of T. 132 N., R. 88 W. The valley is bordered on the north and south by a series of steep slopes separated by wide benches. The rocks belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. Almost the whole thickness of the Cannonball member is exposed within the township, and these strata are typically shown in the steep bluffs along the river. Elsewhere in the township, however, exposures are few. No lignite was found within the township nor is any known at this part of the stratigraphic section in the Cannonball River field.

T. 133 N., R. 88 W.

Cannonball River flows southeastward across the southern part of T. 133 N., R. 88 W., in a comparatively narrow valley. The slopes on the south side of the valley are much more abrupt than those on the north, the northern part of the township being a rolling upland. The Cannonball branch of the Chicago, Milwaukee & St. Paul Railway crosses the northeastern part of the township. The rocks belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The Cannonball member is well exposed in the bluffs of Cannonball River, but the Fort Union strata which underlie the upland areas are very poorly exposed.

About 100 feet above the base of the Fort Union is a bed of lignite, believed to be the Haynes bed, which is mined in a shaft mine in section 12 and in several strip pits in other parts of the township. The bed ranges in thickness from 2 feet in sec. 6 (location 145) to 8 feet 6 inches in sec. 12 (section 152, Pl. XIII). It is possible, however, that the measurement at location 145 is of another bed, as near-by measurements in section 6 (locations 144 and 146) show thicknesses of 3 feet 9 inches and 3 feet 7 inches, respectively.

The presence of a second bed of lignite somewhat higher in the section is indicated by weathered lignite (bloom) in the soil at location 157 in the SE. ¼ sec. 11.

A chemical analysis was made of a sample collected from the Jones mine in sec. 12 (location 152), the results of which are given on page 256. The data concerning the Haynes (?) lignite bed, in addition to the graphic sections given on Plate XIII, are as follows:

Lignite sections on Haynes (?) lignite bed in T. 133 N., R. 88 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	Ft.	in.	No. on map (Pl. XIII).	Location.	Section.	Ft.	in.
145	NW. ¼ sec. 6	Shale. Lignite, much weathered. Clay, sandy.	 2		149	NW. ¼ sec. 9	Lignite in well	2±	
146	NW. ¼ sec. 6	Shale, gray Shale, carbonaceous. Lignite Shale, brown, sandy.	8+ 3	 2 7½	153	NE. ¼ sec. 1 (prospect pit).	Lignite reported	7	
147	NW. ¼ sec. 5	Lignite in well	(a)		154	SW. ¼ sec. 2 (strip pit).	Clay, gray. Lignite Base of bed below water.	 4+	
148	SW. ¼ sec. 5	Lignite in well	(a)		155	NW. ¼ sec. 2	Lignite in well	1	6±
					156	Lot 2, sec. 4	Lignite in well	8	6±

a Unknown.

T. 130 N., R. 87 W.

The surface of T. 130 N., R. 87 W., slopes gradually but irregularly from the upland prairie in the north to the valley of Cedar Creek, which flows eastward near the south township line. The rocks in the township belong to the lower part of the Lance formation and to the Cannonball marine member of the Lance. The brown shale and dark sandstone at the top of the lower part of the Lance are exposed in local badlands in the southern portion of the township, but the greater part of the area is covered with a heavy mantle of soil, and exposures are scarce.

A few thin lenticular beds of lignite appear near the top of the lower part of the Lance, the most important of which is 2 feet 8 inches thick in sec. 13 (section 160, Pl. XIII). At this place a considerable amount of lignite has been mined by stripping. Measurements of a bed which is presumably the same were made at two other places in the township. The sections obtained at these places are as follows:

Lignite sections in lower part of Lance formation, T. 130 N., R. 87 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	Ft.	in.	No. on map (Pl. XIII).	Location.	Section.	Ft.	in.
158	SE. ¼ sec. 19	Sandstone, yellow to brown	3	10	159	NE. ¼ sec. 34	Shale, gray.		
		Lignite		10			Lignite	1	10
		Shale, brown	6	6			Bone		8
		Sandstone, gray	1	6			Shale, gray.		
		Lignite		7					
		Shale, brown		6					
		Sandstone, gray, shaly	4						
		Lignite		6					
		Sandstone and shale	12						

T. 131 N., R. 87 W.

The surface of T. 131 N., R. 87 W., is a gently rolling upland prairie which has been deeply dissected by Snake Creek and other streams. The outcropping rocks belong to the lower part of the Lance formation, the Cannonball marine member of the Lance, and the Fort Union formation, but the strata are not well exposed on account of the heavy mantle of soil. No lignite has been found within the township.

T. 132 N., R. 87 W.

Cannonball River flows southeast across the southern part of T. 132 N., R. 87 W., in a comparatively steep-sided valley. The bluffs of the river are higher and the strata better exposed in this township than in any other part of the field. The comparatively small area which lies south of the river is deeply dissected by small coulees, but in the northern part of the township are considerable areas of land sufficiently level to be cultivated. In the north-central part is a high level-topped mesa with deeply dissected borders, an outlying remnant of the extensive uplands which extend from the north into secs. 2, 3, and 11.

GEOLOGIC MAP OF WESTERN PART OF CANNONBALL RIVER LIGNITE FIELD, NORTH DAKOTA

THE NORRIS PETERS CO., WASHINGTON, D.C.

The rocks that outcrop in the township belong to the lower part of the Lance formation, the Cannonball marine member of the Lance, and the Fort Union formation. The upper beds of the lower part of the Lance are well exposed in the river bluffs in the southeastern part of the township. They disappear below the river bed less than a mile east of Janesburg post office, which is located in sec. 18. No definite line, however, can be drawn between these beds and those of the Cannonball marine member which overlies them. The Cannonball member outcrops over the greater part of the township and is overlain in turn by the lower sandstone of the Fort Union, which caps the high upland areas in the northeastern and southwestern parts of the township.

Lignite within the township occurs only in beds less than 2 feet 6 inches thick in the lower part of the Lance. It is mined, however, by stripping at a number of places for local use. The following table includes all the measurements that have been made within the township:

Sections of lignite beds in lower part of Lance formation in T. 132 N., R. 87 W.

No. on map (Pl. XIII).	Location.	Section.	Ft.	in.	No. on map (Pl. XIII).	Location.	Section.	Ft.	in.
161	SE. ¼ sec. 20 (prospect in river bluff).	Shale.			164	SW. ¼ sec. 36 (outcrop in river bluff).	Sandstone, gray.		
		Lignite	1	6			Lignite	1	4
		Shale.					Shale, brown.		
162	SE. ¼ sec. 35 (outcrop in river bluff).	Shale, gray.			165	SW. ¼ sec. 36 (prospect in river bluff).	Shale, gray.		
		Lignite	1	9			Lignite	2	1
		Shale, brown		2			Shale, brown		2
		Shale, gray.					Shale, gray.		
			1	11				2	3
163	SE. ¼ sec. 35 (prospect in river bluff).	Shale, bluish gray.			166	NW. ¼ sec. 25 (prospect).	Shale, gray.		
		Shale, blue, fissile		5			Lignite	1	3
		Lignite	2	2			Shale, brown		3
		Shale, brown.					Shale, gray.		
			2	7				1	6

T. 134 N., R. 88 W.

The surface of T. 134 N., R. 88 W., is chiefly of the rolling-prairie type of topography characteristic of a large part of the Cannonball River field. The relief is most pronounced in the southeastern part, where there are a number of moderately high elongated buttes. The western part of the township is also higher and somewhat more broken than the central and northeastern parts. In the northern portion the surface slopes gently toward Antelope Creek, which flows eastward, meandering within a stream flat which is from one-fourth to one-half mile wide and is bordered by low bluffs. Probably nine-tenths of the land in the township could be cultivated. The township is crossed by branches of the Northern Pacific and the Chicago, Milwaukee & St. Paul railways.

All the rocks that outcrop in the township belong to the Fort Union formation. The strata, however, are for the most part concealed by a heavy mantle of soil.

Lignite has been found at a number of places, both at the outcrop and in wells. In several places the lignite is mined from strip pits for local use. Correlations on the basis of the carefully determined elevations of all exposures indicate that there are three beds of lignite. Of these the lowest is the thinnest and least important, although it is being mined at two places, one on Antelope Creek in sec. 5 (location 169) and the other on a branch of that stream in sec. 9 (location 167). The sections exposed at these places are as follows:

Lignite sections on lowest coal bed in T. 134 N., R. 88 W.

No. on map (Pl. XIV).	Location.	Section.	Ft.	in.	No. on map (Pl. XIV).	Location.	Section.	Ft.	in.
167	SW. ¼ sec. 9 (small strip pit).	Shale, light brown at top, more carbonaceous and darker below, fossiliferous	4	6	169	SE. ¼ sec. 5 (small strip pit).	Shale, dark blue, carbonaceous at base, fossiliferous	6	6
		Bone		1			Shale, sandy	1	
		Lignite, bony		2			Lignite, good, woody texture	2	3
		Lignite, brown, with bright black streaks, good	1	2			Clay shale.		
		Shale, carbonaceous		1			Total lignite	2	3
		Shale, sandy	2	2					
		Total lignite	1	4					

The bed is also reported to have been found in a well in the SE. ¼ sec. 8 (location 168), where it has a thickness of 2 feet.

The second or middle of the three lignite beds is the most important and is probably the Haynes lignite bed. Locally it has been burned at the outcrop, causing a baking and reddening of the overlying shale, as, for example, near the center of sec. 36, where there is a small knoll of brick-red clinker. At three places in the township the bed is mined for local use; in the NW. ¼ sec. 34 (location 171); on a branch of Antelope Creek in the NE. ¼ sec. 19 (section 176, Pl. XIV, p. 290); and in the SW. ¼ sec. 8 (section 178, Pl. XIV). The bed is also exposed in several wells. In the southeastern corner of the township the bed is 7 or 8 feet thick. Farther northwest it is thinner, being only 2 feet 6 inches at location 176 in sec. 19. Still farther north it becomes thicker and averages between 4½ and 5 feet in the northwest corner of the township. All the evidence regarding the thickness of the bed is shown on Plate XIV or in the following table:

Lignite sections on Haynes (?) lignite bed in T. 134 N., R. 88 W.

[In addition to those shown on Pl. XIV.]

No. on map (Pl. XIV).	Location.	Section.	Ft.	in.	No. on map (Pl. XIV).	Location.	Section.	Feet.
170	SE. ¼ sec. 26...	Lignite in cistern..	5		173	NE. ¼ sec. 15..	Lignite, weathered in side of butte...	(a)
171	NW. ¼ sec. 34 (strip pit).	Sandstone, yellow, friable....	8		174	SE. ¼ sec. 20...	Lignite in well (reported)	3
		Lignite, bony...		5	175	NW. ¼ sec. 20.	Section in well (reported):	
		Lignite, weathered...........	3	5			Lignite............	1
		Shale............		1			Parting...........	1
		Lignite, good....	3	5+			Lignite............	3
		Base of bed below water.						
		Total lignite.	7	3+			Total lignite..	4
172	SE. ¼ sec. 21...	Lignite in well, reported	12		177	NE. ¼ sec. 18 (prospect).	Lignite, concealed by water in prospect.	(a)

a Thickness and relations not determined.

This bed is being successfully mined in the Jones mine in sec. 12, T. 133 N., R. 88 W., and in the Kolbank mine in sec. 7, T. 133 N., R. 87 W.

The uppermost lignite bed is stratigraphically about 50 feet higher than the preceding. It is exposed on the ridge south of Heil in the NE. ¼ sec. 35 (section 179, Pl. XIV), where the total thickness is 4 feet 10 inches including a 1-inch parting of bone. Half a mile southwest on the next ridge (location 180) there is evidence of weathered lignite or "blossom" in the soil at about the same stratigraphic horizon. The bed is apparently entirely concealed from this point northwestward to the SW. ¼ sec. 20 (location 181) where there is a large mound of reddened clinker formed by the burning of the bed. Near a branch of Antelope Creek in sec. 19 (location 182) the total thickness of the bed, inclusive of two partings, is 4 feet 11 inches. The section of the bed exposed at this place is shown graphically on Plate XIV (p. 290).

T. 135 N., R. 88 W.

The surface of T. 135 N., R. 88 W., is a smoothly rolling prairie, broken here and there by rocky buttes which are capped with resistant sandstone. A high rounded ridge extends into the western part of the township and from it the surface slopes gradually downward to the northeast and to the south. The area is drained by small streams, some of which flow north to Heart River and others east or south to Antelope Creek, which crosses the southwestern corner of the township.

All strata that outcrop in the township belong to the Fort Union formation. The surface mantle of soil is so nearly continuous, however, that the underlying rocks are exposed only locally in the more prominent buttes and in the deeply cut stream channels.

Lignite is being mined at the two Tipke mines in sec. 7 (locations 184 and 185), but elsewhere in the township, with the exception of a small mound of clinker in the NW. ¼ sec. 32, surface indications of lignite seem to be entirely lacking. In sec. 36, T. 135 N., R. 89 W., several small strip pits have been opened on the banks of Antelope Creek, at one of which (location 183) a section was measured and is shown graphically on Plate XIV. The total amount of coal is 4 feet 8 inches, but a parting of shale 1 foot 1 inch in thickness separates the bed into two parts. The clinker in sec. 32, T. 135 N., R. 88 W., is probably caused by the burning of this bed.

The two mines in sec. 7 are located on two beds which are separated by a stratigraphic interval of about 30 feet. The lower bed is exposed in the northern mine (location 184), where the thickness is approximately 3 feet, but the bottom of the pit was filled with water and an accurate measurement could not be obtained. In the southern mine (location 185) the bed is nearly 3 feet thick, including a 1-inch parting, and is overlain by a number of thin beds of lignite separated by shale partings. The complete detailed section is shown on Plate XIV.

The bed which is being mined in sec. 36, T. 135 N., R. 89 W., is probably one of the two beds described above.

T. 133 N., R. 87 W.

The northern part of T. 133 N., R. 87 W., lies on the divide between Heart and Cannonball rivers and is a region of broad open prairies interrupted locally by low buttes capped with resistant ledges of sandstone. The land in the southern part of the township is equally smooth and slopes gradually southward toward the valley of Cannonball River. The Cannonball branch of the Chicago, Milwaukee & St. Paul Railway crosses the northern part of the township and the town of Leith is located on that road in sec. 5.

The rocks that outcrop in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The rocks, however, are for the most part concealed by a heavy mantle of soil, so that exposures are rare. The contact between the two formations was sketched from topography alone.

Two beds of lignite outcrop on the sides of a group of high hills which extend into the northwestern part of the township. The lower of these is the more important and is being mined for local use in a drift mine in sec. 7 (location 188). The shaft mine, Jones mine, in sec. 12, T. 133 N., R. 88 W., is on the same bed. The Kolbank mine in sec. 7, owned and operated by Simon Pederson, was a strip pit until the summer of 1913, when an entry was made. The graphic section shown on Plate XIV was measured at the entry. Although the total thickness of the bed is 7 feet 9 inches, only the lower part of the bed is being mined, because the upper part must be left for a roof. A sample for chemical analysis was collected in this mine, the analysis of which is shown on page 256. The thickness of the part mined where the sample was collected was 4 feet 10 inches.

South of the divide in the NE. ¼ sec. 18 (location 186) and in the NW. ¼ sec. 17 (location 187) the same bed was found in a weathered condition near the surface. At location 186, in an old prospect, 2 feet 3 inches of ash and weathered lignite is exposed. At location 187 a few inches of much-weathered lignite outcrops on the side of a low hill. These exposures, however, show only the remnants of the bed, which may confidently be expected to prove much thicker when exposed under a sufficient amount of cover to protect it from weathering. Mounds of clinker at several places within the township show where the bed has been burned at the outcrop. This clinker is especially prominent at the south end of a long ridge in sec. 19 and on the east side of Spring Butte in sec. 17. The same coal bed is exposed in a small strip pit on top of a rounded hill in sec. 10 (location 189), where the thickness of the bed is 4 feet. The lignite at this place, however, is much weathered and therefore of little value.

The upper bed was formerly mined by Mr. Pederson in sec. 7, about 1,000 feet southwest from the mine described above. The outcrop is now concealed, but the average thickness as reported by Mr. Pederson is about 4 feet. This bed is stratigraphically about 40 feet above the lower bed.

T. 134 N., R. 87 W.

T. 134 N., R. 87 W., lies on the northern side of the broad divide which separates the drainage systems of Heart and Cannonball rivers. The general slope of the surface is to the northwest toward Antelope Creek, which flows northeast across secs. 7, 6, and 5. The surface is for the most part well adapted to dry farming, but locally the rolling prairie is interrupted by steep-sided rocky buttes. A branch of the Northern Pacific Railway crosses the township centrally in an east-west direction. The town of Carson on that road is located in sec. 13. The outcropping rocks belong to the Fort Union formation, with the exception of a small area in the valley of Antelope Creek, in secs. 5 and 6, where the Cannonball marine member of the Lance formation is exposed. Practically the only natural exposures of the rocks within the township are in the valley of Antelope Creek and high up on the sides of some of the more rugged buttes.

Groups of rocky hills both north and south of Carson are underlain by the same bed of lignite which is mined at the Kolbank mine near Leith in T. 133 N., R. 87 W. The surface, however, is covered with so heavy a mantle of soil that the lignite bed appears at the surface only at a few places. At the old Carter ranch in the SW. ¼ sec. 24 (location 190) is a drift mine now abandoned and largely caved. The following section was measured at the mouth of the mine:

Section in Carter lignite mine, SW. ¼ sec. 24, T. 134 N., R. 87 W., location 190.

	Ft.	in.
Shale, gray	10	
Shale, light brown		5
Lignite, good quality	2	3
Bone		3
Lignite, good quality	2	11+
Base, concealed by water.		

North of the town of Carson, in a group of three small but prominent hills, a considerable amount of prospecting for lignite has been done. Two drift mines have been opened on the south slope of the central hill in the NW. ¼ sec. 13 (location 192), but both have been abandoned. The following section was measured at the mouth of the west entry:

Section at mouth of abandoned lignite mine in NW. ¼ sec. 13, T. 134 N., R. 87 W.

	Ft.	in.
Shale, gray, sandy	10	
Shale, brown, carbonaceous at base		8
Lignite, bony		9
Bone		1
Lignite, fair quality		5
Bone		1
Lignite, good quality	1	3
Clay shale.		

The owner reported that there is considerable variation in thickness of the bed and that it locally reaches a thickness of 3 feet or more. The above, however, is probably a representative section.

A lower coal bed was reported to have been found at a depth of 40 feet in a well close to the railway track near Carson station (location 191); the driller reported that the well was sunk 2 feet into a bed of lignite and stopped. No other evidence could be obtained with regard to this lower bed.

T. 133 N., R. 86 W.

The northern part of T. 133 N., R. 86 W., lies on the divide between Cannonball River and Louse Creek, a region of wide rolling prairies interrupted by a few high rocky buttes. On the south this upland area is terminated by a moderately steep scarp beyond which is a region of smoothly rounded hills separated by steep-sided valleys. The Cannonball branch of the Chicago, Milwaukee & St. Paul Railway crosses the northern part of the township in an east-west direction. The town of Brisbane in sec. 9 is located on that road.

The rocks outcropping in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The area is largely grass covered and exposures are few. The general character of the Cannonball member is shown by a few exposures along the larger streams in the southern part of the township; practically the only part of the Fort Union exposed is a heavy cross-bedded sandstone which outcrops in the higher buttes in the northeastern part of the township.

The coal bed which is mined at the Kolbank mine near Leith, in T. 133 N., R. 87 W., underlies a group of rounded hills in the northwestern part of the township. The only exposure found, however, was in a railway cut in sec. 7 (location 193), where the thickness of the bed is only 1 foot 6 inches.

T. 134 N., R. 86 W.

The topography in T. 134 N., R. 86 W., is somewhat diversified. Although the general character of the surface is that of a rolling upland prairie, in the southern part of the township a number of prominent rocky buttes rise above this general upland level which in the central and eastern parts is depressed by the wide valley of Louse Creek. The uplands are in most places separated from this valley by an escarpment which is particularly prominent in the north-central part of the township. In the northern part there are local areas of sand dunes. The whole of the township is drained by Louse Creek, one of the principal tributaries of Cannonball River. A branch of the Northern Pacific Railway crosses the central part of the township following the valley of Louse Creek for most of the distance.

The strata that outcrop in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The rocks of the Cannonball member are exposed in the valley of Louse Creek, and those of the Fort Union formation underlie the upland area.

The lignite bed which is mined at the Kolbank mine near Leith, in T. 133 N., R. 87 W., underlies Circle Butte in sec. 31 and a few other high buttes in the southern part of the township. At the north end of Circle Butte some mining and prospecting have been done, but the openings are now largely fallen in and the lignite concealed. The lignite section at location 194, shown graphically on Plate XIV, was measured near the mouth of one of the old drift mines. Local reports indicate that the lignite in other openings is of better quality than that at the point examined and that the bed ranges in thickness from 4 to 6 feet. In a small prospect on an isolated butte in sec. 32 (location 195) the bed is only 1 foot 11½ inches thick and contains a parting of 1½ inches of shale 5 inches from the base. In sec. 26 (location 196), in another small butte, the bed was reported to have a thickness of only 1 foot.

T. 135 N., RS. 86 AND 87 W.

T. 135 N., Rs. 86 and 87 W., lies on the northern border of the broad upland separating the valleys of Heart and Cannonball rivers. The upland surface is a smoothly rolling prairie, above which rise a few rocky buttes capped by sandstone. The northward-flowing streams have cut deep canyon-like gorges through these uplands. The most prominent stream is Antelope Creek which flows northward through the western part of T. 135 N., R. 87 W.

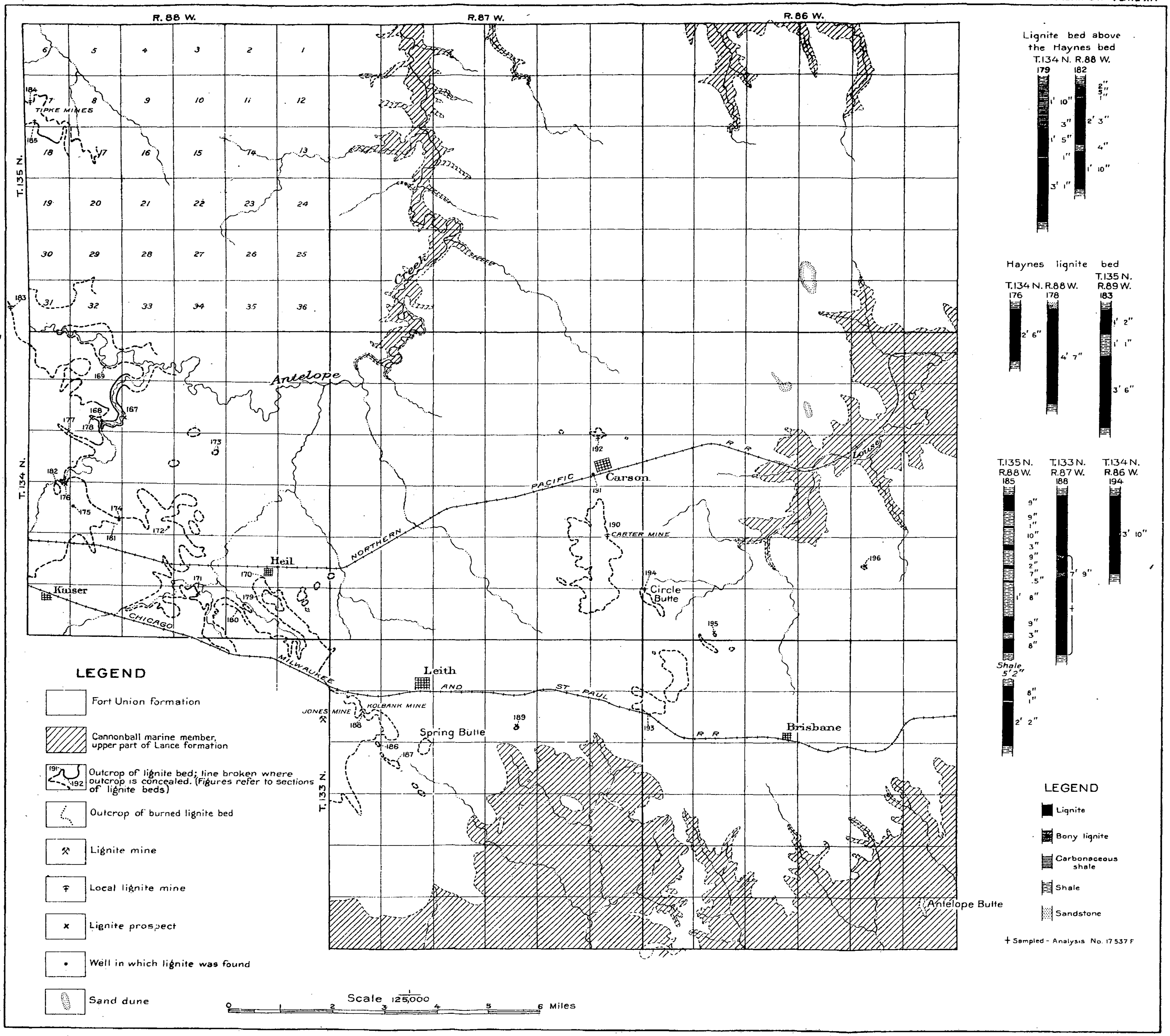
The greater part of the upland surface is sufficiently level for cultivation, but the sandy character of the soil makes large areas almost valueless except for grazing. In the southwestern part of T. 135 N., R. 86 W., is a considerable area of so-called lake beds. These lake beds or playas are dry, except after heavy rainfalls, and are almost surrounded by small areas of sand dunes.

The rocks that outcrop within the two townships belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The upper beds of the Cannonball member are well exposed in the steep stream bluffs, but the Fort Union strata are almost invariably concealed except for beds of resistant sandstone which form the capping of prominent buttes. No lignite bed of any value outcrops in either of the two townships.

EASTERN PART OF CANNONBALL RIVER FIELD.

A brief mention should be made of the thin beds of lignite in the large area examined in 1913 which is not included in the accompanying maps. A map and a more detailed description of this part of the field will be published later.

The majority of the lignite beds in the eastern part of the field belong to the lower part of the Lance formation. This series of strata, about 400 feet in thickness, is separated from the Fort Union formation, in which lie the important lignite beds described in the foregoing pages, by about 300 feet of the shales and sandstones of the Cannonball marine member of the Lance. This latter series contains no lignite and might properly be designated as "barren measures." The lower part of the Lance outcrops in the valleys of Cannonball River and its tributaries. It extends up Cedar Creek nearly to Howe post office, up Cannonball River almost to Janesburg, up Dogtooth Creek to Raleigh, and up Louse Creek several miles above Flasher. This is a region of wide flats bordered by steep badland bluffs in which the strata are well exposed. Numerous examinations were made of the lignite beds exposed in these bluffs and in the strip pits from which the local supply of fuel is obtained. So far as known the maximum thickness of any of the lignite beds in the Lance is in a local mine in sec. 10, T. 134 N., R. 84 W., a few miles south of Flasher, where the following section is exposed:



GEOLOGIC MAP OF CENTRAL PART OF CANNONBALL RIVER LIGNITE FIELD, MORTON COUNTY, NORTH DAKOTA

THE NORRIS PETERS CO., WASHINGTON, D. C.

Lignite section in strip pit in sec. 10, T. 134 N., R. 84 W.

	Ft.	in.
Shale	12	
Lignite, good	2	3½
Shale, brown, carbonaceous	1	2
Lignite, good	1	1
Lignite, bony		9
Bone		2
Shale.		

Half a mile south of this point, in Copenhaver's mine in the NE. ¼ sec. 15 of the same township, the bed is somewhat thinner, but similar with regard to the character and thickness of the partings. At this place about 4,000 tons of lignite has been mined by drifting, but the shale roof proved too weak and the drift was abandoned in favor of the more laborious method of stripping. In the northern part of T. 132 N., R. 84 W., and the southern part of T. 133 N., R. 84 W., strip pits have been opened up at a number of places and considerable amounts of lignite removed. The lignite in these pits ranges in thickness from 10 inches to 2 feet. Similarly thin beds of lignite have been mined in the badland areas west of Wade in Tps. 130 and 131 N., R. 86 W., and in the extensive badland bluffs northwest of Solen in Tps. 134 and 135 N., Rs. 81 and 82 W.

There are a few thin beds of lignite in the lower part of the Fort Union formation near the north border of the field. These beds were examined at several places in T. 136 N., Rs. 82, 83, 84, 86, 87, and 88 W. No bed, however, was found to be more than 2½ feet thick. At an abandoned mine in sec. 1, T. 136 N., R. 84 W., Mr. Woll, the owner, reported that the total thickness is about 3 feet but that there is a considerable amount of shale or bone.

Farther north, in T. 137 N., R. 89 W., a considerable amount of lignite is mined for local use. No examination, however, was made in this township.

LIGNITE IN THE VICINITY OF PLENTYWOOD AND SCOBEY, SHERIDAN COUNTY, MONTANA.

By C. M. Bauer.

INTRODUCTION.

This paper presents the results of an examination of an area in northeastern Montana along the north border of the Fort Peck Indian Reservation, made principally for the purpose of ascertaining the amount and character of the lignite. This investigation was made partly to supplement the information previously obtained relative to the lignite in the northeastern part of the Fort Peck Indian Reservation and partly to classify the land. A geologic reconnaissance of the Fort Peck field had been made by C. D. Smith[1] in 1908, before the land in the northern part of the reservation was surveyed. In 1911, subsequent to the land survey, the reservation was reexamined in detail by the writer. At this time some additional information regarding the lignite was obtained, but owing to the general cover of glacial drift in the northern part of the reservation, exposures of the lignite-bearing rocks are few, and there are extensive areas in this region in which very little additional knowledge regarding the lignite was gained. North of the reservation, along Big Muddy Creek, however, exposures of the lignite-bearing rocks are more numerous, and, chiefly in order to throw light upon the geology within the reservation itself, the writer, assisted by E. T. Hodge, gave this area special attention during the field season of 1912. This work has shown that in this area, and presumably also in the northern part of the reservation, the lignite is commonly weathered and the beds are in general thin. The lignite will probably, therefore, command only a local market, though owing to the scarcity of other fuel in this region it is economically important.

The area here described consists of three parts. The western part is made up of a little more than two townships on Poplar River, near Scobey, Mont., and the eastern part consists of six entire townships as well as parts of two others along Big Muddy Creek, in the vicinity of Plentywood, Mont. The intervening area was examined merely in

[1] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: U. S. Geol. Survey Bull. 381, 1910.

a reconnaissance way owing to the fact that the land was unsurveyed. The results of this examination are included in the general discussion of the district, but detailed mapping was limited to the two areas defined above. The areas in Montana described in this bulletin are shown in figure 9.

FIELD METHODS.

The methods used in mapping in different parts of the field were varied to meet the conditions. The Land Office plats of the eastern and western portions of this field are comparatively recent and appear to be accurate and satisfactory; they were therefore used as a base for the geologic mapping. In the area around Scobey rock

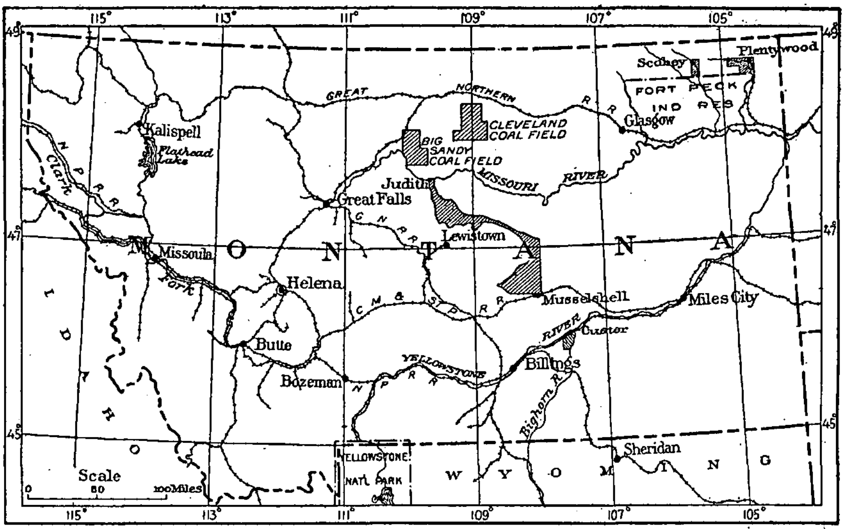


FIGURE 9.—Map showing coal fields of Montana described in this bulletin.

exposures are in general widely separated, and the mapping here consisted chiefly in locating these isolated outcrops. Whenever possible, the method followed was triangulation from land corners, using a plane table and telescopic alidade. In the vicinity of Redstone and Plentywood, in the eastern part of the field, however, outcrops are more nearly continuous, and in this area locations were made by stadia traverse, the altitude of each lignite prospect being determined by vertical angles. Springs, houses, and roads were also carefully located in both districts. The examination of the area between the surveyed portions at either end of the field was in the nature of a reconnaissance, the results of which are included in the general discussion.

SURFACE FEATURES.

RELIEF.

This field is a part of the Great Plains region and is in the main a rolling prairie with broad, gentle slopes. The western portion is drained by Poplar River and the eastern by Big Muddy Creek, and between the two lies a high divide many miles in width. The broad and nearly flat valley of Poplar River traverses the field from north to south in R. 48 E. (Pl. XV, p. 308). In R. 52 E. the somewhat narrower valley of Big Muddy Creek enters the area from the north and extends across it to the southeast corner of the field, where it turns southward to form the east boundary of the Fort Peck Indian Reservation. For a distance of about 6 miles in T. 34 N., R. 55 E., this stream flows through a valley which is much narrower than that in the other portion of its course. This constricted portion seems to represent a more recent valley into which the river was diverted by the partial filling of its old valley with glacial material. The old valley is plainly discernible near Antelope, where a branch of the Great Northern Railway follows it for several miles.

The maximum relief in the region is about 750 feet. For instance, the valley of Big Muddy Creek near the reservation boundary has an elevation above sea level of approximately 2,000 feet, and the land on the divide directly to the west reaches an elevation of about 2,750 feet. However, local differences in altitude are not great, and even in the rough country bordering Big Muddy Creek the height of the bluffs is commonly less than 150 feet.

The summits of all the highest hills and ridges are approximately at the same altitude and are covered with quartzite gravel. The concordance of these hilltops suggests the existence of an old river plain at the close of the first stage in the development of the present topography. The areas known to be covered by this gravel in the districts mapped are shown in Plates XV and XVI (pp. 308 and 314). A second stage in the development is represented by the general level of the country, which has an altitude of about 150 feet above the flood plains of the present streams. The development of this second peneplain, presumably by erosion, was not complete when the country was covered by an ice sheet. The general effect of the glaciation has been to round off the hills and partly fill the valleys. The plain thus formed extends throughout the field and gives a prairie aspect to most of the topography. A third stage in the erosion is shown in the present flood plains of Poplar River and Big Muddy Creek, which are about a mile wide.

DRAINAGE.

The direction of the present drainage is southeastward. Poplar River rises in the Canadian province of Saskatchewan and flows southeast to Missouri River, emptying into that stream at Poplar. Big Muddy Creek also rises in Saskatchewan and flows in a southerly direction as far as T. 35 N., where it is joined from the west by Eagle Creek. For 15 miles beyond this place it trends eastward and then bends and flows southward 50 miles to join Missouri River. The course of Big Muddy Creek is extremely sinuous, though the current is fairly rapid. Along both of these streams lie flats from half a mile to 2 miles in width, the development of which is due partly to the filling in of glacial débris and partly to the normal meandering and aggrading of the streams. The presence of the glacial material is shown in several wells in the valley of Big Muddy Creek in the vicinity of Redstone, which penetrate glacial drift and alluvium to a depth of 30 feet. In this material the channel of the Big Muddy is eroded to a depth of 18 to 25 feet, whereas Poplar River flows in a channel only 10 to 15 feet deep. These flats contain many water holes representing cut-off meanders.

The country is fairly well watered by springs, although the average annual rainfall is only 13.5 inches. Most of the spring water contains some "alkali" but not enough to prevent its use as a domestic supply. Many of the springs issue from the outcrops of lignite beds, probably because the joints in the lignite form channels for the ground water, whereas the rocks immediately below the beds are relatively impervious.

Although the annual precipitation in this part of Montana is only about 13.5 inches, more than half of this amount falls in light rains between the beginning of April and the end of July or during the growing season, when it is most needed for crops. The average annual snowfall is about 40 inches, but the snow is normally light and dry, and the winds generally carry most of it into ravines, leaving the ranges bare and accessible for grazing throughout most of the winter.[1]

CULTURE.

A branch of the Great Northern Railway, which extends as far as Plentywood, renders the eastern part of the field easily accessible. The western part can be reached at present by stage from Poplar, Mont. The principal town in the western section is Scobey, which is located on Poplar River, in T. 35 N., R. 48 E. Redstone, Plentywood, and Antelope are thriving towns in the eastern part of the field.

[1] Summary of the climatological data for the United States by sections; Climatological section No. 30, northeastern Montana, U. S. Dept. Agr. Weather Bureau.

Most of the area has been filed on by settlers as agricultural land. A few quarter sections have been allotted to Indians but are not occupied by them, these lands being leased by farmers and stockmen for grazing or for the natural hay which they produce. The land is arable almost everywhere except along the outcrops of the stratified rocks, where the soil is thin or absent. However, these outcrops are few and are confined for the most part to the roughest portions of the field, particularly along Big Muddy Creek. The bottom land along Big Muddy Creek and Poplar River supports a considerable growth of natural hay which can be cropped every year, but on the uplands the wild hay can be profitably cut only every third year. The principal crops of the region are flax, oats, barley, and potatoes, some spring wheat, and some corn for fodder only. Millet has been raised with success, as has also timothy hay. Likewise most garden vegetables except celery have been raised successfully. These crops are cultivated without irrigation, although in a few places on the flats of Poplar River and Big Muddy Creek irrigation has been applied to the land with mediocre success.

There is very little timber land in the region. Thickets of quaking aspen, cottonwood, box elder, and ash grow in a few of the larger coulees, but the trees are not sufficiently numerous to be utilized even for fence posts. There are also a few willows along the principal streams, but the trees are too widely scattered to be of value.

GEOLOGY.

STRATIGRAPHY.

OCCURRENCE OF THE ROCKS.

The oldest sedimentary rocks exposed in this field are in the valley of Poplar River at a lignite mine in sec. 3, T. 33 N., R. 48 E., and in sec. 26, T. 35 N., R. 48 E. These rocks probably belong to the Lance formation. The formation is lignite bearing in part and is commonly characterized by its somber color. Stratigraphically above these rocks lie the lignite-bearing strata of the Fort Union formation. These strata are predominantly light colored, but in many regions where these formations are well exposed the colors and other lithologic characters of the one formation blend into those of the other so that the line of demarcation is uncertain.

In the area here described, moreover, exposures are generally poor, and it is impossible to determine the exact line of separation between the formations. No fossils were found by which the age of the rocks could be determined, hence the basis on which the approximate boundary line is drawn (Pl. XV, p. 308) is the information obtained in the Fort Peck Reservation by C. D. Smith[1] in 1908, and by the

[1] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: U. S. Geol. Survey Bull. 381, 1910.

writer in 1911. On the reservation the Lance strata are predominantly somber colored, and those of the Fort Union, which also contain a greater number of lignite beds, are light colored. A lignite bed located near the horizon at which the lithology changes was assumed to represent the base of the Fort Union and was mapped as such. However, for 10 miles south of the reservation boundary, exposures near the contact are scanty and the separation was made largely on the basis of the color of outcropping beds.

Owing, therefore, to the absence of a sharp lithologic boundary between the formations, and to the lack of exposures near the critical horizon in this field and also in the northern part of the reservation, the accurate mapping of the Lance-Fort Union boundary is impossible. In drawing the line shown on the map the known outcrops of somber-colored beds were considered to belong to the Lance and those of yellow beds to the Fort Union. A bed of lignite 16 to 22 feet thick, which outcrops on Coal Creek near the international boundary, is thought to be the same as a bed 18 feet thick reported by G. M. Dawson[1] from Porcupine Creek on the international boundary a few miles west of the one hundred and sixth meridian. This is regarded as probably identical with the bed mapped as the base of the Fort Union and its horizon was projected as accurately as possible into the Scobey district. In mapping the inferred outcrop of this horizon it was of course necessary to take into account the topography and also the low eastward dip of the strata (less than 10 feet to the mile).

TERTIARY (?) SYSTEM.

LANCE FORMATION.

In the field here described about 175 feet of strata, consisting of somber-colored shale and cross-bedded sandstone with local lenses of impure lignite, are referred to the Lance formation. The base of the formation is not exposed, but on the adjoining reservation it has a total thickness of 200 to 300 feet. Its separation from the overlying Fort Union formation is based on its stratigraphic position and lithologic character. In these particulars it agrees with the Lance formation as recognized in other areas in eastern Montana and in North Dakota, where it is further characterized by a dinosaur fauna which has not been found in the Fort Union. Formerly the Survey considered the evidence of the age of the Lance so conflicting that it was ascribed to the Cretaceous or Tertiary, but recently the close correlation of the Lance flora with that of well-determined Tertiary formations of the Gulf coast, considered together with the mountain-making movements that are supposed to have immediately preceded the deposition of the strata, has led the Survey to assign the formation to the Tertiary (?) system.

[1] Dawson, G. M., The lignite Tertiary formation: Canada Geol. Survey Rept. for 1879-1880, p. 29a, 1881.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The Fort Union formation, of Eocene age, is the uppermost consolidated formation in this field. It consists of light-colored sandstone, shale, and clay, with numerous beds of lignite, and rests with apparent conformity on the underlying Lance formation. The best exposures of these rocks are in the bluffs along Big Muddy Creek. Masses of sandstone are exposed more commonly than shale or clay, because in the weathering of a hill the sandstone is most resistant, producing irregular projecting ledges, above and below which the hill slopes are generally grass covered.

The following section, compiled from measured sections in three localities in the Plentywood district, illustrates the character of the Fort Union formation in this field:

Section of the Fort Union formation compiled from three localities.

Section in NW. ¼ sec. 28, T. 34 N., R. 55 E.

	Ft.	in.
Sandstone (top eroded)	60+	
Shale, sandy	10	
Sandstone, friable	8	
Shale, carbonaceous	3	4
Lignite		6
Shale	24	9
Sandstone, friable	2	6
Sandstone, hard		10
Sandstone, argillaceous	7	
Shale, sandy	31	
Sandstone, hard		10
Shale, gray	5	
Shale, carbonaceous	4	4
Shale, sandy	34	
Shale, drab	5	
Shale, carbonaceous		4
Shale, brown	4	
Sandstone, light gray	13	11
Lignite (Richardson bed)	2+	

Section in SW. ¼ sec. 29, T. 35 N., R. 55 E.

	Ft.	in.
Lignite (Richardson bed).		
Shale, sandy	12+	
Sandstone	15	
Sandstone (forming ledge)	4	
Sandstone, cross-bedded	48	
Shale	4	10
Sandstone, white, containing streaks of white clay	16	8
Shale, carbonaceous		4
Shale, gray	10+	

Section in SW. ¼ sec. 6, T. 35 N., R. 52 E.

	Ft.	in.
Interval of shale and sandstone, covered in part	80±	
Sandstone, hard	1	6
Sandstone, friable	26	
Shale, carbonaceous		4
Shale, gray	12	
Sandstone	11	6
Clay, drab	1	
Lignite	1	4
Shale, brown	4	5
Sandstone	1	2
Lignite		8
Shale, carbonaceous	1	6
Shale, sandy	11	6
Shale, drab	5	10
Shale, carbonaceous		6
Lignite	1	8
Sandstone	2	3
Lignite (Redstone bed)	2	8+
Total lignite	8	10+
Total	494±	

A complete section of the Fort Union formation in this field would probably measure more than 1,000 feet.[1]

A white clay bed [2] of economic importance occurs in this formation in the vicinity of Redstone and Plentywood. It is a fair-grade clay, suitable for the manufacture of brick, draintile, and stoneware.

In some places red-baked rock known locally as scoria or clinker is found, the old Redstone post office in sec. 16, T. 35 N., R. 52 E., having derived its name from the presence of this clinker in the neighboring bluffs. The clinker is caused by the burning of a lignite bed along its outcrop. The fire may have been started in various ways. It is generally ascribed to lightning, prairie fires, the agency of man, or spontaneous combustion caused by rapid oxidation in weathering. The heat generated may become so intense locally as to cause flowage in the overlying strata, but as the burning progresses under greater cover the fire commonly dies out, owing to lack of air.

TERTIARY OR QUATERNARY SYSTEM.

QUARTZITE GRAVEL.

Certain high hills and ridges, as shown on the maps (Pls. XV and XVI, pp. 308 and 314) are capped by quartzite gravel ranging from a few inches to 14 feet in thickness. This gravel is commonly stratified and was probably deposited by streams. In a few places it is

[1] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, p. 326, 1912.

[2] Bauer, C. M., Clay in northeastern Montana: U. S. Geol. Survey Bull. 540, pp. 369–372, 1914.

consolidated but nowhere, so far as is known, in the area here described. However, in the Fort Peck Reservation, on the high bluff south of Cottonwood Creek, in the SE. ¼ sec. 33, T. 32 N., R. 46 E., the formation consists of consolidated sand and gravel cemented with lime. The lower part is about 8 feet thick and consists of sorted quartzite pebbles cemented with lime, resembling concrete filler for sidewalks. The upper part is a massive white calcareous sandstone having a maximum observed thickness of 4 feet. Some of the pebbles in the lower part are 2 inches in diameter, though most of them are less than 1 inch. In the area under discussion over 90 per cent of the pebbles are red or brown quartzite, though a few pebbles of argillite were noted. All are well rounded and very few are larger than 3 inches in diameter. Many of the pebbles are coated with lime. Where the deposit is best preserved it contains a considerable amount of interstitial yellow sand. As the deposit is lithologically different from the glacial drift, and furthermore is limited in extent to the tops of the highest hills, whereas the glacial drift is scattered generally and in many places overlies it, it is probably pre-Pleistocene. Although no fossils were found in this gravel, a similar deposit containing fossils in the vicinity of the Cypress Hills is described by R. G. McConnell.[1] McConnell gave the age of the beds as Miocene, but more complete identification of the fossils by E. D. Cope [2] reveals the age of the beds as Oligocene or Lower Miocene.

QUATERNARY SYSTEM.

GLACIAL DRIFT.

The stratified rocks are covered generally with glacial material consisting of sand and clay intermingled with bowlders of granite, limestone, basalt, sandstone, and many other rocks. The drift is usually unstratified, and its known thickness in this area ranges from a few inches to 40 feet, being commonly greatest in the valleys. In general it is thinner around Plentywood than in the vicinity of Scobey, but along the railroad, in T. 34 N., R. 55 E., near Antelope, it is probably even thicker than 40 feet. On the west side of Poplar Creek, in sec. 18, T. 34 N., R. 48 E., a well was dug through 40 feet of glacial material containing a few blocks of lignite 1 foot in diameter as well as fragments of granite and limestone.

[1] McConnell, R. G., On the Cypress Hills, Wood Mountain, and adjacent country: Canada Geol. Survey Ann. Rept., new ser., vol. 1, 1886.

[2] Cope, E. D., On Vertebrata from the Tertiary and Cretaceous rocks of the Northwest Territory: Canada Geol. Survey Contr. Canadian Paleontology, vol. 3, pt. 1, 1891.

STRUCTURE OF THE STRATIFIED ROCKS.

In the vicinity of Scobey the lignite-bearing rocks lie nearly flat, but owing to the scarcity of outcrops little knowledge of the exact dip can be obtained. However, from the attitude of the beds to the south it is assumed that they have an easterly dip of about 10 feet to the mile. Along Big Muddy Creek definite information of the structure was obtained by determining the altitudes of the lignite beds at many points. In T. 35 N., R. 52 E., altitudes determined on the Redstone lignite bed indicate a southeastward dip of about 15 feet to the mile, and in T. 34 N., R. 55 E., they indicate a dip of about 16 feet to the mile in the same direction. Minor undulations in the strata alter this dip locally, but these measurements illustrate the general attitude of the beds.

THE LIGNITE.

PHYSICAL AND CHEMICAL CHARACTERS.

The lignite is dark brown in color when fresh and its luster is dull to waxy. The texture is commonly dense, though in places it is woody. In some specimens even the structure of fairly large pieces of wood, generally flattened, is preserved, this being most common in the case of the harder parts such as knots. A pronounced characteristic of lignite is its tendency to slack on exposure to the air, due to the fact that it contains much water, which evaporates on exposure, causing shrinkage and the development of an irregular network of cracks along which the lignite separates into pieces. If the lignite is covered after being taken out of the mine so that the drying proceeds slowly disintegration is materially retarded.

Two samples of lignite from this field were submitted to the United States Bureau of Mines for analysis. Both samples seemed to have been slightly weathered, though they were taken from the deepest mines in the area. Sample No. 14614 was taken from the Richardson mine at location 65 in sec. 21, T. 34 N., R. 55 E., about 90 feet below the surface and about 200 feet north of the opening. This sample included the lignite of the lower bench, which is 5 feet 2 inches thick, as shown in section No. 65 in Plate XVII (p. 314). Sample No. 14670 was taken from the Pierce mine at location 52 in sec. 10, T. 35 N., R. 55 E., about 45 feet below the surface and 250 feet northwest of the opening of the main entry. Only the lower part of the bed was sampled at this place and included 3 feet 9 inches of lignite, as shown in section No. 52 in Plate XVII. For purposes of comparison, three representative analyses (Nos. 10724, 12533, and 11045) of lignite from neighboring fields are also given in the accompanying table (p. 304).

The method followed in taking these samples "involves selecting a representative face of the bed to be sampled; cleaning the face, making a cut across it from roof to floor, and rejecting or including impurities according as these are included or excluded in mining operations; reducing the gross sample, by crushing and quartering, to about 4 pounds; and immediately sealing the sample in an air-tight container for shipment to the laboratory." [1]

The four analyses given below for each sample are not different determinations but are merely four forms of one analysis. Form A is the analysis of the lignite exactly as it comes from the mine. Owing to the fact, however, that the original moisture content of a sample is largely a matter of accident and depends partly on the amount of water in the mine from which it came, it is best for comparative purposes to use form B, which is the analysis of the sample air dried under uniform conditions. Form C is the theoretical analysis of the sample after all moisture has been eliminated. Form D is also computed and is the analysis of the sample after all moisture and ash have been theoretically removed.

[1] Bur. Mines Bull. 22, 1913.

Analyses of lignite samples from Scobey-Plentywood and adjacent lignite fields, Mont.

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

Laboratory No.	Name of mine and location.	Collector.	Location. Quarter.	Sec.	T.	R.	No. on Plate XVI.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.[a]	Fixed carbon.	Ash.	Ultimate. Sulphur.	Heating value. Calories.	British thermal units.
14670	Pierce mine, 2½ miles northeast of Plentywood, Mont.	C. M. Bauer	SE	10	35 N.	55 E.	52	5.9	A	34.3	29.6	28.0	8.1	0.66	3,755	6,760
									B	30.2	31.4	29.8	8.6	.70	3,990	7,180
									C	....	45.0	42.7	12.3	1.00	5,715	10,290
									D	....	51.3	48.7	....	1.14	6,520	11,730
14614	Richardson mine, 3 miles west of Antelope, Mont.	do	NW	21	34 N.	55 E.	65	5.4	A	29.1	29.7	33.8	7.4	.31	4,165	7,500
									B	25.1	31.3	35.8	7.8	.33	4,405	7,930
									C	....	41.9	47.7	10.4	.44	5,880	10,580
									D	....	46.7	53.3	....	.49	6,565	11,820
10724	Bruegger mine, 3 miles north of Culbertson, Mont.	A. L. Beekly	SW	8	28 N.	56 E.	....	23.6	A	32.6	27.4	30.9	9.1	1.28	3,730	6,710
									B	11.8	35.9	40.4	11.9	1.68	4,880	8,790
									C	....	40.7	45.8	13.5	1.90	5,535	9,960
									D	....	47.1	52.9	....	2.20	6,400	11,520
12533	Mine of the United States Reclamation Service, 2½ miles northeast of Williston, N. Dak.	F. A. Herald	....	7	154 N.	100 W.	....	33.2	A	43.9	24.9	25.4	5.8	.49	3,300	5,940
									B	16.0	37.2	38.1	8.7	.73	4,940	8,890
									C	....	44.3	45.3	10.4	.87	5,875	10,580
									D	....	49.5	50.5	....	.97	6,555	11,800
11045	Snyder mine, 6½ miles north of Glendive, Mont.	J. H. Hance	NW	27	17 N.	55 E.	....	23.4	A	32.1	25.6	34.2	8.1	1.36	3,950	7,110
									B	11.4	33.3	44.7	10.6	1.77	5,155	9,280
									C	....	37.7	50.4	11.9	2.00	5,815	10,470
									D	....	42.7	57.3	....	2.27	6,605	11,890

[a] Volatile matter determined by the modified official method. See Bur. Mines Bull. 22, p. 29, 1913.

The samples taken in this field were both slightly weathered, whereas those from the neighboring areas were fresh. Weathered lignite gives up relatively little of its moisture on air drying, whereas fresh lignite generally loses two-thirds or more. This is well shown in the accompanying table. The weathered samples from this field yielded less than 6 per cent of moisture on air drying, but the fresh samples from the other areas yielded 23 to 33 per cent. It is evident that the amount of moisture retained by a weathered sample after the air-drying process must decidedly impair its heating value on the air-dried basis. Thus, the samples from this field yielded 7,180 and 7,930 British thermal units, whereas the fresh samples of representative lignite from the three other localities all gave over 8,700 (form B). On the other hand, the ash in the Plentywood lignite is slightly lower, and the sulphur, especially in the sample from the Richardson mine, is decidedly lower. Furthermore, it is evident that if the ash and moisture be disregarded, and only the lignite substance be considered, the Plentywood lignite compares very favorably with that from the other localities (form D). This suggests that if entirely unweathered lignite could be found and mined in the Scobey-Plentywood field it would probably be equal in every respect to the product of the neighboring fields with which it would come into competition. It is believed, however, that all the lignite mined in the field at the present time is slightly weathered and is for this reason somewhat inferior to that mined in many near-by localities.

DISTRIBUTION.

Thin beds of lignite outcrop in many places along Poplar River, but in the western district considered in this report the beds are generally too thin to be of value at the present time. Owing to the lack of good exposures, it is not known how many beds of lignite occur near Scobey. The locations of the various outcrops that were discovered, however, are shown on the map (Pl. XV, p. 308), and the thickness and character of these beds are discussed under the description of the township in which each is found.

In the eastern part of the field along Big Muddy Creek the exposures are better, and a number of lignite beds are known (Pl. XVI, p. 314). All the surveyed land in the vicinity of Plentywood is underlain at a depth of less than 500 feet by lignite beds 3 feet or more in thickness. These beds outcrop in many localities and are utilized locally for fuel. A detailed description of the topography, geology, and lignite resources of each township mapped follows.

DESCRIPTION BY TOWNSHIPS.

AREA NEAR SCOBEY.

35 N., R. 48 E.—Poplar River flows southward through the central part of T. 35 N., R. 48 E. (Pl. XV, p. 308). The lignite-bearing rocks probably belong both to the Lance and the Fort Union formations, but no fossils were found. Exposures are few, as the stratified rocks are generally covered by glacial drift. In the SW. ¼ sec. 17 about 35 feet of bowlder clay is exposed. In the SE. ¼ SE. ¼ sec. 32 there is a kamelike deposit of glacial drift of which the following is the section:

Section of glacial drift in the SE. ¼ SE. ¼ sec. 32, T. 35 N., R. 48 E.

	Feet.
Gravel, unstratified, 90 per cent quartzite pebbles	4
Sand and gravel, stratified	3
Bowlder clay, unstratified, containing sand and gravel (the lower part consolidated)	8
Shale, dark gray.	
	15

Thin beds of lignite outcrop in secs. 1, 11, 24, and 26. A lignite bed was also reported on unsurveyed land about one-half mile west of the southwest corner of sec. 7. At this place (location 1, Pl. XV)[1] a bed of lignite 1 foot 4 inches in thickness outcrops in a large spring. At location 2, in the SW. ¼ sec. 1, a bed of lignite is exposed, the base of which is concealed by the water of a spring. Above the water level 2 feet 1 inch of lignite is exposed, and this portion of the bed has been stripped for local use. At location 3 two thin beds outcrop. The lower bed contains 1 foot 6 inches of weathered lignite, and the upper bed, which is about 20 feet higher stratigraphically, contains about 8 inches of lignite. At location 4, in the W. ½ sec. 24, a bed contains about 1 foot 6 inches of lignite. Several thin beds occur lower down in the stratigraphic section, one of which outcrops in the SE. ¼ sec. 24 at location 5, where it carries less than 6 inches of lignite. In sec. 26 a thin bed of lignite included in about 40 feet of somber-colored sandstone and sandy shale is exposed. This bed, however, contains only about 10 inches of lignite. The following stratigraphic section was measured in the SE. ¼ SW. ¼ sec. 26:

[1] Locations of points at which lignite sections were measured are shown by numbers on the maps (Pls. XV and XVI); and the sections, numbered correspondingly, are either shown in Pl. XVII or are given in the text

Section at location 6, in the SE. ¼ SW. ¼ sec. 26, T. 35 N., R. 48 E.

	Ft.	in.
Glacial drift (containing limestone and igneous bowlders)	5+	
Shale, yellow, sandy	2+	
Shale, dark gray (containing gypsum)	2	8
Shale, gray, sandy	18	
Shale, brown	1	6
Shale, gray	3	
Lignite		10
Shale, gray	12+	
Total	45+	
Lignite		10

T. 34 N., R. 48 E.—The surface features of T. 34 N., R. 48 E. are very similar to those of the township immediately to the north. Poplar River flows through the central portion of the township in a valley about 2 miles wide. The lignite-bearing rocks are exposed only at a few places and no fossils were found in them. From the general character of these strata it is believed that they probably belong both to the Lance and the Fort Union formations. The boundary shown on the map (Pl. XV) indicates approximately the areal extent of each formation. So far as could be determined from the outcrops the strata lie flat. The hills in the western part of the township are covered with small quartzite pebbles, the significance of which has been discussed above. The area was at one time covered by the continental ice sheet and therefore is now generally covered with glacial drift. The drift contains bowlders and fragments of limestone, quartzite, sandstone, lignite, basalt, granite, and schist. In the broad valley of the creek which traverses sec. 18 the drift is 40 feet thick, as shown in a well, and contains bowlders of lignite, some as large as 1 foot in diameter. Measurements of lignite beds were very difficult to obtain owing to the thick cover of glacial drift.

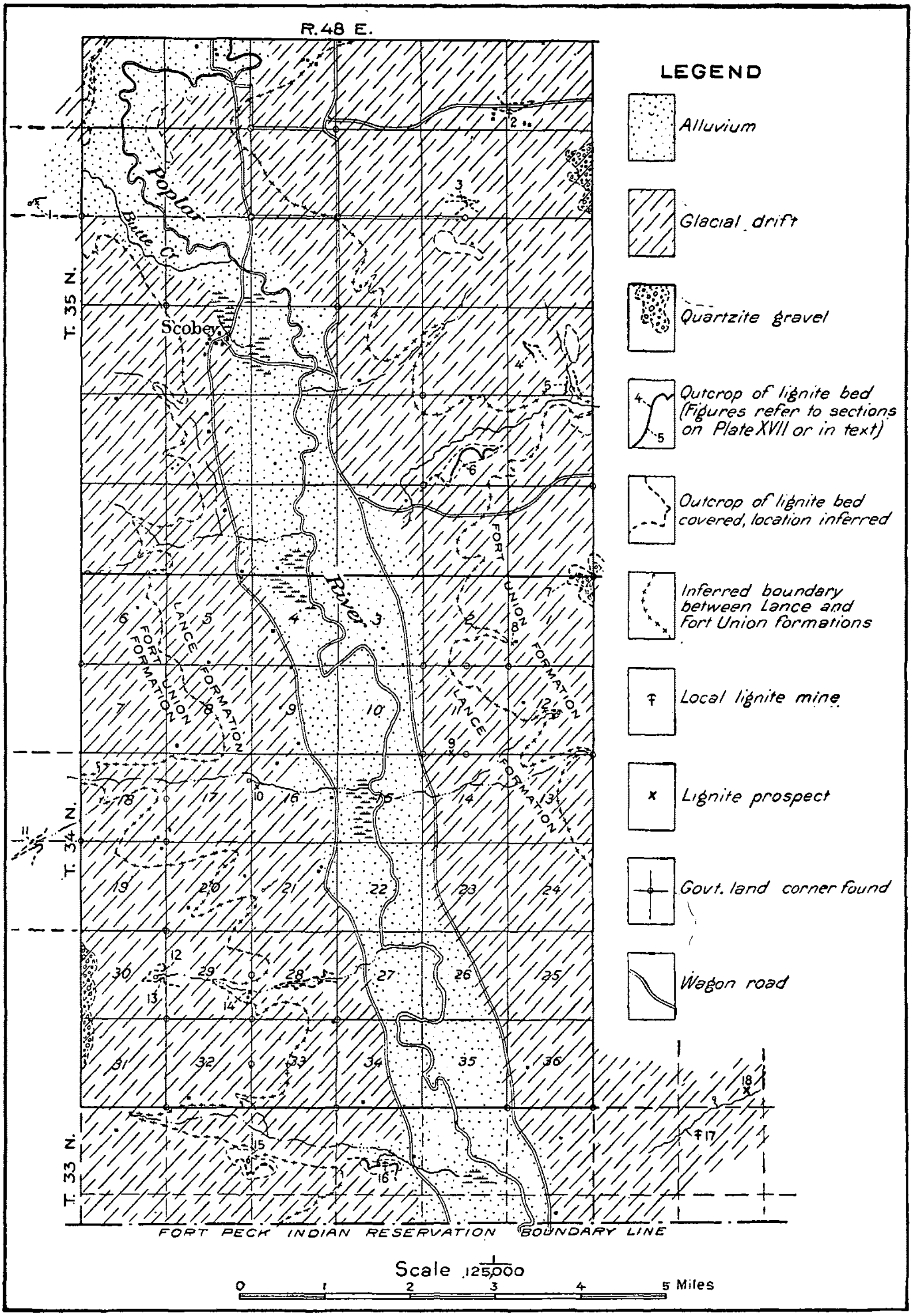
A thin bed of lignite outcrops in the NE. ¼ sec. 1 at location 7, where it carries 1 foot 2 inches of lignite. At location 8, in the SW. ¼ sec. 1, a bed of lignite about 3 feet thick was reported in a well at a depth of about 30 feet. Section No. 9 (Pl. XVII, p. 314) shows a bed of lignite as it is exposed in the SE. ¼ SW. ¼ sec. 11. The bed at this place contains 2 feet of much weathered lignite. At location 10, in the NW. ¼ sec. 16, a bed of lignite less than 10 inches thick is exposed, the outcrop being marked for a considerable distance by springs and seeps. Section No. 11 was measured about one-half mile west of the west border of this township, or near the north quarter corner of sec. 24, T. 34 N., R. 47 E. This section and sections Nos. 12 and 13, which are believed to be on the same bed, show an average thickness of 3 feet Sections Nos. 11 and 13 are shown in Plate XVII. The thickness of the lignite at location 12 is the same as that at location 13, though the bed rests on carbonaceous shale at location 12.

T. 33 N., R. 48 E. (fractional).—The area comprised in fractional T. 33 N., R. 48 E. is an unsurveyed strip of land between T. 34 N., R. 48 E., on the north and the Fort Peck Indian Reservation on the south and includes about 9 or 10 square miles. This area lies mostly in the valleys of Poplar River and a small tributary. It is for the most part rolling and grass covered but is broken into badland bluffs along the smaller streams. The lignite-bearing rocks probably belong to both the Lance and Fort Union formations, the inferred boundary between which is shown in Plate XV. The strata have a slight easterly dip. Exposures of the stratified rocks are few, owing to the general cover of glacial drift. Lignite beds and other adjacent strata outcrop in secs. 3 and 5. Section No. 15 (Pl. XVII, p. 314), which was measured on a hill in sec. 5, shows 3 feet of lignite, but the bottom of the bed was not reached owing to the presence of water from a spring. This bed is higher than the one measured in sec. 3 and is believed to be in the Fort Union formation. Section No. 16 was measured in sec. 3, at a strip pit from which considerable lignite has been taken within the last few years. At the pit the bed ranges in thickness from 1 foot 8 inches to 2 feet 6 inches, which suggests that it is elsewhere variable and probably belongs to the Lance formation.

Tps. 33-34 N., R. 49 E.—In T. 33 N., R. 49 E., only secs. 5 and 6 were examined and in T. 34 N. only a part of sec. 32. The lignite-bearing formation is believed to be Lance. It outcrops mainly in a coulee just north of the reservation line, most of the area being covered with glacial drift. Section No. 17 (Pl. XVII) was measured at a strip pit on the south side of the coulee, where the bed contains about 5½ feet of lignite. The pit is operated by farmers who live in the immediate vicinity. The lignite, which is poor in quality, has not been carefully mined, and a great deal of bone has been excavated with it for use as fuel. Section No. 18 (Pl. XVII) was measured on a bed 15 feet higher stratigraphically than the one at the strip pit. This bed is associated with sandstone and carries 2 feet 4 inches of fair lignite.

AREA NEAR PLENTYWOOD.

T. 35 N., R. 52 E.—Big Muddy Creek flows southeastward across the north-central part of T. 35 N., R. 52 E. Eagle Creek, a tributary of the Big Muddy, flows into the township in the SW. ¼ sec. 6, leaves it in the NE. ¼ sec. 6, enters it again near the north quarter corner of sec. 5, and empties into the Big Muddy near the center of this section. The township in general is very rough, having a relief of about 400 feet The interstream ridges in the southwestern part have about the same altitude, and their broad, flat tops suggest a former continuous plain. The remnants of this plain are now well covered with glacial drift, but in most of the stream valleys in the central and northwestern



MAP OF AREA NEAR SCOBEY, SHERIDAN COUNTY, MONT.

By C. M. Bauer.

portions of the township outcrops of the stratified rocks are abundant. The strata consist of shale, clay, and sandstone, as shown in the section given below. The dip of the beds southward is about 15 feet to the mile as shown by altitudes determined by plane-table traverse on the Redstone lignite bed.

Section at location 19, in the SW. ¼ SW. ¼ sec. 6, T. 35 N., R. 52 E.

	Ft.	in.
Shale and sandstone, partly concealed	60+	
Sandstone, hard	1	6
Sandstone, light yellow, friable	26	
Shale, brown, carbonaceous		4
Shale, gray	12	
Sandstone, argillaceous	11	6
Clay, gray		10
Shale, brown		2
Lignite, weathered	1	4
Shale, gray	4	
Shale, gray, finely laminated		5
Sandstone, yellow, friable	1	2
Lignite		8
Shale, carbonaceous	1	6
Shale, gray, sandy	11	6
Shale, black, carbonaceous		10
Shale, gray, sandy	5	
Shale, brown		6
Lignite	1	8
Shale, dark gray		3
Sandstone	1	9
Shale, brown		3
Lignite (Redstone)	2	8+
Talus	10	
Water in Eagle Creek.		
	155	10+

This section, however, does not include the highest strata outcropping in the township, which are generally concealed by glacial drift.

At least three beds of lignite outcrop in this township. The lowest one was measured in the NW. ¼ NW. ¼ sec. 8, at location 22, where 1 foot 7 inches of lignite is exposed. About 50 feet stratigraphically above this bed is the Redstone bed, which is mined at several localities. This bed was measured at locations 19, 20, 21, 25, 26, and 29, and the sections at these points are shown graphically in Plate XVII. The bed ranges in thickness from about 3 feet to nearly 5½ feet. In the NW. ¼ NW. ¼ sec. 8, at location 21, this bed is mined by a combination of stripping and drifting. The lignite at this place is very good in quality. The bed is also mined in sec. 16 at the Bergh mine (location 25), where it attains its maximum observed thickness, 5 feet 5 inches. At location 23, a well in the bottom of a coulee, 3 feet of lignite is reported. This bed is probably the Redstone bed. Lignite is reported in a well at location 24, but the stratigraphic position of the bed could not be determined. Sections Nos. 27 and 28 were measured on a bed about 80 feet above the Redstone lignite. This bed is probably the same as that measured at locations 30, 31, 33, and 35, but as the outcrops are isolated this correlation is not certain. The sections as given in Plate XVII show the bed to range in thickness from a little over 1 foot to more than 4 feet. Section No. 32, measured in sec. 35, is on a bed which may be the same but contains only 1 foot 4 inches of impure lignite.

T. 35 N., R. 53 E.—Big Muddy Creek flows through the central part of T. 35 N., R. 53 E. It meanders widely over a flat which is approximately a mile in width, and the meanders are entrenched from 15 to 18 feet. About 30 feet above the alluvial flat, on the south side of the creek, lies a terrace which is generally covered with gravel and glacial drift. It is well grassed, in places cultivated, and the soil appears to be very good. This terrace includes parts of secs. 16, 17, 19, 21, 22, 24, 25, and 27. Another terrace approximately 150 feet above this one is plainly discernible in secs. 28, 29, and 30. A still higher terrace, which is about 250 to 300 feet above the Big Muddy Creek flat, is present in secs. 1, 2, 3, 4, 5, 11, 12, and 14 of this township. The highest part of this terrace lies in sec. 14, where a deposit of quartzite gravel several feet thick is exposed. All the terraces and gentle slopes are covered with glacial drift, which in some places reaches a thickness of 50 feet or more. Exposures of the underlying stratified rocks are most abundant along the north bluff of Big Muddy Creek, and in the northern part of sec. 14 badlands are developed. The weathering of certain clay and sandstone beds at this place gives a general white appearance to the exposures and the locality is known as Chalky Buttes. The beds dip about 15 feet to the mile in a southeastward direction.

There are many isolated outcrops of thin lignite beds in this township. Sections Nos. 36, 37, and 38 were measured on the same bed, which probably corresponds with the bed exposed at locations 33 and 35 in the township immediately to the west. These sections are shown graphically in Plate XVII (p. 314).

Another thin bed, which carried about 6 inches of lignite, was measured in NE. ¼ NW. ¼ sec. 27, at location 42. The thickest bed exposed in this township was measured at locations 39 and 40, where it is 3½ and 8 feet thick, respectively. Section No. 43 was probably measured on the same bed and shows a thickness of 3 feet 7 inches. These sections are shown in Plate XVII. At location 41, in the SW. ¼ NW. ¼ sec. 23, lignite is reported in a well, but the thickness of the bed is not known.

T. 35 N., R. 54 E.—In general the surface features of T. 35 N., R. 54 E., are very much like those of the township immediately to the west. The lowest terrace, which in the township to the west is about

30 feet above the creek flat, is in this township about 50 feet above it. This terrace is confined to secs. 19 and 20. The second terrace is about 175 feet above the flood plain of the creek and is well marked in secs. 25, 26, 27, 31, 34, 35, and 36. In places there are cliffs about 100 feet in height at the edge of this terrace, but in general the slopes are gentle between the second and the first terraces. The highest land in the township, which lies in secs. 8 and 9, reaches an altitude of about 300 feet above Big Muddy Creek. Outcrops of the lignite-bearing rocks occur along the small creeks in the northern part of the township and in deep gullies in secs. 26, 32, and 33 in the southern part of the township. Although the exact structure was not determined here, the strata probably dip about 16 feet to the mile to the southeast, as indicated by the dip in the township to the east.

Two beds of lignite that outcrop in this township were mapped in secs. 25, 28, 32, 33, and 34. Section No. 45 (Pl. XVII), measured in sec. 33, shows both of these beds, which are separated by 15 feet of sandstone. At this place a strip pit on the lower bed has been worked for local use. Section No. 46, in sec. 32, shows the thickness of the same beds at that place. Another bed was mapped for a short distance in sec. 25. This bed is not exposed in this township, and was mapped by inference from exposures in the township immediately to the east. An isolated outcrop of a thin bed of lignite at location 44, in the NW. ¼ NW. ¼ sec. 5, shows 1 foot 2 inches of lignite.

T. 34 N., R. 54 E.—Crazy Horse Creek flows in a northerly direction through T. 34 N., R. 54 E., its source being just outside of the southern boundary. In secs. 20, 28, 31, and 32 the valley is smooth and grass covered and outcrops of the lignite-bearing rocks are scarce, but in secs. 5, 6, 7, 8, 17, and 18 the creek flows through badlands and the rocks are well exposed. Sec. 7 is especially rough and the relief is from 300 to 400 feet. The central portion of the township is an undulating plain sloping gently toward Crazy Horse Creek. In the eastern part of the township two hills or ridges rise about 150 feet above this plain, one in secs. 2, 11, 14, and 24, and the other in secs. 29 and 30. They are very nearly of the same altitude and suggest the remnants of a higher plain which formerly extended over a considerable area. The hills are covered with quartzite gravel, which in sec. 29 is stratified and 12 feet thick. The township is generally covered with glacial drift.

The badlands in the northwestern part of the township contain several beds of carbonaceous shale but no lignite beds of value. Several isolated outcrops of lignite were found in secs. 6 and 7, but the beds were not of sufficient thickness or of good enough quality to justify mapping. At location 47, in sec. 4, however, a lignite bed over 4 feet thick outcrops (Pl. XVII) and is mined for local use. The lignite in the lower portion of the bed is of fair quality. At location 48, in sec. 5, the same bed outcrops, but a reliable measurement could not be obtained on account of erosion and slumping. Lignite is reported 25 feet below the surface in a well at location 49, in sec. 9. In the SE. ¼ NW. ¼ sec. 30, at an isolated outcrop of a thin lignite bed, 1 foot 11 inches of lignite is exposed. The upper part of the bed is weathered and covered with glacial drift, however, and it is probable that this measurement does not include the entire thickness of the bed.

T. 33 N., R. 54 E. (fractional).—Only that part of T. 33 N., R. 54 E., which lies outside of the Fort Peck Indian Reservation is described here. The area is smooth and nearly level and is generally grass covered. No outcrop of lignite-bearing rocks was found in the township. However, as the land is high, it is probable that the beds of lignite described in the townships to the north and west dip beneath this area and underlie it at a depth of less than 500 feet.

T. 35 N., R. 55 E.—The southwestern part of T. 35 N., R. 55 E., is traversed by Big Muddy Creek, which meanders on a flat about 1½ miles wide. Except for the valley of Spring Creek, a tributary of this stream, the remainder of the surface of the township is largely a rolling prairie. The lignite-bearing formation is generally concealed by glacial drift from a few inches to 40 feet thick. However, along Spring Creek, which flows through secs. 10, 15, 22, 21, and 28, there are limited exposures in which beds of lignite outcrop. Along the bluff on the south side of Big Muddy Creek a lignite bed outcrops at several places. A section was obtained in the SW. ¼ sec. 29 and is given below:

Section in the SW. ¼ SW. ¼ sec. 29, T. 35 N., R. 55 E.

	Ft.	in.
Sandstone.		
Lignite	1	1
Shale		7
Lignite (Richardson)	3	
Shale, yellow	1+	
Covered	12	
Sandstone	15+	
Sandstone, hard, calcareous	4	
Sandstone, cross-bedded, friable	48	
Shale, light gray		8
Shale, carbonaceous		2
Shale, dark gray, containing gypsum	4	
Sandstone, white, containing streaks of clay	16	8
Shale, carbonaceous		4
Shale, light gray	10+	
Water in Big Muddy Creek.		
Total	116	6+
Lignite	4	1

From the altitudes determined at several points on the Richardson bed the strata dip southeastward about 16 feet to the mile. At least two beds of lignite occur in this township at a depth of less than 200 feet. The lower exposed bed (Richardson), which was mapped along Spring Creek and in the bluffs along the Big Muddy, is represented by sections Nos. 52 to 58, inclusive. This bed ranges in thickness from 3 feet 4 inches to about 8 feet, and in general the quality is better on the south side of Big Muddy Creek than it is on the north side of that stream. The measurements of this bed, with the exception of No. 55, are shown in Plate XVII. At location 55 stripping was attempted in the summer of 1912, but only 3 feet 4 inches of badly weathered lignite was found. The bed is stripped at several places, and at location 52 it is mined by drifting. The mine at this place is owned by the Pierce brothers, who lease it to miners. A sample of lignite from this mine was obtained and its analysis is shown as No. 14670, on page 304. Several entries have been driven into the hill a distance of about 400 feet, and lignite has been taken out for a number of years and sold at the mine for $2 a ton. Owing to weathering the lignite is not of the best quality, and in the NW. ¼ NW. ¼ sec. 22 it is reported to be almost worthless. South of Big Muddy Creek the lignite appears to be less weathered. In a coulee in the SE. ¼ sec. 12, at location 51, lignite is found in a well at a depth of 18 feet and reported to be 3 feet 6 inches thick. The same bed was struck in another well in sec. 13, about 200 yards to the south.

T. 34 N., R. 55 E.—Big Muddy Creek flows southeastward through the center of T. 34 N., R. 55 E. The valley is narrower here than elsewhere and is generally bordered on either side by steep bluffs or badlands. In the vicinity of Antelope, and extending along the railroad for about 5 miles, lies a broad, gentle depression, probably representing an old valley, now nearly filled with glacial material, which suggests the former course of Big Muddy Creek. The land in this valley is excellent for farming. The part of this township that is shown on the map (Pl. XVI) as covered by glacial deposits is a gently rolling plain. The land in sec. 19, which includes the highest area in this township, is covered with quartzite gravel. Elsewhere the surface material is glacial drift, except where lignite-bearing rocks are exposed along the valley of the Big Muddy and its tributaries. A section of the stratified rocks as measured in the NW. ¼ sec. 28 is given below:

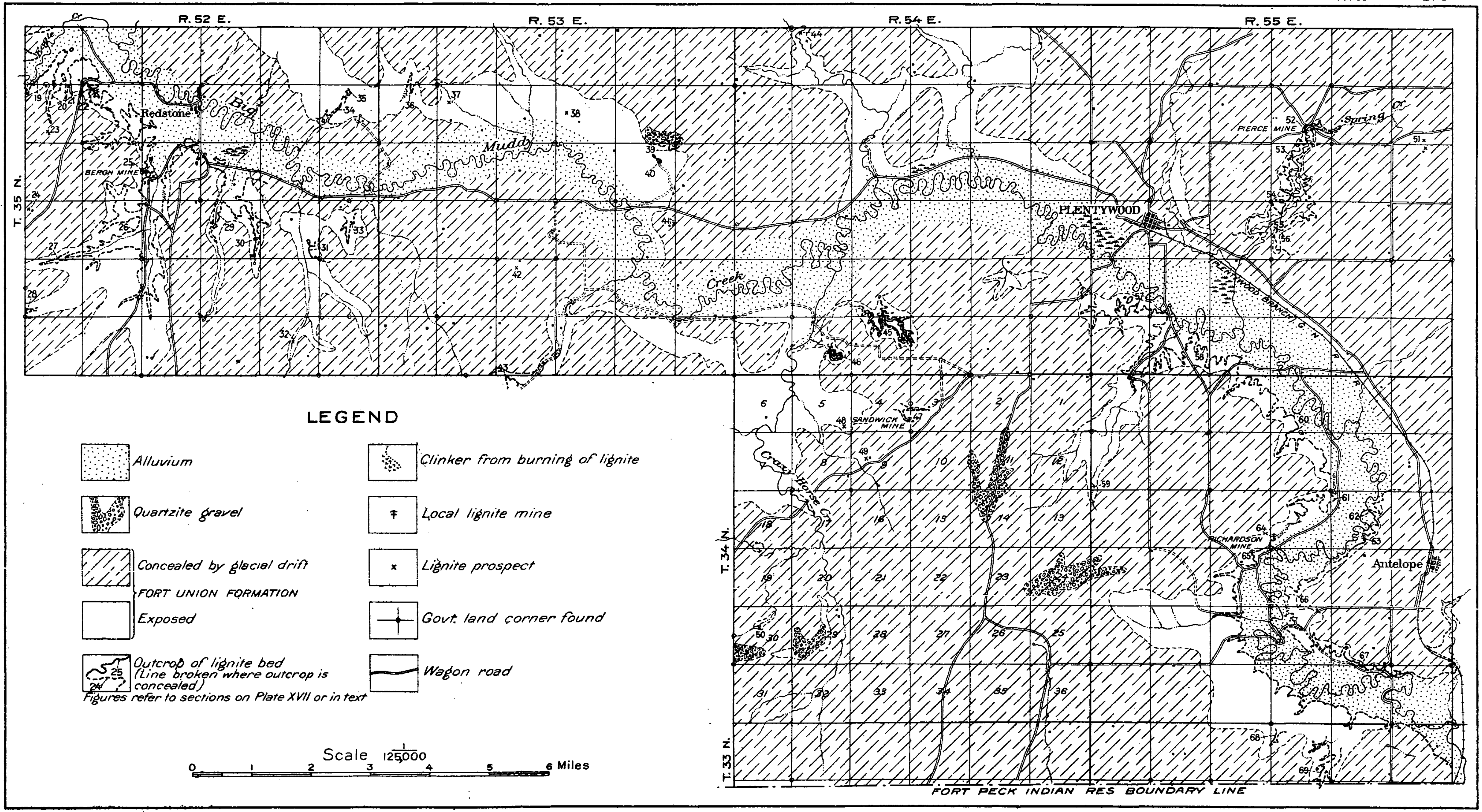
Section in the NE. ¼ NW. ¼ sec. 28, T. 34 N., R. 55 E.

	Ft.	in.
Drift.		
Sandstone, light yellow, massive	60+	
Shale, sandy, and sandstone, interbedded	10	
Sandstone, friable	8	
Shale, carbonaceous	3	4
Lignite		2
Shale, carbonaceous		5

	Ft.	in.
Bone		4
Shale, dark gray	24	4
Sandstone, buff, friable	2	6
Sandstone, hard		10
Sandstone, buff, friable	7	
Sand and shale, light, interbedded	31	
Sandstone, hard		10
Shale, light	5	
Shale, carbonaceous	4	4
Shale, gray	12	
Shale, drab	17	
Shale, gray, containing gypsum	2	6
Shale, brown, hard		10
Shale, brown, hard, containing streaks of lignite	1	6
Shale, containing streaks of limonite	5	
Shale, carbonaceous		2
Lignite		2
Shale, gray	4	
Sandstone, yellow, light	13	11
Lignite (Richardson)	2+	
	217	2+

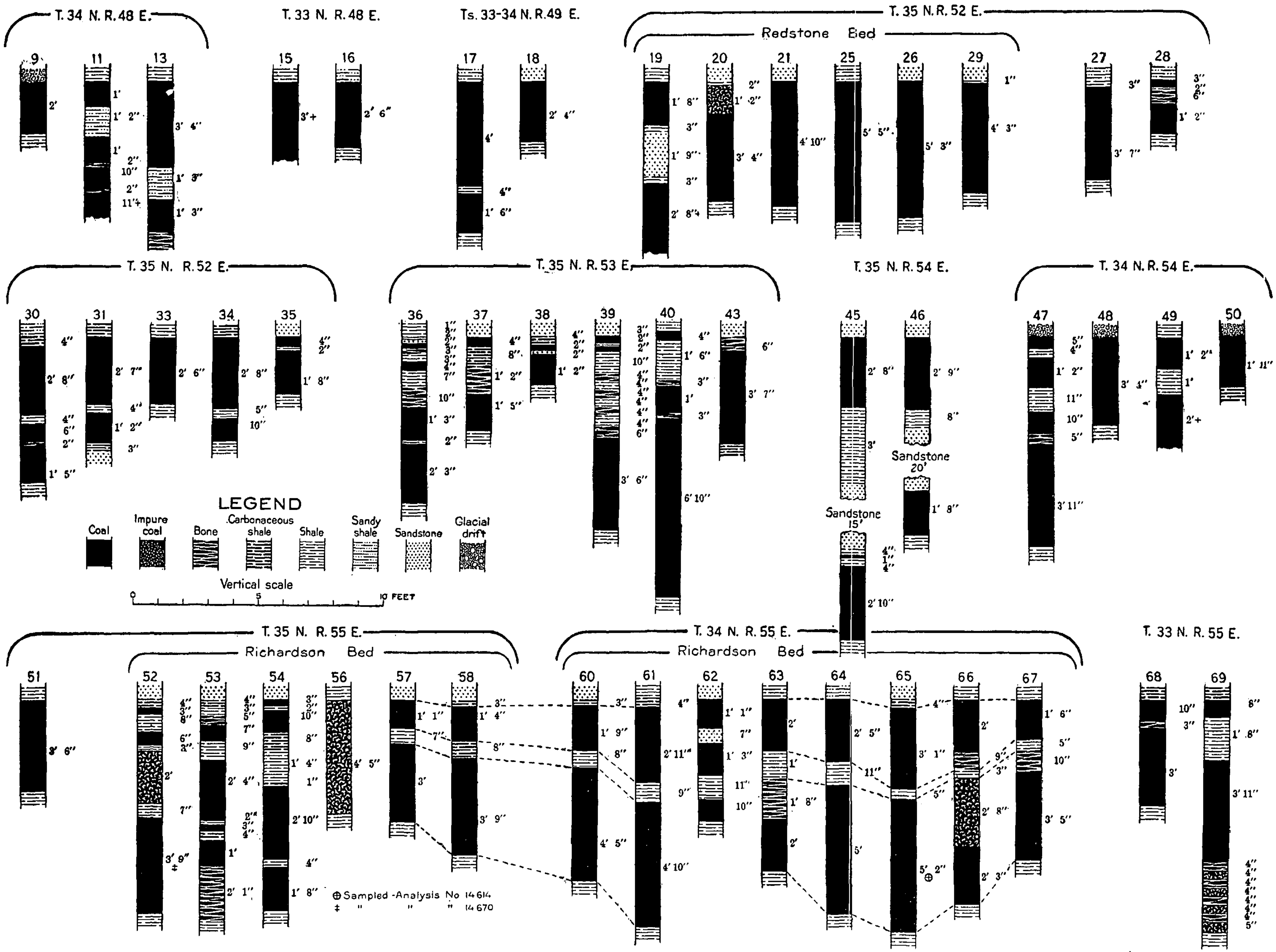
The strata dip southeastward about 16 feet to the mile as determined from altitudes on the Richardson lignite bed. Two important beds of lignite outcrop in the township, the lower one (Richardson) being represented in sections Nos. 60 to 67 inclusive and the higher by section No. 59. At location 59, in the SW. ¼ SW. ¼ sec. 7, lignite has been taken out for local use. At the time of the examination a slump had covered the bed with many feet of talus and a measurement could not be made, but the bed is reported to be over 3 feet thick. The Richardson bed can easily be traced by its clinker and also by its outcrop in many places on either bluff along Big Muddy Creek. About one-fourth mile south of location 66 the red baked clay and shale caused by the burning of the bed measured 17 feet. On the west side of Big Muddy Creek, a short distance north of the Richardson mine, the clinker is 40 feet or more in thickness. This lignite bed is in general thicker and of better quality on the west side of Big Muddy Creek than on the east. It is thickest in the vicinity of the Richardson mine in the northern part of sec. 21, where it carries over 8 feet of lignite. This mine, opened in 1909, is at present operated by Fred Richardson and M. J. Morris. The main entry is about 400 feet long and runs northwestward from the opening. Side entries have been started. A sample of lignite was procured from this mine (location 65) and its analysis is given as No. 14614 on page 14. At location 63, in the SE. ¼ SE. ¼ sec. 14, a strip pit is operated by farmers in the vicinity.

T. 33 N., R. 55 E. (fractional).—Only that part of T. 33 N., R. 55 E. which lies north of the Fort Peck Indian Reservation is described



MAP OF AREA NEAR PLENTYWOOD, SHERIDAN COUNTY, MONTANA

By C. M. Bauer



SECTIONS OF LIGNITE BEDS IN THE SCOBEY-PLENTYWOOD FIELD, SHERIDAN COUNTY, MONT.

here. The land in general is high, sloping in the eastern part of the township to Big Muddy Creek. The lignite-bearing rocks outcrop in secs. 2, 3, and 4. No determinations of the dip of the beds were made in this township, but the structure is believed to be similar to that in the township to the north. Sections 68 and 69 were measured on a bed of lignite which has been mined for local use at the localities indicated by the respective numbers. However, very little lignite has been removed. The sections of the bed at these places are shown in Plate XVII. This township is believed to be underlain by the lignite bed which outcrops along Big Muddy Creek in the township to the north, as well as other lignite beds which outcrop along Big Muddy Creek farther west.

DEVELOPMENT AND USE OF THE LIGNITE.

The value of the lignite in this field is enhanced by the shortage of wood and also by the lack of transportation facilities for importing coal. Fuel is difficult to obtain and, as the winter season is long and severe, thin beds of lignite are prospected and worked, in many places even where they are weathered and impure.

In the vicinity of Scobey any bed is considered workable by the residents that is a foot or more thick and is near enough to the surface for the overburden to be stripped off by shovels or by a horse scraper. Strip pits have been worked in the SW. ¼ SW. ¼ sec. 1, T. 35 N., R. 48 E., and in the NW. ¼ SE. ¼ sec. 3, T. 33 N., R. 48 E., and in the NW. ¼ sec. 5, T. 33 N., R. 49 E., for local use.

In the eastern part of the field lignite is mined by stripping and drifting at a number of places, as indicated on the map (Pl. XVI) and mentioned under the township descriptions. The most important mines in this area are the Bergh mine (location 25), near Redstone, in the NW. ¼ SW. ¼ sec. 16, T. 35 N., R. 52 E.; the Pierce mine (location 52), in the NW. ¼ SE. ¼ sec. 10, T. 35 N., R. 55 E.; and the Richardson mine (location 65), in the NW. ¼ NE. ¼ sec. 21, T. 34 N., R. 55 E. Although the drifts at these places have been driven a considerable distance, no unweathered lignite has yet been obtained. The lignite sells for $2 a ton at the mine.

The use of the lignite in this field is largely confined at present to domestic heating and cooking. Lignite has been used with success in traction engines for plowing and threshing, but owing to its property of slacking it can not be stocked very long or shipped very far. Its future development will depend largely on the application of briquetting[1] or similar methods of preserving the lignite for use in manufacturing.

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[1] Wright, C. L., Briquetting tests of lignite: Bur. Mines Bull. 14, 1912.

GEOLOGY AND COAL RESOURCES OF THE AREA SOUTHWEST OF CUSTER, YELLOWSTONE AND BIGHORN COUNTIES, MONTANA.

By G. Sherburne Rogers.

INTRODUCTION.

The area described in this paper is located on the west side of Bighorn River, Mont., in the angle formed by its junction with the Yellowstone (fig. 9, p. 294). The coal-bearing strata outcrop on Pine Ridge in the form of a comparatively small outlier on the western edge of the great coal field which covers most of eastern Montana. Only the northwestern part of the area known to be underlain by coal-bearing strata was examined, further work being prevented by the beginning of cold and stormy weather. The coal in this district is a fairly high grade subbituminous coal and compares favorably with the commercial varieties now sold in neighboring markets. Inasmuch as little is known of this isolated coal field the results of the writer's examination are set forth in this paper, although only about one-third of the area believed to be coal bearing was investigated.

The district here described comprises parts of Bighorn and Yellowstone counties, which are located in the south-central part of the State. It covers an area of 125 square miles, only 6¼ square miles of which, however, is underlain by coal. As shown on the map, the area examined comprises those portions of Tps. 3, 4, and 5 N., Rs. 33 and 34 E., lying south of Yellowstone and west of Bighorn rivers, together with portions of Tps. 2, 3, and 4 N., R. 32 E., and of T. 2 N., R. 33 E.

The Northern Pacific Railway traverses the northern portion of the field, following the valley of Yellowstone River. Custer, located on the railroad in sec. 1, T. 4 N., R. 33 E., is the principal town and is the chief market center for the country within a radius of about 20 miles. Waco is a smaller settlement about 8 miles farther west. The most important wagon road in the field is the old Yellowstone Trail, which follows the railroad from Billings to Custer, and there, owing to the difficulty of crossing Bighorn River and the generally rough country to the east, crosses the Yellowstone and traverses the comparatively flat land on the north side. The road to Hardin, a thriving town situated on the Chicago, Burlington & Quincy Railroad at the point where it crosses Bighorn River, about 30 miles to the south, runs southeast from Custer, striking the valley of the Bighorn near the mouth of Mission Creek. (See map, Pl. XVIII, p. 326.) Besides these two principal roads many secondary trails lead through the area, the best of which are approximately located on the map.

In the examination of this area, which was made in October, 1913,[1] the writer was ably assisted by Messrs. Wallace Lee, R. C. Moore, and A. H. Sloan. This party had been previously engaged in the detailed examination of a large area lying east of Bighorn River for the purpose of classifying the public domain. Although no public land remains in the district described in this paper, the same exact field methods were used. That is, after carefully prospecting the district for coal, the outcrops of all beds thicker than 18 inches were meandered by stadia and plane-table methods, the traverse being tied to land corners. The angle at which the beds dip was determined by means of a careful line of elevation carried throughout the traverse. The coal was examined at short distances and the measurements recorded. In the area not underlain by coal, however, no traverse was made, and the positions of roads and creeks shown on the map (Pl. XVIII) are taken for the most part from the plats of the General Land Office.

The General Land Office surveys of most of the townships in this district are recent. They appear to be accurate and satisfactory, and the cornerstones are generally well marked.

TOPOGRAPHY.[2]

The dominant topographic feature in the district lying in the western angle of Bighorn and Yellowstone rivers is Pine Ridge, the northeastern extremity of which lies within the area described in this paper. From the foot of this high and abrupt ridge the land slopes more gently to another relatively steep escarpment which limits the flat bottom land along the two rivers. (See Pl. XVIII.)

Yellowstone and Bighorn rivers meet at a rather acute angle, and Pine Ridge constitutes the high divide between them, the present shape and position of the ridge being controlled partly by the geology. The top of the ridge is remarkably level and rises only slightly to the south, maintaining an average height of about 1,100 feet above the rivers. Because of the level character of its crest and its thick covering of gravel, it is believed to represent an old river terrace. In other words, at some time in the past the river beds must have been about 1,100 feet higher than at present, and the rivers, in mean-

[1] Although this work was done in 1913 the unavoidable delay in publishing the volume for 1912 has made it possible to include this paper in that volume.

[2] The Fort Custer topographic sheet of the U. S. Geol. Survey, published in 1894, shows the southern portion of the district described in this paper.

dering, deposited the gravel which now covers Pine Ridge. The ridge itself rises about 400 feet above the immediately surrounding country, and its level crest is in this district commonly less than 200 feet wide. Its slopes are everywhere steep, and are broken into characteristic rounded hills. The foot of the ridge approximately coincides with the outcrop of the coal bed south of the large fault shown on the map (Pl. XVIII), the northern end of the ridge being located in sec. 6, T. 3 N., R. 33 E. Owing to the steepness of the slopes, the narrowness of the ridge, and its heavy covering of gravel, this land is valuable chiefly for grazing. Numerous springs on the east slope and a somewhat smaller number on the west serve to make the land available for either summer or winter range. As the name Pine Ridge implies, its slopes are covered by a fairly thick growth of pine, suitable for mine timbers and other rough lumber.

East of the main ridge the land slopes gently toward the Bighorn and is for the most part fairly smooth. This area includes the greater part of Tps. 3 and 4 N., R. 33 E., and although there is a drop of about 500 feet in a distance of 5 miles or less much of the land is sufficiently level for dry farming. In the extreme eastern part of these townships, and extending also into R. 34 E., the land is almost perfectly flat and thinly gravel covered; hence, it seems to represent the first terrace above the present river bottoms. The east and north boundary of this flat area as approximately indicated on the map is formed by a steep and fairly regular escarpment about 200 feet high. It is particularly well marked along the Bighorn and also along the Yellowstone as far west as Sand Creek. At the foot of this slope lies the flood plain of the rivers, ranging in width from half a mile to 2 miles. This bottom land is level and fertile and is now practically all under cultivation.

The district east of Pine Ridge is drained chiefly by Mission and Sorrel Horse creeks and a large creek south of Sorrel Horse Creek. These streams are intermittent, but along their courses springs are fairly common and on Sorrel Horse strong enough, except in the heat of summer, to give rise to a flowing stream.

The creeks have excavated valleys somewhat narrow in proportion to their length and have to only a slight extent dissected the gentle slope to the east of the ridge. A striking feature of this drainage, especially near the headwaters at Pine Ridge, is the abundance of almost parallel valleys. Thus, for distances of 2 or 3 miles the streams flow within a mile of each other, and at the foot of the ridge many of the smaller coulees flow for a mile or more within 1,000 feet of each other. This seems to be due to the steep gradient near their sources and to the abundance of gravel which, being homogeneous in character, has not interfered with the natural course of the streams as determined by the uniform easterly slope.

In contrast to the gentle valley slopes of Mission and Sorrel Horse creeks are the steep gorges of Sand Creek and the other northward-flowing streams that drain the northern end of Pine Ridge. Owing to the proximity of the river, which causes a drop of about 700 feet in a distance of 4 miles or less, the coulees are narrow and steep. The area at the north end of the ridge is therefore strikingly different from that on the gently graded east slope and is dissected into almost impassable badlands. The lower terrace is also practically obliterated in this district, so that the escarpment shown on the map here marks merely the limit of the bottom land rather than a well-developed terrace.

The small area lying west of Pine Ridge is drained by Reid Creek, a large northward-flowing stream, which has bisected the northern end of the ridge and which flows just west of the border of the district.

GEOLOGY.[1]

STRATIGRAPHY.

The Lance formation outcrops throughout this district, except in about a square mile in the southeast corner, where Pierre shale is exposed. Quaternary gravel in many places overlies and partly conceals the older formations. (See columnar section, Pl. XVIII, p. 326.)

CRETACEOUS SYSTEM.

PIERRE SHALE.

Although an important formation in the area to the south, the Pierre shale is practically negligible in this district. It is concealed by the flood plain of Bighorn River, and the upper boundary shown on the map is inferred from the boundary exposed on the opposite side of the river. The Pierre is composed almost entirely of dark greenish-gray shale containing abundant limestone concretions. The fossils inclosed by these concretions indicate that the formation is of marine origin.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

The Lance formation in this area may be divided into two parts, namely, a coal-bearing member, which comprises the upper 250 feet, and a lower portion about 900 feet thick. This distinction is made partly on lithologic grounds and partly because of the slight difference in the fossils found in the two divisions.

Lower part of the Lance formation.—The total thickness of the lower part of the Lance formation was not accurately measured in the field, but the figure given, 900 feet, is a close estimate. This portion of the

[1] A more complete description of the geology of this general region will be found in a forthcoming bulletin by the writer on the geology of the Tullock Creek coal field, Rosebud County, Mont.

formation, as shown on the map, outcrops over most of the area described in this report. No detailed stratigraphic section was made, but the following facts were observed: The strata consist entirely of sandstone and shale, and contain no coal. The sandstone for the most part is soft and yellow, occurring in beds from 1 to 50 feet thick. Through these beds, however, are scattered numerous lenses of hard gray sandstone, which on weathering tend to stand out prominently, forming cap rocks, which are common in the area underlain by these strata. These cap rocks in certain localities are very persistent and in conjunction with the soft yellow sandstone form prominent escarpments, which locally are impassable for considerable distances. In general, however, the sandstone beds are lenticular and can be traced only 2 or 3 miles, and in many places a sandstone 30 or 40 feet thick disappears within 300 feet. The shale which alternates with the sandstone beds ranges in color from yellowish gray to greenish yellow, the latter tint being more common and characteristic of this portion of the Lance formation. In the upper 300 feet of the section, or the portion immediately underlying the coal-bearing member, the shale markedly predominates over the sandstone, whereas in the lower 600 feet the amount of each is about equal. No fossils were collected in the district considered in this report, but numerous invertebrates found in these strata just east of Bighorn River constitute a typical Lance fauna.

Coal-bearing (upper) member of the Lance formation.—The coal-bearing member of the Lance formation resembles the lower portion of the Lance in a general way, but certain differences are apparent on close examination. Although the sandstone is lithologically similar to that in the lower portion, it commonly occurs in beds less than 20 feet thick. These beds, however, are much more persistent than the thicker ones which are common in the lower portion of the formation. The shale is for the most part yellowish gray to brownish, the greenish tint being uncommon. Many bands of carbonaceous shale are present in the member, most of which contain at least a few inches of coal or bone. The base of the member is marked by a coal bed, which ranges in thickness from 1½ to 4 feet. Although none of the carbonaceous bands above this horizon contain more than a foot of coal in this area, as many as eight coal beds thicker than 18 inches have been observed in the district east of Bighorn River. These strata may therefore be distinguished in the field from those of the lower portion of the Lance by the presence of carbonaceous beds, by the generally yellowish-brown color of the shale, and by the greater regularity of the sandstone. Furthermore, fossils are less numerous in the coal-bearing member than in the lower part of the Lance, and collections made east of Bighorn River contain a fauna slightly different from that which is typical of the Lance formation. The total thickness of the coal-bearing member is not present in this district, the maximum observed being about 250 feet.

QUATERNARY SYSTEM.

The oldest unconsolidated deposit in this district is the gravel on Pine Ridge, which is about 1,100 feet above the present rivers. It is believed to be Quaternary in age because of its close resemblance to later undoubted Quaternary gravel deposits. The great amount of erosion which has taken place since its deposition, however, indicates that it is either early Quaternary or possibly late Tertiary. It is made up for the most part of pebbles from half an inch to 3 inches in diameter, although pebbles 6 or 8 inches in diameter are not rare. There is also an interstitial filling of fine gravel and sand. The thickness of the gravel is difficult to estimate, owing to the fact that it constantly slumps down, never forming cut banks. The thickness of 40 feet given in the columnar section (Pl. XVIII, p. 326) probably represents a maximum, and the average thickness is probably less than 30 feet. As mentioned above, the gravel has exercised a distinct influence on the topography and drainage and is constantly being carried down and reworked by the streams which have their sources in Pine Ridge. Probably more than half of the gravel is composed of quartzite, chert, and other siliceous rocks, but a very wide range of igneous rocks also enters into its composition, and all the main types, from rhyolite to pyroxenite, have been observed by the writer.

The next well-defined Quaternary deposit is the gravel of the lower terrace, which lies at a height of about 200 feet above the river. This gravel is most apparent on the slope and at the foot of this terrace, having been almost entirely removed from its flat top. It is apparently similar in every way to the gravel on Pine Ridge. As it lies close to the railroad it may at some time become valuable for concrete work, for which it would be adapted after screening. The supply is practicably inexhaustible.

The most recent deposit in the district is the alluvium of which the present bottom land is formed. It is a rather clayey loam, and its fertility makes it valuable for agriculture.

STRUCTURE.

In a general way the area described in this paper is situated near the boundary between the Great Plains district, in which the strata characteristically lie almost flat, and a piedmont district in which the strata have been somewhat disturbed by more or less distant upheavals. Thus this area lies at the extreme northern edge of the so-called Bighorn uplift, the center of which is about 70 miles to the south. The strata dip gently to the north and east at angles averaging about 1°.

The dip is monoclinal in general character, but appears to be interrupted in places by minor rolls, one of which crosses the southern part of this area. Thus at the most southerly point in the area examined the dip is slightly to the south (2 feet in 1,000), whereas elsewhere in the field it is about 1° to the north or northeast. The axis of this gentle anticline passes through sec. 36, T. 3 N., R. 32 E., and north of this point for at least 8 miles the dip is uniformly to the north and northeast.

The dips shown on the map (Pl. XVIII) are computed from numerous elevations determined on the coal bed, and as they are all low are given in feet in 1,000 feet rather than in degrees.[1] The dip is too low to measure with a clinometer except locally, and accurate data are therefore not available in the non coal-bearing area. It is believed from observations made on the east side of Bighorn River that the general dip throughout this area is in a direction about N. 20° E., but that it decreases north and east of Pine Ridge until the strata along the rivers lie almost flat.

Faults are not uncommon in the district, and it is probable that those shown on the map are only a small proportion of those which actually exist. Owing to poor exposures and to the lack of key strata in the lower part of the Lance, it is impossible to detect faults without very careful work, and none are mapped except in the coal-bearing area. All the faults found are approximately parallel to the strike except the one in secs. 19 and 30, T. 3 N., R. 33 E. This fault was mapped inferentially on the evidence of the elevations, which show a drop of about 75 feet to the east, but although its position could not be actually seen it is believed that it is located within close limits. The small fault in sec. 6, T. 3 N., R. 33 E., is clearly visible, however, as is also that in sec. 13, T. 3 N., R. 32 E. Each of these faults has a displacement of 30 feet. The fault in sec. 7, T. 3 N., R. 33 E., has a total displacement of 76 feet downthrown to the south, but no trace of it could be found on the west side of the divide. The largest fault is that which repeats the coal outcrop at the north end of the ridge. Its position was determined with reasonable accuracy at a number of points in the coulees which it crosses, the displacement ranging from 130 feet on the west to 100 feet on the east. These two faults apparently inclose a block, which is tilted slightly to the east as would be expected if the faults die out to the west. The small fault in sec. 1, T. 3 N., R. 32 E., has a downthrow of 29 feet to the south.

[1] A dip of 17.5 feet in 1,000 feet is equivalent to a dip of 1°.

All these faults are normal, with fault planes inclining probably less than 45° from the vertical. As has been shown, some of them are step faults and others are block faults. Several other small breaks with displacements of less than 10 feet were observed, mostly at the northern end of the ridge, and it is probable that the simple monoclinal dip described above is broken in many places by similar small faults.

THE COAL.

OCCURRENCE AND CHARACTER.

The one coal bed thicker than 18 inches in the area examined lies at the base of the coal-bearing member of the Lance formation. Above this bed therefore are the yellow shale and generally thin sandstone beds of this member, and beneath it are the greenish shale and the sandstone of the lower part of the Lance. The generally shaly character of the strata that incloses it is shown in the sections given below. The measured sections of the bed itself, shown graphically on Plate XVIII, are numbered to correspond with the locations at which the sections were measured, as shown on the map. In every section of the bed measured a parting of a peculiar sandy carbonaceous material was found, ranging in thickness from three-fourths of an inch to 1¼ inches; in nearly every section this parting is located from 1 to 10 inches below the top of the coal bed.[1] The most notable exception is in section No. 10, where the presence of a lenticular upper bench has caused the parting to assume a position below the middle of the coal. The bed can generally be easily recognized by the characteristic appearance, thickness, and position of this parting.

[1] Rogers, G. S., Occurrence and genesis of a persistent parting in a coal bed of the Lance formation: Am. Jour. Sci., 4th ser., vol. 37, p. 299, 1914.

Stratigraphic sections measured across the coal bed.

SE. ¼ sec. 7, T. 3 N., R. 33 E.

	Ft.	in.
Shale, yellow	10	
Shale, brown, carbonaceous	3	
Shale, yellow	4	
Shale, brown, carbonaceous, with some bone	3	
Shale, yellow	8	
Sandstone, yellow, soft	6	
Shale, gray	10	
Shale, yellow	6	
Coal (section No. 6, Pl. XVIII)	3	2
Shale, carbonaceous	1	
Shale, greenish gray	20	
	74	2

SW. ¼ sec. 31, T. 4 N., R. 33 E.

	Ft.	in.
Shale, yellowish gray	10	
Coal (section No. 14, Pl. XVIII)	1	10
Shale, carbonaceous	1	
Shale, greenish yellow	12	
Sandstone, yellow, soft	29	
	53	10

SW. ¼ sec. 32, T. 4 N., R. 33 E.

	Ft.	in.
Sandstone, yellow, soft	25	
Shale, yellow	20	
Shale, brown, carbonaceous, with some bone	2	
Shale, gray	7	
Bone	1	
Shale, brown, carbonaceous	2	
Coal (section No. 11, Pl. XVIII)	2	1
Shale, brown, carbonaceous	1	
	60	1

Center W. ½ sec. 12, T. 3 N., R. 32 E.

	Feet.
Sandstone, yellow, soft	4
Shale, yellow, sandy	8
Coal (section No. 19, Pl. XVIII)	3
Shale, carbonaceous	2
Shale, yellowish green	5
	22

The thickness and character of the coal bed are shown in the graphic sections on Plate XVIII. These sections show the bed to be thicker than 18 inches everywhere except in the center of the northern part of the ridge and to consist for the most part of clean coal not badly broken by partings. These sections show the actual measurements of the bed, but on figure 10 are shown the isopachous lines [1] or thickness contours, which are a device for showing at a glance the estimated thickness of the bed at any point. In drawing these contours the measured sections of the bed were first evaluated in terms of solid coal without partings, according to the method of the land-classification board of the United States Geological Survey. This is done on the broad assumption that in mining the cost of removing a parting is generally about equal to the profit on a similar thickness of coal, so that to obtain the thickness of coal which may profitably be mined an inch of coal should be disregarded for every inch of parting. Thus, 24 inches of coal separated in the center by 3 inches of shale is considered to be equivalent in value to 21 inches of solid coal. All the measured sections have been thus treated, and the results are given in figure 10. By grading between these sections the points were established at which the coal is thought to be 18, 24, and 30 inches thick, and so on, and lines were then drawn

[1] An isopachous line, in the sense here used, is an imaginary line connecting the points at which the coal bed is of equal thickness.

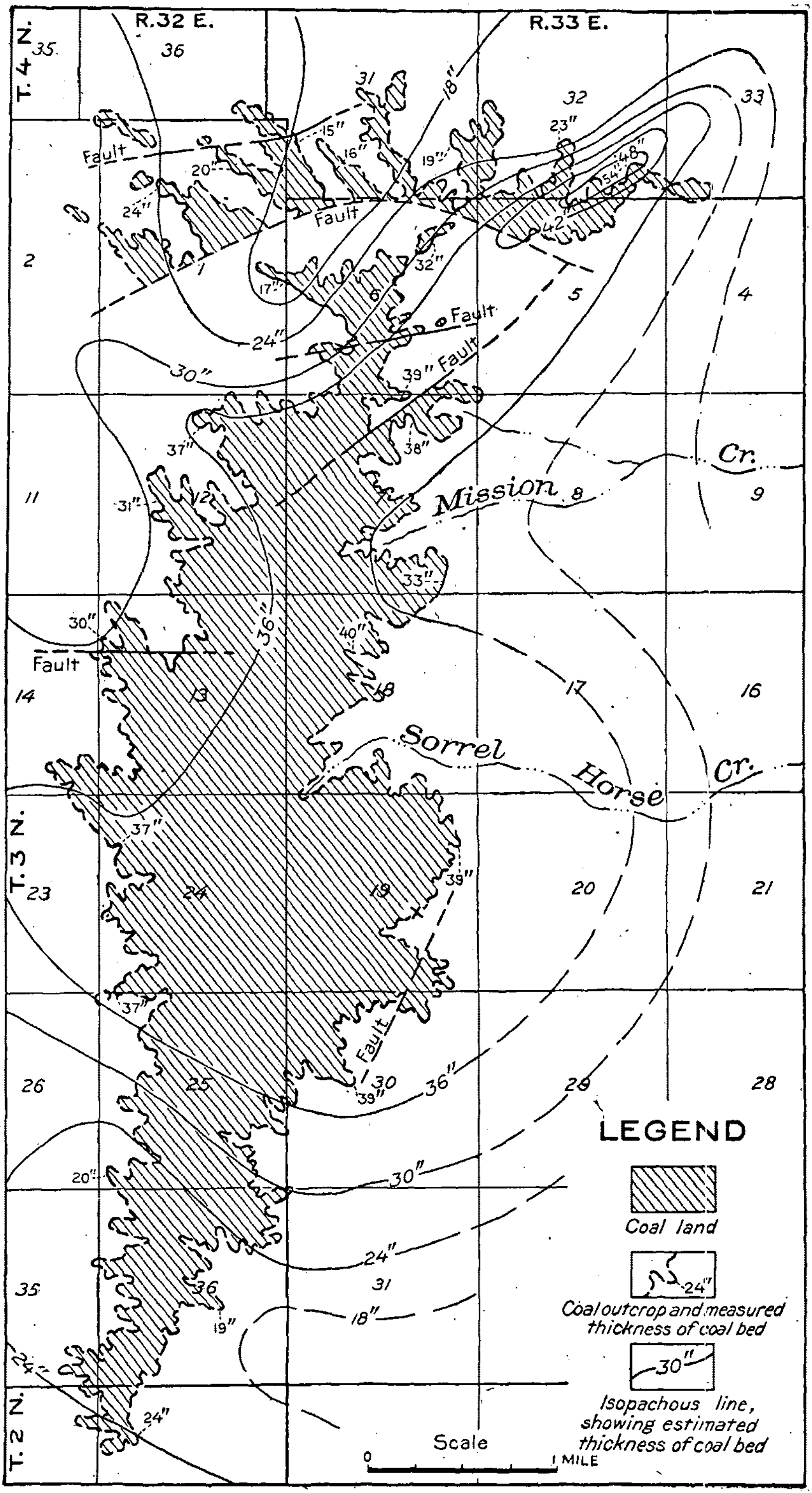


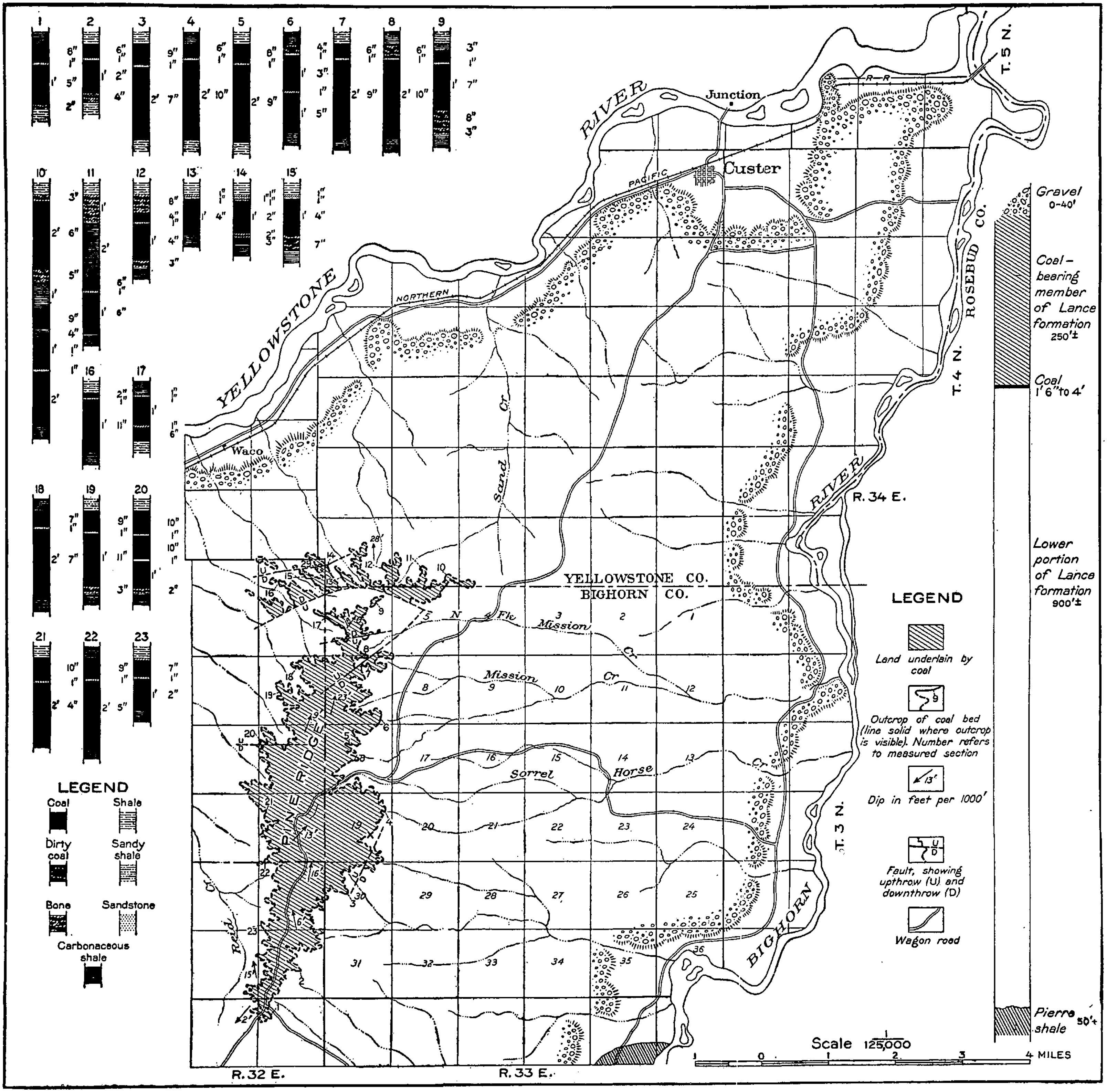
FIGURE 10.—Map of northern part of Pine Ridge coal field, Mont., showing lines along which the coal bed is probably of equal thickness (isopachous lines).

connecting these points. Thus, at all points along the 30-inch contour the coal bed is believed to be 30 inches in thickness, calculated on the above basis, and between the 30 and 36 inch contours the bed is believed to be between 30 and 36 inches thick and to average 33 inches. For example, the south quarter corner of sec. 12, T. 3 N., R. 32 E., lies almost halfway between these contours, so that although the coal is concealed at that point it may be inferred that it is 32 or 33 inches thick. The value of these contours depends of course upon the number and relative positions of the measured sections upon which they are based, and as in the area under consideration many sections have been measured at favorable locations, it is believed that the contours are reliable and fairly accurate.

These contours show that the bed is thickest in sec. 32, T. 4 N., R. 33 E., but that most of the central portion of the ridge is underlain by coal between 36 and 39 inches in thickness. The bed is thinnest in a long embayment from the north, where, in sec. 31, T. 4 N., R. 33 E., it is less than 18 inches thick. In the southern part of the area the bed is also thin but appears to become somewhat thicker farther south.

Thickness contours roughly define the limits of the ancient swamp in which the coal was deposited. Inasmuch as the contours in this area are concentric in character and appear to close within a short distance beyond its borders, it may be inferred that the center of the swamp was not far distant. Owing to the small size of the area examined the data gathered are hardly sufficient for any statement as to the thickness of the coal to the west or south, but if the center of the swamp was located within this district it is reasonable to suppose that the coal is thinner in those directions. On the other hand it must be remembered that other swamps, semi-independent in character, may have existed contemporaneously, and hence that, although the coal bed decreases in thickness for a few miles, it may farther on become thicker. Furthermore, it is possible that the overlying carbonaceous zones, which in this field are of no value, may at a distance of a few miles carry several feet of coal. It is evident, therefore, that no reliable generalizations can be made before the adjacent areas are examined.

The strata above the base of the coal-bearing member in this area do not contain any coal beds more than a foot thick. At locality 10 an upper bench of the main coal bed is exposed, and this is represented in other localities by a carbonaceous streak a few feet above the horizon of the sandy parting. About 30 feet above the principal bed are two fairly constant carbonaceous beds (see section measured in the SE. ¼ sec. 7, T. 3 N., R. 33 E., on p. 324), but neither of these beds contains more than 6 inches of coal. A detailed section of one of them is as follows:



MAP OF AREA SOUTHWEST OF CUSTER, YELLOWSTONE AND BIGHORN COUNTIES, MONT., INCLUDING PART OF PINE RIDGE COAL FIELD, AND SECTIONS OF THE COAL.

By G. Sherburne Rogers.

Section of coal bed in NW. ¼ sec. 13, T. 3 N., R. 32 E.

	Ft.	In.
Shale, carbonaceous		11
Coal		2
Shale, gray		4
Coal		3
Clay, white		1½
Bone		10
Shale, yellow.		
	2	7½

Above this bed occur several lenticular carbonaceous streaks, containing at certain places a few inches of coal but nowhere attaining economic importance.

QUALITY OF THE COAL.

The coal of this field is of good subbituminous grade. It has no visible woody structure and is black in streak as well as in color. It has a bright vitreous luster and weathers in the platy manner characteristic of subbituminous coal. It is brittle when fresh, and most of it is clean and fairly pure.

In this area no opportunity was afforded the writer of observing the behavior of perfectly fresh coal when exposed to the air, but from facts observed east of Bighorn River it seems probable that it would check within a month or so and would partly fall to pieces if too roughly handled. The checking that takes place within the first few months after the coal is mined does not, however, entirely penetrate it, but rather tends to form a protective coating around a core of unchecked material beneath. If proper precautions are observed in moving it, therefore, this coal should form a fairly satisfactory fuel. It is possibly somewhat "light" for a good forced-draft steam coal, but it might be successfully used in stationary engines and as domestic fuel. If it ever commands a distant market, however, it is probable that closed cars will be needed for shipment.

This coal in physical appearance and in inferred stocking qualities is superior to that mined near Sheridan, Wyo. It resembles closely the Roundup and other coal mined in the Bull Mountains, about 50 miles northwest of this area. It is probably somewhat inferior, however, to the Red Lodge and Bear Creek coal, which is extensively mined about 80 miles southwest of this field.

As no development work has been done in this area there was no chance of obtaining a sample of fresh coal for analysis. At a point about 20 miles northeast of Pine Ridge, however, a sample was obtained by blasting 8 feet back under a heavy sandstone bed. The coal in that district appears to be somewhat lower in quality than that in this area, and the calorific value of the sample was furthermore undoubtedly impaired by its slightly weathered condition. This sample in the air-dried condition yielded 9,376 British thermal units, and taking the above facts into consideration it is probable that perfectly fresh coal (air dried) in this area would give over 10,500 British thermal units, nearly the heat value of the average Bull Mountain coal.

QUANTITY OF THE COAL.

On figure 10 the thickness contours of this coal bed are shown, and the principle of their construction has been described above. As the outcrop of the bed is a rather sinuous line entirely surrounding the coal area, and as 23 accurate measurements of the coal were made along the outcrop, it is believed that these thickness contours are located with considerable accuracy, and that they form the best basis for computing the tonnage. The area of the coal land between each two of these contours was separately determined, and the thickness of the coal in each area was assumed to be the average between the two inclosing contour lines. On this basis it is estimated that there is a total of 20,869,760 tons of coal in this field, of which at least 60 per cent is recoverable.

OUTLOOK FOR DEVELOPMENT.

At the present time practically no development work has been done. In the SE. ¼ sec. 19, T. 3 N., R. 33 E., the coal has been opened, but work was stopped after driving the entry about 5 feet.

On figure 10 is shown the thickness of the coal bed at all localities in the coal-bearing area. The bed reaches a maximum of 54 inches in sec. 32, T. 4 N., R. 33 E., and this locality has the added advantage of being nearest to the railroad (Pl. XVIII). On the other hand, there is not a great body of coal in that district, and the cover averages less than 40 feet, so that the coal is probably more weathered than in the area to the south. Furthermore, faults seem to be more common, and the thickness of the coal is more variable. For a mine of any size, therefore, the area at the head of Mission and Sorrel Horse creeks would probably be the most favorable. As the dip to the northeast is fairly constant, the entry should be driven from the east side of the ridge in order to take advantage of the natural drainage and to lessen the cost of hauling out the loaded cars. Springs are common along the coal bed, and it is probable that the water would be a constant source of trouble in an entry driven from the west or down the dip. In the area south of Sorrel Horse Creek the coal is somewhat thinner, and owing to the northerly dip the bed is within 60 feet of the top of the ridge.

As stated above, the coal in this bed seems to be superior in quality to that mined near Sheridan, Wyo., and to be nearly equal to the Bull Mountain coal. It is probably inferior, however, to the Red Lodge and Bear Creek coal, which sells in Custer for less than $3 a ton. At the present time it would be impossible to mine it in competition with these coals, owing to the long haul to the railroad, and its commercial importance is therefore dependent largely on better transportation facilities.

COAL DISCOVERED IN A RECONNAISSANCE SURVEY BETWEEN MUSSELSHELL AND JUDITH, MONTANA.

By C. F. Bowen.

INTRODUCTION.

As coal-bearing formations were known to be exposed in the central part of Montana, between Missouri and Yellowstone rivers, an examination of this area was undertaken in 1912 in order to obtain definite information regarding the quantity of the coal and the extent of the beds. This examination has shown that the coal is confined to the area north of the Judith Mountains, that the beds are thin and few in number, and that the coal is of low grade. The field is therefore not of commercial importance.

The area lies in the central part of Montana and ranges from less than 1 mile to about 30 miles in width. It extends from Musselshell, on Musselshell River, northwestward to Judith, at the mouth of Judith River on the Missouri, a distance of about 125 miles. This area is about 1,400 square miles in extent. Its geographic location is shown on the index map (fig. 9, p. 294).

The purpose of this report is to give a brief account of the stratigraphy and coal resources of the formations in the area above described. A more detailed report on the stratigraphy and age of the formations is in preparation and will be published later. The field work on which this report is based was done during the period from June 25 to August 5, 1912, and was in the nature of a careful reconnaissance survey.

The mapping was done by Harvey Bassler and the writer. The residents of the region were courteous and hospitable and furnished much information that was of value in carrying on the work, for which the writer here expresses his acknowledgments.

In 1853 Hayden did his first work in the upper Missouri region. Following him, Cope, C. A. White, Peale, Marsh, and others studied the section along Missouri River but did not attempt detailed mapping of the individual formations. In recent years more detailed work has been done in this and adjacent areas by Stanton and Hatcher,[1] W. R. Calvert,[2] and C. T. Lupton.[3]

As a rule the township boundaries in this area are well established. The subdivisions of the townships, however, are for the most part unsatisfactory, except where the original surveys are comparatively recent or where resurveys have been made.

The United States Geological Survey is preparing a map of the United States on the scale of about 16 miles to the inch, and part of this map was enlarged to a scale of 4 miles to the inch and used as a base for geologic mapping. The land lines and the drainage on this map are fairly accurate. The slight discrepancies which occur are so small that they do not appreciably affect the accuracy of the map on the scale on which it is here published, and therefore no adjustments were made.

Horizontal control for geologic mapping was furnished by the land survey. A main stadia traverse was carried throughout the area and was tied to land corners generally not less than once in each township. A Johnson plane table and telescopic alidade were used in running the traverse. Side traverses, which were tied to the main traverse and to land corners, were made by horse pacing and by triangulation, a 15-inch plane table and open-sight alidade being used for the work. By these methods the structure was platted and the boundaries of the formations of the Montana group were mapped, but no attempt was made to map or study the formations above and below the Montana. The map thus prepared is reproduced here as Plate XIX. On it the formation boundaries are represented by solid lines where they are located with considerable accuracy and by broken lines where their location is only approximate.

Although the country is very sparsely settled, satisfactory wagon roads connect the post offices and the large stock ranches and furnish a ready route of travel throughout the field.

The Chicago, Milwaukee & St. Paul Railway passes through the southeast corner of the area. A branch of this road built several years ago from Harlowton north to Lewistown has been extended north to Hilger and is now under construction to Roy. The construction of a branch line from Lewistown east to Winnett is also contemplated.

TOPOGRAPHY.

The area lies wholly within the plains region, although it is not far removed from several important mountain masses which have influenced its topography, drainage, and structure. Broadly considered,

[1] Stanton, T. W., and Hatcher, J. B., The geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, 1905.

[2] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, 1909.

[3] Lupton, C. T., The eastern part of the Bull Mountain coal field, Mont.: U S. Geol. Survey Bull. 431, pp. 163-189, 1911.

the topography is that of an uneven plain more or less dissected by streams, but locally there is a considerable development of badland forms, which occur where the Eagle sandstone or Judith River formation is exposed at the surface in a comparatively flat-lying attitude, as in the area between Willow and Flat Willow creeks, or near the larger drainage lines, as along Judith River.

The drainage belongs to the Missouri River system, and the streams enter that river either directly or indirectly by way of Musselshell River. The principal streams tributary to Musselshell River are Willow, Flat Willow, McDonald, and Boxelder creeks. These streams rise in the Big Snowy and Judith mountains and flow eastward across the plains to the Musselshell, which enters the Missouri a few miles east of the eastern boundary of the area represented on Plate XIX (p. 336). The northwestern part of the area is drained by Judith River and Dog Creek, which rise in the mountains and flow northward to Missouri River.

GEOLOGY.

STRATIGRAPHY.

Rocks ranging in age from Carboniferous to Tertiary are exposed in the area lying between the crests of the Big Snowy and Judith mountains on the west and Musselshell River on the east. As no detailed study was made of any formations except those of the Montana group, this discussion is confined primarily to these rocks and only brief mention is made of the immediately subjacent and superjacent formations. The formations of the Montana group and their stratigraphic relation in north-central Montana were described by Stanton and Hatcher[1] in 1905. Their grouping of the formations is followed in this paper. Dr. Peale,[2] in a paper on the stratigraphic position and age of the Judith River formation, dissents, however, from Stanton and Hatcher's conclusions. The succession, thickness, and character of these formations as determined by the writer in this field are presented in the following table:

[1] Stanton, T. W., and Hatcher, J. B., op. cit.

[2] Peale, A. C., The stratigraphic position and age of the Judith River formation: Jour. Geology, vol. 20, pp. 530-549, 640-652, 738-757, 1912.

Generalized section of the sedimentary rocks discussed in this report.

System.	Group.	Formation.	Thickness.	Characteristics.
Tertiary (?).		Lance formation.	*Feet.* 700-800	Alternating gray sandstone and clay shale, with thin beds of coal near the top.[a]
Cretaceous.	Montana.	Bearpaw shale.	1,100±	Marine shale, dark gray to black in upper part but with greenish tinge in lower part in southern portion of the field. The shale contains numerous calcareous concretions which yield *Baculites ovatus, Baculites compressus, Scaphites nodosus, Inoceramus barabini*, and other forms characteristic of the Pierre shale.
		Judith River formation.	250-500	Alternating beds of sandstone, clay, and shale including carbonaceous members, mainly of brackish or fresh water origin. In the northern part of the area a more or less persistent coal bed occurs near the top of the formation and is in most places overlain by a bed of marl or breccia, containing *Ostrea subtrigonalis* in great numbers. The formation also contains bones of vertebrates, fragments of leaves and stems, and much silicified wood.
		Claggett formation.	200±	Alternating sandstone and shale, becoming chiefly sandstone at top. Marine fossils occur in these sandstones along Missouri and Judith rivers but have not yet been found in the southern part of the area. The common forms are *Tancredia americana, Cardium speciosum, Mactra formosa, Mactra alta*, and other species formerly considered characteristic of the Fox Hills sandstone.
			500±	Marine shale which is not easily distinguished either lithologically or paleontologically from the Bearpaw shale. The most common fossils are *Baculites ovatus, Baculites compressus, Gervillia borealis, Inoceramus barabini*, and *Leda evansi*.
		Eagle sandstone.	200-300	In the northern part of the field the Eagle consists of an upper division of gray thin-bedded sandstone with some shaly members, a middle division of dark-colored shale containing thin beds of carbonaceous shale and coal, and a lower division, about 120 feet thick, of white to buff massive to heavy-bedded sandstone. In the southern part of the field the carbonaceous shale is replaced by thin-bedded shaly sandstone and the basal sandstone is dirty gray to brownish in color. Fossils are rare, but a few marine invertebrates have been found.
	Colorado shale.		(b)	In its upper part the Colorado is a black marine shale with alternating thin beds of sandy shale and sandstone. At one locality examined a calcareous fossiliferous sandstone occurs in the upper part of the formation. Baculites sp., *Dosinia orbiculata, Gyrodes conradi, Inoceramus deformis, Inoceramus labiatus, Scaphites ventricosus*, and other forms were collected from this formation.

[a] Lupton, C. T., loc. cit. [b] Not measured.

The width of outcrop and the surface distribution of the formations which are controlled by structure and erosion are shown on the map (Pl. XIX). Where the structure is monoclinal and the dips steep, as along the north side of the field east of Black Butte, the width of outcrop of the entire Montana group may be less than 1 mile. In such places the Eagle sandstone and Judith River formation, because of their greater resistance to erosion, form hogback ridges whose crests are marked by sandstone ledges, whereas the soft shales of the Claggett and Bearpaw formations occupy valleys. In proportion as the dip decreases the width of outcrop of the formations increases, and where the slope of the surface accords with the dip the width of outcrop of a given formation may be many miles across. These conditions are illustrated by the width of outcrop of the Judith River formation northwest of Roy. In such places the Judith River strata are commonly eroded into badland forms so that the formation is well exposed and easily traced. In some places, as at Hilger, the formations occupy synclinal depressions between mountain uplifts; this structure gives rise to a wide outcrop of the formation occupying the central part of the synclinal depression, though the dips near the mountains may be comparatively steep.

For the most part the formations are well exposed throughout the field. Because of this condition they can be followed almost continuously and there is no difficulty in correlating outcrops. The chief exceptions to the above statements occur at the crossing of stream valleys and along the base of the Judith and North Moccasin mountains. Near these mountains the formations are more or less obscured by bench gravels, so that the outcrops may be separated by considerable distances, and there is in places considerable discordance in dip and strike between two successive exposures. These conditions render the exact position of the beds beneath the covered area more or less uncertain, but there is commonly little doubt as to the formation to which an outcrop belongs.

STRUCTURE.

The dominant structure in the eastern part of the area is a broad symmetrical anticline on which are superimposed several smaller folds, thus producing the type of fold known as an anticlinorium. The axis of the major fold trends northwest and pitches to the southeast. In the southeastern part of the field the strata dip away from the axis of the anticline at angles ranging from 20° to 70°, the steeper dips occurring nearest the axis of the fold, but as the mountains are approached the dips decrease in amount, and around the north base of the Judith and North Moccasin mountains they do not exceed 45° and the anticline loses its distinctive character.

The minor folds which complicate the major anticline are also open symmetrical folds whose axes pitch to the southeast and trend roughly northwest-southeast, although they are somewhat sinuous in character. The dips on opposite limbs of these folds as a rule range from 2° to 6°.

A dome structure has been produced by the uplift of Black Butte and the North Moccasin Mountains. So far as examined the beds dip steeply away from these uplifts except at the southeast side of Black Butte, where the strata dip steeply toward the butte, probably as the result of faulting.

Out on the plains north of the Judith and North Moccasin mountains the strata dip at a low angle to the north or northeast.

Faults are not important structural features except in the area along Judith River north of the northern boundary of T. 20 N. Two minor faults cut the beds on the north side of the Judith Mountains, and, as already pointed out, there may be a small fault at the southeast side of Black Butte. Between Fullerton and Missouri River three prominent faults, striking a little west of north, cross the valley of Judith River. At the first and second faults north of Fullerton the beds dip steeply to the north near the fault plane, but a short distance away they are nearly flat. At the fault nearest Missouri River the dip is to the south, or in the opposite direction to that at the faults farther south, and there is evidence of some minor faults, the details of which were not worked out. The northernmost fault exhibits the maximum throw observed at any of these displacements, and at that place the white massive sandstone at the base of the Eagle sandstone is brought into contact with the sandstone beds constituting the upper part of the Claggett formation. If the thickness of that part of the Eagle above the white massive sandstone be considered as 150 feet and that of the lower or shale portion of the Claggett as 500 feet, the throw would be about 650 feet.

These same lines of disturbance were seen on the east side of Dog Creek in T. 21 N., R. 19 E., where the structure seems more complicated than on Judith River. The maximum disturbance, however, is probably shown along Missouri River between Armells Creek and Dog Creek. In speaking of this area Hayden says:[1]

> It presents perhaps the most rugged scenery on the Missouri River, the denudation and erosion having been much greater than at the Bad Lands of White River. But the most remarkable feature of this basin is the wonderful disturbance of the strata. So much are the beds disturbed and blended together by forces acting from beneath that it seems almost hopeless to obtain a section showing with perfect accuracy the order of superposition of the different strata.

THE COAL.

In the northwest part of the field the Eagle sandstone and the Judith River formation contain some coal which is locally valuable, but no important coal beds occur southeast of Black Butte. For convenience of description, the coal beds of the Eagle and Judith River formations will be described separately.

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[1] Hayden, F. V., Notes explanatory of a map and section illustrating the geological structure of the country bordering on the Missouri River from the mouth of the Platte River to Fort Benton: Philadelphia Acad. Nat. Sci. Proc., vol. 9, pp. 115–116, 1858.

COAL IN THE EAGLE SANDSTONE.

The easternmost indications of coal in the Eagle sandstone were found near the northern side of sec. 12, T. 17 N., R. 23 E. At this place there is a bed of carbonaceous shale about 1 foot thick. Near the northwest corner of the same township a bed that is probably the same is about 2 feet thick and contains 3 inches of coal at the top and 6 inches at the bottom, with carbonaceous sandstone and shale between. On the southeast side of Black Butte, at locality 1,[1] a bed of coal 2 feet thick is exposed. It seems to be of local occurrence, as no other exposures could be found in this vicinity.

In the NE. ¼ sec. 8, T. 18 N., R. 18 E., a carbonaceous bed containing about 4 inches of bony lignite at the top is exposed at an old surface pit. Coal is also reported as being mined from the Eagle sandstone near Deerfield, but this locality was not visited.

Between Fullerton and Judith the Eagle sandstone is exposed by faulting at several places, and at each place it contains some coal of subbituminous quality. At locality 5 there is 13 inches of good coal, and at locality 2 (see section in Pl. XIX) the coal is 26 inches thick. At locality 3, sec. 13, T. 22 N., R. 16 E., there is 4 feet 7 inches of coal in two benches, separated by 1 foot 3 inches of bone and clay, as shown in section No. 3 (Pl. XIX). At locality 4, sec. 11, in the same township, 36 inches of coal is exposed. Some coal was also observed in exposures of the Eagle sandstone on Dog Creek near the northwest corner of T. 22 N., R. 17 E.

From the sections given above it seems probable that the Eagle sandstone may contain coal of commercial value in the northern part of the field. As the formation is exposed only in the vicinity of faults, a careful survey on a scale large enough to show all the details of structure is necessary before the probable extent of the coal can be determined.

COAL IN THE JUDITH RIVER FORMATION.

The Judith River formation contains beds of carbonaceous shale throughout the field, but no coal was found south of the southern boundary of T. 19 N.; north of that township line some coal occurs in the Judith River formation, but its full extent is not known. The region in which the Judith River is believed to be coal bearing is the triangular area between Armells and Dog creeks and Missouri River. Coal beds occur near the top of the formation and are said to have a maximum thickness of 7 feet, but in the area described in this report the beds are thin, ranging for the most part from a few inches up to 30 inches in thickness. Sections Nos. 6 to 16 (Pl. XIX) were measured on coal beds in the Judith River formation.

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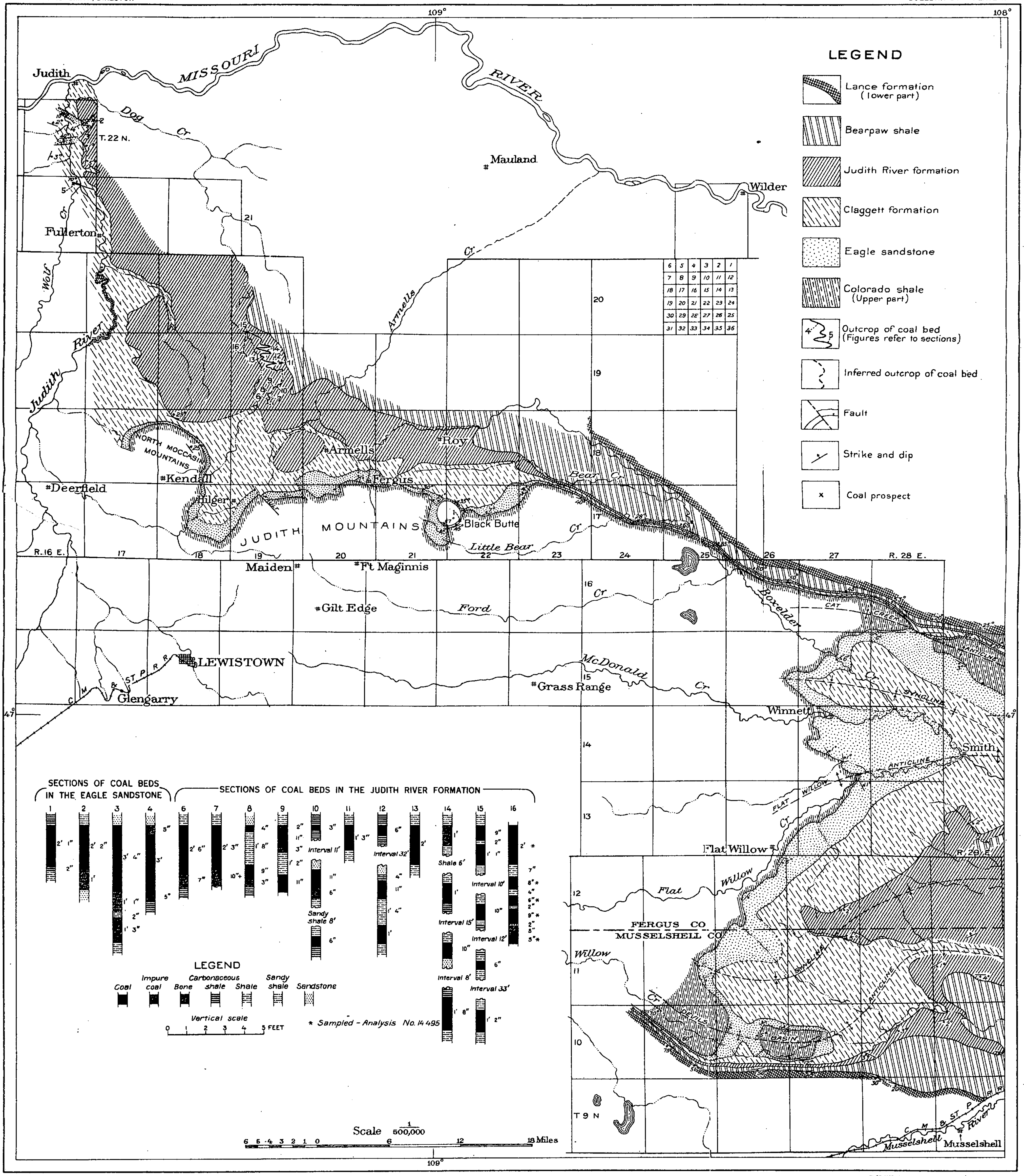
[1] These numbers refer to the locations and the coal sections shown in Pl. XIX.

In T. 19 N., R. 19 E., where a detailed search for coal was made, a zone of clay and carbonaceous shale is exposed containing one or more thin beds of coal, one of which locally attains a thickness of 4 feet. Immediately above these coal beds lies a thick indurated stratum made up almost wholly of invertebrate shells inclosed in a sandy matrix, which serves as an excellent marker in tracing the coal. This *Ostrea subtrigonalis* marl or breccia, as it is commonly called from its abundant content of the shells of that species, was regarded by Stanton and Hatcher as the top of the Judith River formation. The outcrop of the principal coal bed across the township is shown on the map (Pl. XIX), and sections Nos. 6 to 16 on the same plate represent the thickness and character of the beds at the localities indicated. These sections show that the principal bed commonly ranges from 1 foot to 2½ feet in thickness, but that at locality 16 the total thickness is 6 feet. At this locality, however, the bed contains four partings in its lower portion, leaving but 2 feet of unbroken coal at the top of the section. At this place there is a short entry on the bed and a small amount of coal is mined for local use, chiefly as fuel for traction engines. The property is owned and operated by Mr. Stone and is therefore called the Stone prospect.

At the Stone prospect the coal shows the following physical properties: Color black, streak black to brown, fracture conchoidal, a tendency to prismatic jointing, a bedded structure, and a lack of prominent woody characteristics. When exposed to the atmosphere the coal slacks readily and breaks up into small irregular fragments.

A sample of the coal was taken from the face of the entry and sent to the Pittsburgh laboratory of the Bureau of Mines for analysis. In collecting the sample the face of the bed was first freed from all foreign matter and the bed was then trenched across from top to bottom, but the shale partings and bone were excluded from the sample. A section of the bed at the point of sampling is represented by section No. 16 in Plate XIX. The total thickness of the bed at that place is 6 feet, but the sample, which included only the coal, represents a thickness of 4 feet 4 inches. The bed is dry and the face from which the sample was taken was fresh. The results of the analysis are as follows:



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF AREA EXAMINED BETWEEN MUSSELSHELL AND JUDITH, MONTANA

By C. F. Bowen

Analysis of coal from the Stone prospect, sec. 7, T. 19 N., R. 19 E.

[Made at the Pittsburgh laboratory of the Bureau of Mines, A. C. Fieldner, chemist in charge. Laboratory No. 14495. Air-drying loss, 11.1 per cent.]

	As received.	Air dried.	Moisture free.	Moisture and ash free.
Moisture	23.1	13.5		
Volatile matter [a]	33.5	37.7	43.5	52.2
Fixed carbon	30.6	34.4	39.8	47.8
Ash	12.8	14.4	16.7	
Sulphur	1.08	1.22	1.4	1.68
Calories	4,305	4,845	5,600	6,720
British thermal units	7,750	8,720	10,080	12,090

[a] Determined by the modified method, the use of which generally results in a higher percentage of fixed carbon than when determined by the official method.

This analysis shows that the coal is high in moisture and ash and low in calorific value. From its physical and chemical properties, and the fact that it slacks readily when exposed to the atmosphere, the coal is regarded as low-grade subbituminous, which is distinguished from lignite chiefly by its black color.

The coal in the Eagle sandstone may prove to be of importance in localities near Missouri River, where, because of the lack of timber and the distance from the railroad, conditions may favor its development for local use.

The coal in the Judith River formation in this area is not of sufficient importance to justify development on a large scale. Farther north, however, on lower Dog Creek and Missouri River, the beds attain a greater thickness and will no doubt prove valuable, for local consumption at least, in a country where timber and other forms of fuel are practically absent.

THE CLEVELAND COAL FIELD, BLAINE COUNTY, MONTANA.

By C. F. Bowen.

INTRODUCTION.

The writer made an examination in the fall of 1912 of land lying east of the Bearpaw Mountains, Montana, for the purpose of determining whether or not coal is present here, and if so the character of the coal and the thickness of the beds. Only a small area was found to be underlain by coal and the beds are thin and apparently lenticular in character. The coal has little prospective importance except for settlers in the immediate vicinity.

This area, called the Cleveland coal field from the chief town within its borders, comprises an area of about 423 square miles included in Tps. 28 to 31 N., Rs. 20 to 22 E. (in part), and T. 28 N., R. 19 E. of the Montana principal meridian. The northern end of the district is about 6 miles south of Milk River, and the area lies for the most part between the Fort Belknap Indian Reservation on the east and the Bearpaw Mountains on the west. Its relation to other well-known places in Montana is shown in figure 9 (p. 294).

The geologic mapping was done by the writer assisted by Harvey Bassler. The writer wishes to acknowledge the hospitality and hearty cooperation of the residents of the district.

As land classification, which is based on land surveys, was the prime object of the investigation, the Land Office plats were made the bases for geologic mapping. All locations were made with reference to corners established by the land survey. The mapping was done on a plane table, on a scale of 2 inches to the mile. Telescopic alidade and stadia were used in mapping coal beds and open-sight alidade and pacing in meandering geologic boundaries.

The igneous rocks of the Bearpaw Mountains have been briefly described by Weed and Pirsson,[1] and the glacial geology of the region has been discussed by Calhoun.[2] In 1908 and 1909 L. J. Pepperberg[3]

[1] Weed, W. H., and Pirsson, L. V., The Bearpaw Mountains, Mont.: Am. Jour. Sci., 4th ser., vol. 1, pp. 283-301, 351-362, 1896; vol. 2, pp. 136-148, 188-189, 1896.

[2] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.

[3] Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, pp. 82-108, 1910; The southern extension of the Milk River coal field, Chouteau County, Mont.: U. S. Geol. Survey Bull. 471, p. 359, 1912.

studied the coal resources of the Milk River field, which adjoins the Cleveland field on the north and exhibits conditions similar to those reported here.

EXPLANATION OF MAP.

The geologic map accompanying this report (Pl. XX, p. 350) was compiled from the plane-table sheets prepared during the field examination and from the General Land Office plats. It shows the distribution and attitude of the geologic formations as interpreted from a study of their widely separated exposures, the outcrops of the principal coal beds, the locations of points at which coal sections were measured, and also the principal roads and streams of the district. In interpreting the geologic map it must be remembered that the greater part of the area is covered by glacial drift, which obscures the outcrops of the rock formations. For this reason the positions of the geologic boundaries are in part hypothetical. The formation boundaries are indicated by broken lines where there is more or less certainty regarding their location and are omitted entirely where their location is largely hypothetical.

GEOGRAPHY.

All parts of the field except the mountain area are readily accessible by wagon roads from the town of Chinook, on the north side of Milk River on the Great Northern Railway.

As the area lies in the western part of the Great Plains province, its surface partakes more or less of the character of a plain, but in this part of the State the surface is broken by several isolated mountain ranges, one of which, the Bearpaw Mountains, lies partly in this area and extends westward for a distance of about 40 miles. In the field three rather distinct types of topography are represented. These are: (1) The mountainous type; (2) the foothills type, lying between the mountains and the lowlands; and (3) the plains type, which varies from a gently rolling, grass-grown, drift-covered plain, still undissected and containing numerous undrained depressions, to a somewhat well dissected and drained surface in which numerous steep, narrow gorges, locally termed coulees, have been eroded. In the northeastern part of the field this topography approaches the badland type, which is typically developed immediately south of the district along Missouri River and its tributaries.

The area is drained by tributaries of Milk and Missouri rivers. The principal streams are Snake, Boxelder, and Peoples creeks on the north and Suction Creek on the south. These streams rise in the Bearpaw Mountains and, with the exception of Boxelder Creek, are perennial within the area surveyed, though some of them may become intermittent farther out on the plains

GEOLOGY.

STRATIGRAPHY.

CHARACTER OF THE ROCKS.

The sedimentary rocks represented in this field range in age from Mississippian to Recent, the latter consisting of the alluvial deposits along stream valleys. Because the coal resources were the primary object of the examination, the field study was confined to the coal-bearing formations, and these are here discussed in more detail than are the other formations present. The table given below shows the stratigraphic succession, character, and thickness of the formations of the district.

Generalized section of the sedimentary formations of the Cleveland coal field.

System.	Series.	Group and formation.		Character.
Quaternary.	Recent.	Alluvium.		Deposits found along the streams; of small extent in this area.
		Bench gravel.		A mixture of gravel and finer material derived from the near-by mountains. The pebbles are mostly igneous rock and are not well rounded or waterworn.
	Pleistocene.	Glacial drift.		Ground and terminal moraines containing numerous bowlders of granite, gneiss, and some quartzite not found in place in this part of the State.
Cretaceous.	Upper Cretaceous.	Montana group.	Bearpaw shale.	Dark-colored marine shale, containing calcareous concretions in which are found *Baculites ovatus*, *B. compressus*, *Scaphites nodosus*, and other Pierre forms; thickness exposed in this field 200± feet.
			Judith River formation.	Brown to light-yellow sandstone alternating with ash-colored clay yielding fresh and brackish water invertebrates and also remains of vertebrates; contains some coal. Thickness 500± feet.
			Claggett formation.	Like the Bearpaw both lithologically and paleontologically. Thickness 350-500 feet.
			Eagle sandstone.	Massive and cross-bedded yellow to brown sandstone, in places containing many large brown concretions; when well exposed forms prominent ledges; in few places contains fossils. Thickness 250-300 feet.
		Colorado shale.		Dark marine shale with intercalated sandy beds in upper part; numerous large calcareous concretions in places near top of formation; yields some invertebrate fossils and locally an abundance of fish scales.
	Lower Cretaceous (?).	Kootenai (?) formation.		Alternating beds of shale and sandstone underlying the Colorado shale and overlying rocks known to be of Jurassic age; no fossils found.
Jurassic.	Upper Jurassic.	Ellis formation.		Dark-gray fine-grained limestone, richly fossiliferous.
Carboniferous.	Mississippian.	Madison (?) limestone.		Gray crystalline limestone, containing numerous fossils; not certainly found in place.

CARBONIFEROUS SYSTEM.

MADISON (?) LIMESTONE.

Stratigraphically the lowest formation exposed in the field is a gray crystalline limestone, which is very different lithologically from any other rocks in the region and which outcrops at the extreme eastern end of the Bearpaw Mountains. Fossils collected from this limestone in secs. 1 and 12, T. 28 N., R. 20 E., have been identified by George H. Girty as Carboniferous forms and tentatively referred by him to the Madison limestone. The specimens obtained from sec. 12 were found in loose fragments along one of the branches of Suction Creek and had evidently been brought down from some higher elevation. The fossils from sec. 1 were obtained at the top of one of the mountain ridges in connection with a collection from the Ellis formation. At the time of making the collection it was not recognized that two formations were involved and the collector is not now sure whether or not all of the specimens were obtained from rock in place. Whether the fossils were actually found in place or not, they demonstrate the existence of Carboniferous rocks in the region, as the Bearpaw Mountains were not overridden by the continental ice sheet, and therefore the fossils could not have been brought to their present position from some extraneous locality except by the agency of man, a contingency which does not seem probable.

Previous to the discovery of these fossils sedimentary rocks older than the Colorado shale had not been recognized in the Bearpaw Mountains, and despite the slight uncertainty as to location and exact age which attaches to them the find is an important one. It may be confidently stated that careful stratigraphic work in the older formations involved in the Bearpaw uplift will differentiate the rocks of Carboniferous age, but at present nothing can be said of their distribution or thickness.

JURASSIC SYSTEM.

ELLIS FORMATION.

The Ellis formation is best exposed on a tributary of Suction Creek, sec. 1, T. 28 N., R. 20 E., 2 or 3 miles above Henry Martin's ranch in sec. 7. At this place there is 200 feet of dark-gray to lead-gray, fine-grained, richly fossiliferous limestone, which is overlain by an apparently conformable succession of alternating beds of calcareous sandstone, sandy shale, and shale having a thickness (if not repeated by faulting) of about 1,300 feet. Fossils were obtained from the limestone and one of the lower beds of calcareous sandstone and submitted to Mr. Stanton, who refers the beds to the Ellis formation. The 1,300 feet of sandstone and shale overlying the fossiliferous limestone are here provisionally referred to the Kootenai, although future work may show them to belong to the Ellis formation. On the west in this locality the Ellis formation is cut off by a sharp fault along which it abuts against younger rocks. How widespread the Ellis formation may be in the Bearpaw Mountains has not been determined, but rocks of similar character were seen at several localities in the eastern end of the range.

CRETACEOUS (?) SYSTEM.

KOOTENAI (?) FORMATION.

The only direct evidence of the presence of the Kootenai, or some other formation occupying the same stratigraphic position, is the existence of a great thickness of dark-gray shales and gray sandstone lying between the undoubted Ellis formation and the Colorado shale. No fossils have been obtained from these beds, so that it is impossible to correlate them on a paleontologic basis. Lithologically the rocks are not similar to the red or maroon-colored members so characteristic of the upper part of the Kootenai in the Lewistown and Great Falls fields, so that if these beds do represent the Kootenai or a part of it they probably correspond to the lower unvariegated portion, although the thickness shown here seems to be much greater than that assigned to the Kootenai by Fisher[1] and Calvert[2] in the fields farther south. Like the Ellis formation, the distribution of these rocks, whatever their age, is undetermined; they were observed at the same localities as the Ellis, which they overlie with apparent conformity.

CRETACEOUS SYSTEM.

COLORADO SHALE.

Above the Kootenai (?) formation lies the Colorado shale, the oldest formation in the field positively identified as Cretaceous. This formation is so well developed on the flanks and in the foothills of the Bearpaw Mountains that the term Bearpaw, if it were not preoccupied, would be an appropriate designation. The term Colorado shale is applied to what in other States is known as the Colorado group, embracing the Benton shale and Niobrara limestone.

The formation is more or less fossiliferous. In some localities a sandstone member 400 feet below the top of the formation contains an abundance of fish scales and some invertebrates. Fossils collected from it have been identified as of Colorado age by Mr. T. W. Stanton.

The Colorado shale is a black to lead-gray clay shale, containing in its upper part, at least locally, many large calcareous concretions. These concretions weather yellowish brown and carry numerous veins of calcite, which give a septarian-like character to the entire mass.

[1] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, p. 30, 1909.
[2] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, p. 27. 1909.

This part of the formation resembles very closely the shales of the Claggett formation. Below the concretionary member the formation contains numerous thin sandstone bands alternating with the black shale. Some of these sandstone members are fossiliferous, the most abundant remains being fish scales.

The thickness of the entire formation was not determined. A thickness of about 525 feet is exposed around Eagle Butte, in sec. 6, T. 29 N., R. 21 E., but it is probable that only a part of the formation is exposed. Near Henry Martin's ranch, in sec. 7, T. 28 N., R. 21 E., a thickness of more than 1,400 feet of black shale overlies the rocks described above as the Kootenai (?) formation. Whether this is the true stratigraphic thickness of the Colorado or whether the formation is repeated by faulting is not known.

The Colorado shale is extensively developed around the east end of the Bearpaw Mountains, and is by far the most widespread of the pre-Montana rocks. Perhaps the type locality for the formation in this field is the undifferentiated area lying south and southeast of Cleveland.

The Colorado shale exhibits apparently conformable relations both at top and bottom. It is sharply delimited from the overlying Eagle sandstone by the striking lithologic difference between the two formations. The change to the underlying formation is not well shown in the localities where the two were studied, but it seems to be less abrupt lithologically than is the change to the overlying formation.

EAGLE SANDSTONE.

Above the Colorado shale in apparent conformity lies the Eagle sandstone, so named by Weed[1] from its development at the mouth of Eagle Creek on Missouri River, about 40 miles below Fort Benton. This sandstone, according to Stanton and Hatcher,[2] represents the lower part of the Montana group. All the fossils collected from it by the writer have been reported by Stanton to be of Montana age.

In this field the formation consists of buff to gray, massive to heavy-bedded sandstone, which is locally cross-bedded and becomes more thinly bedded toward the top. Large reddish-brown sandstone concretions are locally very numerous and form conspicuous bowlders which strew the surface of the weathered outcrop. Where not covered by drift the sandstone forms prominent ledges, which constitute a striking topographic feature.

Few places in this area afford favorable opportunities for measuring the thickness of the formation, but in the NE. ¼ sec. 18, T. 29 N., R. 21 E., both upper and lower boundaries are well shown in a clean-cut exposure; the thickness at this locality is 310 feet.

[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (No. 55), 1899.

[2] Stanton, T. W., and Hatcher, J. B., The geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, pp. 63, 66, 1905.

The Eagle is well exposed only locally in this district. As a rule the outcrop is concealed beneath drift or gravels or is interrupted by igneous intrusions, so that the actual surface distribution of the formation is difficult to determine. In a general way it occupies a narrow zone encircling the Bearpaw Mountains in the region where the foothills merge into the plains.

The Eagle is the lowest formation of the Montana group and is conformable with both subjacent and superjacent formations. It forms a striking lithologic contrast to them, however, and is easily distinguishable in the field.

CLAGGETT FORMATION.

Above the Eagle sandstone lies a formation consisting chiefly of dark marine shale which Stanton and Hatcher [1] designated the Claggett formation and correlated with the lower part of the Pierre shale. This formation contains *Baculites ovatus, Baculites compressus, Inoceramus barabini, Gervillia borealis,* and other forms characteristic of the Pierre shale.

The Claggett in this area consists of dark lead-gray shale, containing numerous calcareous concretions which range up to several feet in diameter. The concretions are usually seamed with veins of calcite and as a rule contain invertebrate fossils. At the base of the formation there is a zone of sandy shale transitional to the Eagle sandstone below, and at the top there is a similar narrow transition zone. Crystals of gypsum are locally abundant in the Claggett and are conspicuous on many weathered outcrops. The shale weathers to a black gumbo soil that becomes very tenacious when wet. The formation is not well exposed in the field and no opportunity was afforded for determining accurately its thickness. Farther south, along Missouri River, it is about 500 feet thick, whereas to the north, on Milk River, Pepperberg determined it to be 350 feet thick.

Except locally, the Claggett is even less well exposed than the Eagle and its surface distribution is correspondingly more uncertain. On the accompanying map (Pl. XX, p. 350) the inferred distribution of the formation is shown, but this is of course largely hypothetical.

The Claggett overlies the Eagle sandstone conformably, and by reason of its shaly character, its dark color, and the presence of limestone concretions presents a sharp lithologic contrast to the latter. The exact line of demarcation between these formations, however, and also between the Claggett and the overlying Judith River is in some places difficult to determine, owing to the sandy transition zones mentioned above.

[1] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds, with a chapter on the fossil plants by F. H. Knowlton: Bull. U. S. Geol. Survey 257, pp. 13, 66, 1905.

JUDITH RIVER FORMATION.

The Judith River formation, which overlies the marine Claggett, is for the most part of fresh or brackish water origin. This formation was first named by Hayden,[1] although its stratigraphic relation was at that time not understood. Stanton and Hatcher in their work on the Judith River formation[2] determined it to be a subdivision of the Montana group, and the stratigraphic equivalent of a part of the Pierre shale. This conclusion was borne out by the work of the writer in this area.

The Judith River formation comprises a series of fresh and brackish water beds, consisting of light-colored alternating sandstone and clay with some coal, the most persistent and important beds of which occur near the top of the formation. The sandstones are in places cross-bedded and ripple marked and contain ferruginous and sandy calcareous concretions, many of which are seamed with veins of amber-colored calcite and bear a general resemblance to the concretions found in the Claggett. Crystals of selenite occur to some extent in the darker-colored clay of the formation. Near the top of the formation occurs a rather persistent bed of marl composed almost entirely of shells of *Ostrea subtrigonalis*. The thickness and character of individual beds vary considerably within short horizontal distances, sandstone changing to clay, and coal to carbonaceous shale, and vice versa. It is therefore impossible to select any key rocks which can be used to correlate sections measured at separate localities. The best reference stratum is the Ostrea-bearing marl or breccia bed near the top of the formation. The following detailed sections measured at various localities serve to show the character and variability of the beds:

Section of Judith River formation one-half mile north of Kerr mine on Sixmile Coulee, sec. 30, T. 32 N., R. 20 E.

	Ft.	in.
Concretionary band		6
Clay shale	10	
Shale, brown, carbonaceous	2	
Shale, gray, sandy	1	6
Concretionary band		4
Shale, sandy	1	6
Shale, brown, carbonaceous	2	
Coal, bony, and bone	1	
Coal, good	2	
Shale, carbonaceous	2	
Shale, gray, sandy	5	
Shale, carbonaceous	1	

[1] Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey of Wyoming and portions of contiguous Territories; Preliminary (second) Rept. Progress, p. 97, 1872.

[2] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds, with a chapter on fossil plants by F. H. Knowlton: Bull. U. S. Geol. Survey 257, p. 63, 1905.

	Ft.	in.
Shale, somewhat sandy	2	
Sand, gray, with 6-inch concretionary band	4	
Clay shale, gray	10	
Shale, brown, carbonaceous		5
Coal, bony		7
Shale, carbonaceous	1	2
Clay shale, drab	5	6
Ironstone, concretionary band		3
Shale, gray	3	
Coal		5
Bone		9
Shale, carbonaceous		5
Coal		11
Bone		2
Coal		2
Bone		4
Shale, carbonaceous		11
Clay, dark gray	1	8
Clay, carbonaceous		8
Sandstone, gray		5
Clay with iron concretions	1	
Clay, gray, sandy	3	
Bone and bony coal		6
Shale, carbonaceous	2	8
Coal, bony		9
Bone		2
Clay	1	6
Shale, carbonaceous		5
Coal		9
Coal, bony		4
Coal		6
Bone and carbonaceous shale		10
Shale	2	
Sand, argillaceous	2	
Concealed, probably sand	4	
Sand and sandstone	2	
Concealed by alluvium	10	
Concretionary layer	1	
	96	

Section of Judith River formation at Rattlesnake Butte, sec. 12, T. 28 N., R. 21 E.

	Ft.	in.
Sandstone, cross-bedded	2	
Clay shale with sandy layers	18	
Sandstone, yellow, massive, cross-bedded, with small ferruginous concretions at base	15	
Clay, in part arenaceous	43	
Sandstone, massive, cross-bedded	8	
Clay, sandy	20	
Sandstone, shaly	7	
Sandstone, yellow, cross-bedded	5	
Sandstone, yellow, massive	15	
Sandstone, thin bedded, and shale	8	

	Ft.	in.
Shale	8	
Sandstone, yellow, cross-bedded, weathers cavernous	15	
Clay, sandy	8	
Sandstone, massive, cross-bedded	2	
Clay	2	
Sandstone, massive	2	
Shale, sandy	2	
Shale, carbonaceous at bottom, grading upward into clay	6	
Sandstone, white, bedded, beds usually less than 1 foot thick, weathers to rough, irregular forms	18	
Sandstone, white to cream colored, massive to heavy-bedded	15	
Sandstone, yellow, massive, with concretionary layers	16	
Sandstone, platy, and clay (partly concealed)	32	
Sandstone, yellow, massive	9	
Sandstone, gray, hard		6
Clay	2	
	278	6

Section of Judith River formation near south quarter corner sec. 31, T. 28 N., R. 22 E.

	Feet.
Drift.	
Clay shale, dark, gypsiferous, containing narrow band of *Ostrea subtrigonalis* at base	50
Clay, sandy	5
Shale, brown, carbonaceous	4
Clay shale, drab	10
Sand, unconsolidated	15
Shale, carbonaceous	1
Sand	5 (?)
Clay, drab, contains ferruginous concretions and *Ostrea subtrigonalis*, grades into sandy clay below	40
Sandstone, white, with ferruginous members and concretions forming ledges, exposed	60
	190

A complete section of the formation is not exposed at any locality in this district and the total thickness could not be determined. On Missouri and Milk rivers, where the exposures are better, the formation is about 500 feet thick.

The surface distribution of the Judith River formation is probably greater than that of all the other sedimentary rocks in the field combined. This is due to its flat-lying attitude and to the fact that erosion has removed the overlying Bearpaw shale from most of the area but has not yet cut through the Judith River to the underlying formations. Over much of the area these beds are covered by glacial drift and the boundaries of the formation as shown on the map (Pl. XX, p. 350) are more or less hypothetical.

The Judith River formation is conformable with both the underlying and overlying formations. The beds grade into the underlying Claggett through a narrow transition zone at the top of that formation, but are more or less sharply separated lithologically from the dark marine shale of the overlying Bearpaw.

BEARPAW SHALE.

The Bearpaw shale was so named by Stanton and Hatcher[1] from the supposed extent of its outcrop around the Bearpaw Mountains. The Bearpaw shale, in common with the Claggett formation, contains a fauna which elsewhere is regarded as typical of the Pierre. The Bearpaw is therefore the equivalent of the upper part of the Pierre and in areas to the southeast is directly overlain by the Lance formation.

The Bearpaw is a lead-colored marine shale, bearing calcareous concretions which yield most of the fossils so far found. In both lithologic and paleontologic character the Bearpaw is so similar to the Claggett that the two can not be definitely distinguished except by their stratigraphic relations. As only a part of the formation is exposed in this field, its thickness was not determined, but in other localities it is known to be 1,000 to 1,100 feet.

Exposures of this formation are confined to a small area in the northwest corner of T. 30 N., R. 22 E., and to the contiguous portions of adjoining townships, but because of the heavy covering of drift over the greater part of the field exposures are poor and it may be that the Bearpaw occurs beneath the drift at other localities.

The Bearpaw conformably overlies the Judith River formation, from which it is distinguished by its lithologic character, its color, and the marine fossils which it contains.

QUATERNARY SYSTEM.

Glacial drift.—Most of the plains area is covered with glacial deposits, which, except where locally removed along drainage lines, obscure all of the older rocks. These deposits consist of an unassorted mixture of bowlders and finer material. The most common bowlders are of granite, gneiss, and quartzite, which have been transported from localities far to the north in Canada, where similar rocks are found in place. The deposits are terminal and ground moraines. The best example of the terminal moraine is the ridge north of Peoples Creek.

Bench gravel.—Near the Bearpaw Mountains areas which are not drift covered are as a rule overspread by bench gravel derived chiefly from the igneous rocks of the near-by mountains. In general, this bench gravel obscures the outcrops of the older formations almost as completely as does the drift.

[1] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds, with a chapter on the fossil plants by F. H. Knowlton: U. S. Geol. Survey Bull. 257, p. 62, 1905.

Alluvium.—Alluvial deposits are of minor importance. They occur in narrow belts along the most important streams, especially Suction, Peoples, and Snake creeks.

IGNEOUS ROCKS.

The Bearpaw Mountains consist of igneous rocks of intrusive and extrusive origin and of both acidic and basic character. Dikes and sills of these rocks, radiating from the main mountain mass, outcrop in places at a considerable distance from the mountains. These dikes and sills have had little effect on the inclosing strata, which as a rule are but slightly metamorphosed and have suffered no displacement by the intrusion.

STRUCTURE.

On all sides of the Bearpaw Mountains the strata dip steeply away from the central igneous mass. A short distance away from the mountains, however, the dips are much lower and out on the plain the rocks lie nearly flat. Because of the general covering of glacial drift and alluvium, however, continuous exposures of the underlying formations are lacking and the structure is extremely obscure and difficult to interpret. Except locally, where the drift cover is very thin, exposures of sedimentary rocks are confined to coulees, in which the glacial material has been removed. These exposures show that the original attitude of the rocks has been locally very much disturbed by faulting, but because the stratified rocks are covered by drift the faults are commonly not exposed at the surface. The evidence, moreover, is in general limited merely to a marked change in the dip or strike of the formation at two near-by localities. The locations of a few of the most obvious faults are shown on the map. Suggestions of other fault lines are numerous and it is probable that still others are entirely obscured by the surface covering.

THE COAL.

OCCURRENCE AND DISTRIBUTION.

Coal beds occur in this district only in the upper part of the Judith River formation, none having been found in the Eagle sandstone. In the northeastern part of the area the coal beds are from 15 to about 100 feet below the top of the Judith River, but elsewhere the top of this formation is not exposed and the stratigraphic position of the coal within it has not been definitely established. Because the surface is covered and there are few mines and prospects, coal outcrops can not be traced for any considerable distance. So far as known no coal occurs south of Peoples Creek except near the southwest corner of the field.

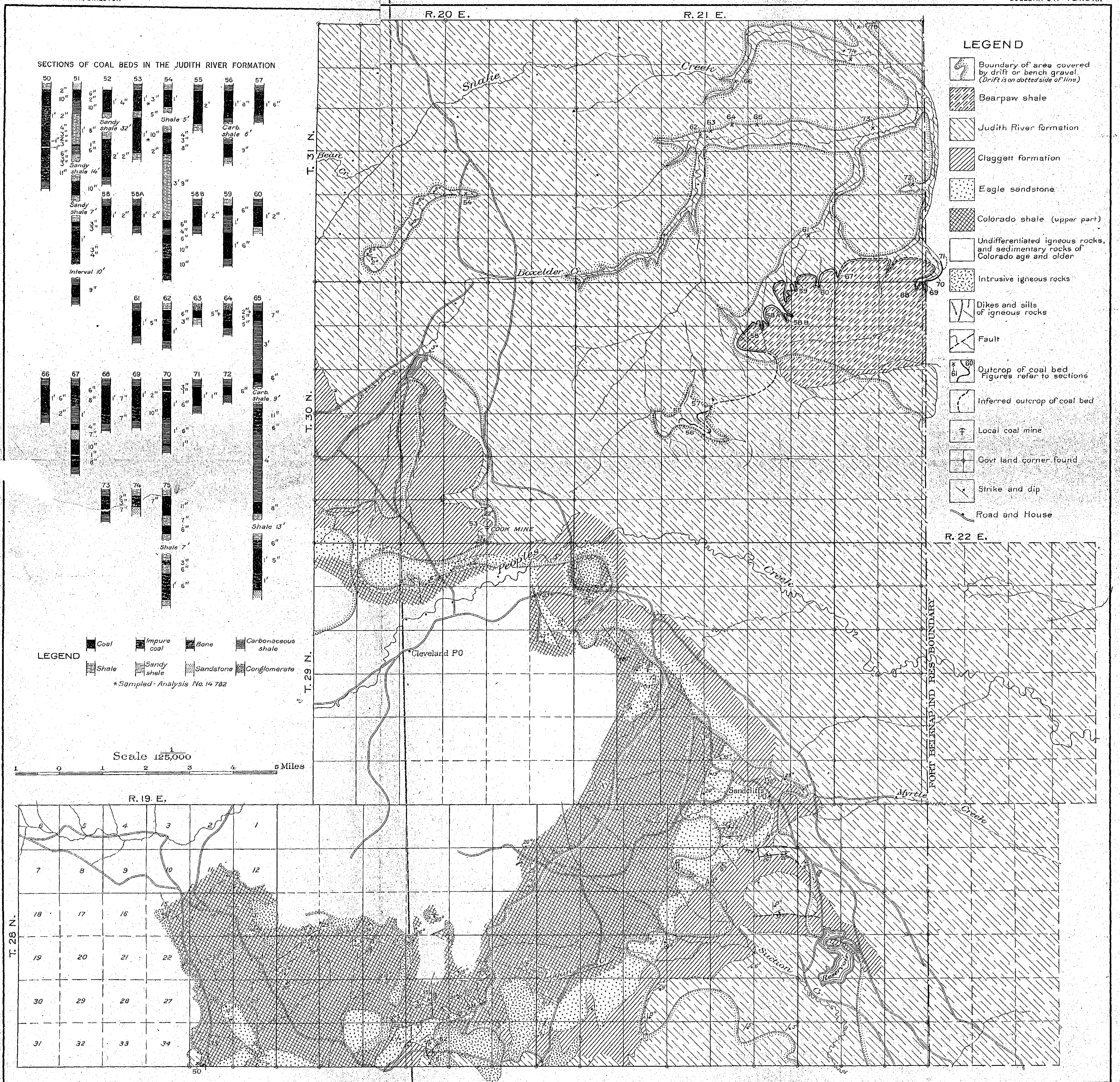
By reference to the graphic sections [1] (Pl. XX) it will be seen that with few exceptions the coal beds where exposed are less than 2 feet thick and that a majority of the outcrops show less than 1 foot 6 inches of coal. Furthermore, where the beds have a thickness of more than 2 feet, partings and impurities detract from the value of the coal.

The Cook mine, at locality 53, T. 30 N., R. 20 E., is the only mine in the field. The bed at this place, represented by section No. 53 (see Pl. XX), contains a total thickness of 3 feet 3 inches of coal, separated into two benches, however, by a shale parting about 5 inches thick. The coal is fairly clean but slacks readily on exposure to the atmosphere. No other outcrops of this coal bed could be found and its extent is not known. It is probably small, however, as the bed appears to be included in a downthrown fault block and is therefore cut off at either end by faults. At the mine the beds dip rather steeply to the south, whereas at only short distances both north and south of the mine the normal dip of the strata is to the north.

In the southwestern part of the field several isolated outcrops of coal were examined, but the beds could not be traced for any distance. The character and thickness of these beds are shown in sections 50 to 52 on Plate XX. In the northeastern part of the field a coal bed whose outcrop is traceable for about 5 miles is exposed and this bed was mapped from sec. 11, T. 30 N., R. 21 E., to the east side of the area. This bed is from 1 foot 2 inches to 1 foot 6 inches thick at localities 58 to 60. At locality 67, where a few ranchers obtain their fuel supply from a surface prospect on this bed, the coal is 1 foot 6 inches thick and has an inch parting near the middle. Above it occur two other thin beds which are 4 and 6 inches thick, respectively. Two miles east of locality 67, sections Nos. 68 to 71 (Pl. XX) were measured on the same bed. At localities 68 and 69 the bed is thicker than at any of the other places at which it was measured. At each of these localities, however, the lower part of the bed is bony and of little value as fuel. In secs. 16 and 21, T. 30 N., R. 21 E., a bed outcrops at about the same horizon and is believed to be the same bed. As shown in coal sections 55 to 57 this bed ranges in thickness from 1 foot 6 inches to 2 feet and consists of clean coal unbroken by partings.

In T. 31 N., Rs. 21 and 22 E., thin beds of coal are exposed at several places on Snake and Boxelder creeks and their tributaries. Sections Nos. 61 to 66 and 72 to 75, measured at the places indicated on Plate XX, show the thickness of the coal at these localities, but the beds can not be traced or correlated. At locality 62 a bed 1 foot 9 inches thick is exposed but is separated into two benches by 3

[1] The numbers used to designate the coal sections correspond with the location numbers on the map (Pl. XX). The first number used is 50 and the last is 75.



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF CLEVELAND COAL FIELD, BLAINE COUNTY, MONTANA

By C. F. Bowen

inches of bone, which occurs 6 inches below the top of the bed. The thickness of the lowest bed shown in the section at locality 65 was 2 feet 11 inches, but 6 inches in the upper part and 12 inches in the lower part contain too much shale and bone to be of any value as a fuel, leaving but 1 foot 5 inches of good coal. In the same section four other beds of coal are exposed at higher horizons. Three of these beds are each less than 10 inches thick and the other one consists of 6 inches of bone and 11 inches of impure coal. At locality 66 a coal bed 1 foot 6 inches thick is exposed. At locality 75 there is exposed a bed of very impure coal which is 1 foot 6 inches thick. Above it are two other beds, one of which is 6 inches thick and the other 11 inches. At each of the other exposures in this part of the field the coal is less than 1 foot thick. As the surface in this part of the field is generally covered with drift the coal beds can not be traced and therefore their outcrop is not shown on the map. A surface prospect in T. 31 N., R. 20 E., near the south side of sec. 22 has supplied fuel for settlers for two or three years. This bed is exposed at locality 54, which is at the east end of a prominent ridge forming the divide between Boxelder and Snake creeks. As shown in section No. 54 three beds of coal are exposed here, separated from each other by several feet of shale. The two upper beds are thin and have not been worked. Most of the fuel obtained from the prospect was taken from the lower bed. At the time of the writer's visit the prospect had been abandoned because of the great amount of bone present and the poor quality of the coal. There are no other exposures of this bed and its extent could not be determined. The coal so far as could be ascertained by the writer is very pockety in character and does not give promise of furnishing a good grade of fuel.

In this field the coal differs considerably in thickness and purity at the localities where it is exposed, but as a rule the beds can not be traced laterally and nothing is known of their thickness or of the quality of the coal between the points of exposure. Immediately north of the field along Milk River, where exposures are more numerous because of greater postglacial erosion, Pepperberg [1] found that the coal beds are lenticular in character and range in thickness "from a fraction of an inch to 9 feet at different points on the outcrop."

PROPERTIES OF THE COAL.

Accurate determination of the properties of the coal in this district was difficult, owing to the fact that for the most part only weathered coal could be obtained. At the Cook mine, however, fresh coal was available and at this and other localities where the coal seemed least altered the following properties were observed: The coal is black to

[1] Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, p. 88, 1910.

brownish black but becomes brown on weathering, streak brown, luster bright to dull, fracture irregular, texture dense, coherence tough to brittle. In places the coal shows a tendency to prismatic jointing. The observed impurities consist of flakes of selenite in crevices and seams and a brownish coating of an undetermined substance on weathered surfaces.

One sample for analysis was taken from the Cook mine, the only working mine in the field. In taking the sample the face of the bed was first freed from all impurities and the bed was then trenched across from top to bottom. The thickness and character of the bed at the point of sampling is indicated by section No. 53 (Pl. XX). At that place the bed has a total thickness of 3 feet 8 inches, but the sample, from which the shale and bone were excluded, represents a thickness of only 3 feet 1 inch. The sample was taken from a freshly broken face at the end of the mine workings, which consist of a devious entry about 500 feet long having a general southward course. At the point of sampling the bed is about 65 feet below the surface. The analysis (No. 14782) is presented below together with representative analyses of samples from the Milk River, Big Sandy, and Great Falls coal fields.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. This form is not well suited for comparison because the amount of moisture in coal as it comes from the mine is largely a matter of accident and may vary widely. Analysis B represents the sample after it has been dried at a temperature of 30° to 35° C. until its weight becomes constant. This form of analysis is best adapted to general purposes of comparison. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated, and analysis D its composition 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 represent conditions that do not actually exist, are derived from the others by recalculation.

In making these analyses the volatile matter in analyses 14782, 9150, 6318, 6380, and 14613 was determined by the modified method, whereas in the other analyses the volatile matter was determined by the official method. The difference between these two methods lies in the fact that in determining the volatile matter by the modified method the sample is first given a preliminary heating of 4 minutes over a small flame and a final heating of 7 minutes over a flame 20 centimeters high, whereas in the official method the preliminary heating is omitted. This preliminary heating allows the moisture to escape slowly and thus prevents the sputtering which occurs when coal that is high in moisture is placed directly over a hot flame. The mechanical loss due to such sputtering, though almost negligible in bituminous coal, may amount to as much as 25 per cent in some lignite. With lignite the modified method, by reducing the mechanical loss caused by sputtering, has the effect of decreasing the percentage of volatile matter and increasing the percentage of fixed carbon. It is now customary to use this method in determining the volatile matter in lignite, subbituminous coal, and all other coal which has a moisture content of more than 10 per cent.

Analyses of coal samples from the Cleveland and adjacent coal fields.

[Made at the Pittsburgh laboratory of the Bureau of Mines, F. M. Stanton and A. C. Fieldner, chemists in charge.]

Laboratory No.	Locality.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
		Quarter.	Sec.	T. N.	R. E.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
	CLEVELAND FIELD.																	
14782	Cook mine	SW	35	30	20	7.1	A	18.8	31.5	40.4	9.3	0.73					5,075	9,140
							B	12.5	33.9	43.5	10.1	.79					5,465	9,830
							C		38.8	49.7	11.5	.90					6,250	11,250
							D		43.8	56.2		1.02					7,060	12,710
	MILK RIVER FIELD.																	
9150	Chinook district, Roder prospect.	NW	5	31	19	14.7	A	21.4	28.0	41.6	8.99	.58	5.84	51.96	1.22	31.41	4,965	8,940
							B	7.9	32.8	48.8	10.54	.68	4.94	60.91	1.43	21.50	5,820	10,480
							C		35.7	52.9	11.44	.74	4.40	66.11	1.55	15.76	6,315	11,370
							D		40.2	59.8		.84	4.97	74.65	1.75	17.79	7,135	12,840
6318	Tumbler mine	NW	32	32	19	11.8	A	21.5	26.6	41.1	10.83	.64	5.73	50.43	1.09	31.28	4,810	8,650
							B	10.9	30.2	46.6	12.28	.72	5.01	57.18	1.24	23.57	5,450	9,820
							C		33.8	52.4	13.79	.81	4.26	64.19	1.39	15.56	6,120	11,020
							D		39.3	60.7		.94	4.94	74.45	1.61	18.06	7,100	12,780
6380	Matheson mine	SW	10	33	20	14.9	A	23.3	29.9	33.1	13.74	.72	5.80	44.90	.89	33.95	4,330	7,800
							B	9.9	35.1	38.9	16.15	.85	4.86	52.76	1.05	24.33	5,090	9,160
							C		38.9	43.2	17.91	.94	4.18	58.52	1.16	17.29	5,645	10,160
							D		47.4	52.6		1.15	5.09	71.29	1.41	21.06	6,880	12,380
6479	Havre Fuel Co. mine	NW	31	33	16	15.5	A	22.0	23.8	43.9	10.34	.60	5.67	47.98	.99	34.42	4,565	8,210
							B	7.6	28.2	52.0	12.24	.71	4.67	56.78	1.17	24.43	5,400	9,720
							C		30.5	56.3	13.25	.77	4.14	61.48	1.27	19.09	5,845	10,530
							D		35.2	64.8		.89	4.77	70.88	1.46	22.00	6,740	12,130
	BIG SANDY FIELD.																	
14613	Mackton mine	SW	18	28	14	1.8	A	13.0	36.3	40.1	10.6	.53					5,340	9,620
							B	11.4	37.0	40.8	10.8	.54					5,440	9,790
							C		41.7	46.1	12.2	.61					6,140	11,060
							D		47.5	52.5		.69					6,995	12,590
	GREAT FALLS FIELD.																	
4119	Gerber mine at Sand Coulee.	NE	23	19	4	2.6	A	7.5	27.3	51.4	13.78	2.32	4.68	62.21	.88	16.13	6,115	11,010
							B	5.0	28.1	52.8	14.15	2.38	4.51	63.87	.90	14.19	6,280	11,300
							C		29.5	55.6	14.90	2.51	4.16	67.25	.95	10.23	6,610	11,900
							D		34.7	65.3		2.95	4.89	79.02	1.12	12.02	7,765	13,980

A comparison of the results of the analyses given in the above table shows that there are no essential differences between the coal of the Cleveland field and that of the Milk River field.

As compared with the coal of the Big Sandy field, the coal of the Cleveland field is considerably higher in moisture, slightly higher in fixed carbon and in heating value, and somewhat lower in volatile matter and ash. The essential difference between the coal from these two fields lies in the greater amount of moisture contained in the Cleveland coal. Because of this the coal slacks much more readily when exposed to weathering.

The coal of the Cleveland field is very much higher in moisture, somewhat higher in volatile matter, and considerably lower in fixed carbon, ash, and heating value than the coal of the Great Falls field. The Cleveland coal is therefore inferior in quality to the coal of the Great Falls field.

The coal of the Cleveland field contains a high percentage of moisture. When it is exposed to the atmosphere the moisture evaporates, and as a result the coal cracks badly and finally crumbles to pieces. This property of the Cleveland coal separates it from the bituminous coal of the Great Falls field and all other high-grade coals. On the other hand, its black color and lack of woody structure separate it from lignite. The coal of the Cleveland field belongs, therefore, to the subbituminous class.

DEVELOPMENT.

The one mine in the Cleveland field is the Cook mine, situated near the west quarter corner of sec. 35, T. 30 N., R. 20 E. It is operated during the winter season and has an output of about 600 tons a year. At this place the bed has a total thickness of 44 inches, of which 37 inches is coal. There is evidence of structural disturbance in this vicinity, for the beds at the mine dip rather steeply to the south, whereas the normal direction of dip, both north and south of the mine, is to the north. It is probable, therefore, that the Cook coal occurs in a downfaulted block and that the bed is of small horizontal extent.

A surface prospect near the south side of sec. 22, T. 31 N., R. 20 E. (location 54), has supplied coal to settlers for two or three seasons, but has been practically abandoned because the coal is impure and difficult to obtain.

The thinness of the beds and the impurity of much of the coal in this area, together with the occurrence of coal of better quality on Milk River immediately north of this district, render it probable that there will be little or no systematic development of the coal beds of this field.

THE BIG SANDY COAL FIELD, CHOUTEAU COUNTY, MONTANA.

By C. F. Bowen

INTRODUCTION.

The Big Sandy field as here defined comprises an area of about 345 square miles included in Tps. 25 to 28 N., Rs. 13 and 14 E., and Tps. 25 and 26 N., R. 15 E. of the Montana principal meridian. It lies in north-central Montana, north of Missouri River and for the most part west of the Bearpaw Mountains. Its location is shown on the index map, figure 9 (p. 294).

In the Big Sandy field coal occurs in the Eagle sandstone and Judith River formation of Cretaceous age and the Fort Union formation of Tertiary age. The importance of the field as a coal producer is almost entirely dependent on the extent of the Fort Union coal. These beds occupy a small area in the vicinity of the Mackton mine, about 6½ miles northeast of Big Sandy. The areal extent of the coal, though not accurately known, is probably small. At the present time no beds of commercial value are known to occur outside of sec. 18, T. 28 N., R. 14 E. The coal in the Eagle sandstone and Judith River formation occurs in the southern part of the field. These coal beds are too thin and irregular in character to be of present commercial importance.

During a part of the field season of 1912 this area was examined to obtain data for the classification and valuation of the land with respect to its coal content. In this report, the general geology of the field, the character of the coal, and the distribution of the coal beds, so far as could be ascertained, are set forth.

The stratigraphy of the southwestern part of the area has been described by Weed[1] and the glacial geology by Calhoun.[2] The coal resources have been briefly discussed by L. J. Pepperberg, who visited the Mackton coal mine in 1908 and made a brief examination of mines and prospects in the vicinity.[3]

The geologic mapping upon which the present paper is based was done by Harvey Bassler and the writer, assisted by T. K. Harns-

[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (No. 55), 1899.
[2] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.
[3] U. S. Geol. Survey Bull. 381, pp. 102-103, 1910.

berger and J. R. Jaquet, who, although engaged as camp hands, rendered considerable scientific assistance. The writer acknowledges his indebtedness to the residents of the district for their generous hospitality, and is especially obligated to Messrs. Paul H. Schwartz, president of the Mackton Mine Co., and John Pearson, foreman of the mine, for much valuable information regarding the geology in the vicinity of their property.

As land classification was the prime object of the investigation, the General Land Office plats were made the base for geologic mapping, and all locations were made with reference to the established land corners. The work was done on a 15-inch plane table on a scale of 2 inches to the mile, using telescopic alidade and stadia for tracing coal beds and open-sight alidade and pacing for meandering geologic boundaries.

The accompanying map (Pl. XXI, p. 372) was compiled from the field sheets made in the course of the writer's examination and also from the General Land Office plats, from which most of the drainage and roads were taken. The map presents the distribution and attitude of the geologic formations as interpreted from a study of the scanty exposures, the outcrops of the principal coal beds, the locations of measured coal sections, and also the principal roads and streams of the district. The greater part of the area is covered by glacial drift, which obscures the outcrops of the older formations and renders both the geologic structure and the positions of the formation boundaries uncertain; in many places, therefore, the distribution of the formations shown on the map is partly hypothetical. The boundaries are indicated by solid lines where there is reasonable certainty regarding their location and by broken lines where there is less certainty; where their location is entirely hypothetical they are omitted. In the northern part of the field, in the vicinity of the Mackton mine, the drift covering is so nearly universal, and the structure of the older rocks where they are exposed is so complicated, that it was not possible to determine the extent of the coal-bearing formation; therefore, on that part of the map only the drift is shown.

The Montana Central division of the Great Northern Railway, extending from Great Falls to Havre, crosses the extreme northwestern corner of this field. All parts of the area are accessible by wagon roads from the railroad town of Big Sandy. Because of the somewhat rugged character of a portion of the area the roads in general follow the crests of ridges.

At present the area is very sparsely settled. Big Sandy, which has a population of about 250, is the only town and is the distributing center for a large extent of country. Considerable stimulus has recently been given to the acquisition and settlement of lands in this part of the State by the method of raising crops without irrigation, known as "dry farming." Farming and stock raising are the principal industries.

TOPOGRAPHY.

This coal field lies in the Great Plains province, which extends from the Rocky Mountain front eastward. In this part of Montana the plains are broken by numerous isolated mountain ranges, one of which, the Bearpaw Mountains, lies partly within the Big Sandy field and extends eastward for a distance of about 40 miles. The remainder of the field is an elevated, somewhat dissected plain. Locally badlands are developed, being especially prominent along Missouri River in the southwestern part of the area. There the river is bordered by vertical sandstone cliffs 75 to 100 feet high known as the "stone walls," which are sculptured by weathering into many curious and picturesque forms. Another modification of the prevailing type of topography occurs in the northwestern part, where a broad, flat alluvial valley, the preglacial channel of Missouri River,[1] forms a marked contrast with the other topographic features.

The area is drained by branches of Missouri River. Most of the streams are small and enter that river directly, but some of them flow into Milk River, which joins the Missouri about 160 miles farther east. The more important tributaries of Missouri River are Eagle Creek, Sheep Coulee, Alkali Coulee, and Little Sandy Creek; those of Milk River are Big Sandy and Gorman creeks. There is an interesting adjustment of drainage in the western part of the area, where Big Sandy and Little Sandy creeks are diverted almost at right angles from their westward courses. Big Sandy Creek on entering the abandoned channel of Missouri River follows it northward to Milk River, whereas Little Sandy Creek on entering this same channel turns toward the south just west of the area mapped and flows to the present channel of the Missouri. In this old channel the divide separating Big and Little Sandy creeks is so low that it is scarcely perceptible to the eye, but according to Calhoun[1] it is formed by a terminal moraine that marks the southernmost extent of the last advance of the ice sheet.

GEOLOGY.

STRATIGRAPHY.

OCCURRENCE AND CHARACTER OF THE ROCKS.

The sedimentary rocks exposed in the Big Sandy field consist of beds of sandstone, shale, and clay of Upper Cretaceous and Tertiary ages and deposits of glacial drift and alluvium of Quaternary age.

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[1] Calhoun, F. H. H., op. cit.

Inasmuch as the coal, with which this report is primarily concerned, occurs in the Montana group of the Cretaceous and in the overlying Fort Union formation, the field study was confined chiefly to these formations and they are discussed in more detail than are those that contain no coal. These rocks have been previously studied in adjacent areas in Montana by Weed[1] and by Stanton and Hatcher,[2] who have subdivided them into groups and formations and determined their geologic ages. The following table shows the stratigraphic succession, character, and thickness of the formations in the Big Sandy field:

Generalized section of the sedimentary rocks of the field.

System and series.	Group and formation.	Thickness.	Character.
Quaternary.	Alluvium.	*Feet.* 0-20±	
	Bench gravel.	0-10±	A mixture of gravel and finer material derived from the near-by mountains.
	Glacial drift.	0-50±	Contains numerous bowlders of granite, gneiss, and quartzite; a loess-like material containing a few waterworn pebbles caps the bluffs along Missouri River and its tributaries.
Tertiary (Eocene).	Fort Union formation.	700±	A lower massive sandstone, overlain by thin sandstone beds, alternating with clay shale; contains the best coal in the field.
Cretaceous (Upper Cretaceous).	Montana group: Bearpaw shale.	(a)	Dark-colored marine shale, containing calcareous concretions in which are found *Baculites ovatus*, *B. compressus*, *Scaphites nodosus*, and other Pierre forms.
	Montana group: Judith River formation.	500±	Brown to light-yellow sandstone and ash-colored clay and shale, containing fresh and brackish water invertebrates; also remains of vertebrates; contains thin beds of low-grade coal.
	Montana group: Claggett formation.	350-500	Like the Bearpaw both lithologically and paleontologically.
	Montana group: Eagle sandstone.	250-300	Thin-bedded to shaly sandstone, some massive to heavy-bedded white to buff sandstone, drab to light-colored clay and shale, some of which is carbonaceous and contains thin beds of low-grade coal.
	Colorado shale.	(a)	Dark marine shale alternating with thin beds of sandstone and sandy shale.

[a] Undetermined.

[1] Weed, W. H., op. cit.

[2] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, 1905.

CRETACEOUS SYSTEM.

COLORADO SHALE.

The oldest formation exposed in the field is the gray Colorado shale. This shale outcrops along Missouri River and its lower portion is typically developed at Fort Benton, 30 miles to the southwest, which is the type locality of the Benton shale. In the Dakotas, Nebraska, Colorado, and elsewhere the upper limit of the Benton shale was fixed by an overlying limestone—the Niobrara—which is typically developed on Missouri River at the mouth of the Niobrara. These two formations—the Benton and Niobrara—constitute the Colorado group, but in this field, as elsewhere in north-central Montana, the Niobrara limestone as such is not present and the Colorado shale appears to be the time equivalent of both the Benton shale and Niobrara limestone of other localities. It has therefore become customary to refer to the formation in this part of the State as the Colorado shale rather than as the Benton shale.

The upper part of the Colorado consists of lead-gray shale alternating with thin beds of sandy shale and impure sandstone. Lower down in the formation the shale is more homogeneous and uniformly dark gray. The shale contains limestone concretions in which marine fossils are found. Only the upper part of the formation is exposed in this field and the entire thickness of the formation was therefore not determined; in the Fort Benton quadrangle its thickness as measured by Weed[1] is 1,850 feet, but this includes, at the base, part of the rocks now referred to the Kootenai formation. The Colorado shale is exposed in the Big Sandy field only in the valley of Missouri River. In general only a few feet of the formation is exposed above water level, but in some places it has been elevated by faulting to the top of the river bluffs, as for example at the mouth of Alkali Coulee.

EAGLE SANDSTONE.

The Colorado shale is overlain by the Eagle sandstone, so named[1] from its excellent exposures at the mouth of Eagle Creek in the southwest corner of the field. This sandstone, according to Stanton and Hatcher[2] represents the lower part of the Montana group; all the fossils collected from it by the writer have been reported by Stanton to be of Montana age.

As developed in this locality, the Eagle consists, typically, of three members. The lowest is a massive cross-bedded and locally heavy-bedded white sandstone, containing numerous small sandstone concretions that appear rusty on the weathered surfaces; the maximum thickness of this member is 120 feet. The middle division consists

[1] Weed, W. H., op. cit.
[2] Stanton, T. W., and Hatcher, J. B., op. cit., pp. 63, 66.

of 75 to 100 feet of dark-colored shale, which is carbonaceous at some horizons and contains thin irregular beds of coal. The upper division consists of thin-bedded gray sandstone. The total thickness of the formation is 250 to 300 feet, but its full thickness is not exposed in any one section. It outcrops only in the southwestern part of the area along Missouri River and its tributaries, where the overlying glacial drift has been removed by erosion. The massive sandstone at the base of the formation is more resistant than the underlying and overlying shales and forms cliffs 75 to 100 feet high.

The Eagle sandstone lies conformably on the Colorado shale, from which it is distinguished by its striking lithologic differences, but below the base of the Eagle as here considered there is a transition zone consisting of alternating beds of shale and sandstone that are of lighter color and more sandy than the typical Colorado shale. No fossils from which age determinations can be made were found in the transition beds, but lithologically they seem to belong to the Colorado, and because of the change from them to the overlying massive sandstone the base of the sandstone is taken as the line of separation between the Eagle and the Colorado.

CLAGGETT FORMATION.

The Claggett formation, so named by Stanton and Hatcher,[1] is in this area a dark-colored marine shale overlying the Eagle sandstone. The Claggett formation has been determined to be the equivalent of a part of the Pierre shale. It contains *Baculites ovatus*, *Baculites compressus*, *Inoceramus barabini*, *Gervillia borealis*, and other forms characteristic of the Pierre.

The Claggett consists chiefly of dark-gray shale containing numerous calcareous concretions, the largest of which are several feet in diameter. These concretions contain most of the fossils found in the formation. Because of poor exposures the thickness of the formation was not determined in the Big Sandy field, but in the vicinity of Judith, about 40 miles farther east, the shale is about 500 feet thick.

The lower part of the formation is well exposed in the southwestern part of the field along many of the coulees tributary to Missouri River, but elsewhere it is in general covered by glacial drift and the boundaries can not be accurately located except in a few places. For this reason the boundaries shown on the map are only approximately correct. For the most part the outcrop of the Claggett occupies a zone between the exposures of the Eagle sandstone and those of the Judith River formation, but in some places in the vicinity of Big Sandy Creek small exposures of dark shale are apparently surrounded by the Judith River formation. These are represented as

[1] Stanton, T. W., and Hatcher, J. B., op. cit., p. 13, 1905.

Claggett on the map, on the assumption that the shale underlies the Judith River and has been exposed by folding and erosion. It is possible, however, that the shale exposed at some of these localities belongs in reality to the Bearpaw, and has been faulted down among the Judith River beds.

The Claggett overlies the Eagle sandstone conformably and is rather sharply contrasted with it lithologically by reason of its shaly character, its dark color, and the presence of limestone concretions. At the base of the Claggett, however, a zone of sandy shale constitutes a transition to the Eagle sandstone below, and at the top there is a similar transition zone to the overlying Judith River formation.

At the mouth of Judith River and elsewhere in that region there is between the main body of shale in the typical Claggett and the overlying fresh-water beds from 100 to 200 feet of alternating marine shale and sandstone, which becomes more sandy toward the top, where there is a bed of massive yellow sandstone ranging from a few feet up to 20 feet or more in thickness. This zone of alternating shale and sandstone carries a marine invertebrate fauna which is perhaps most abundant in the upper massive sandstone. Because of the marine fauna and because of the previously defined base of the Judith River formation above them, Stanton and Hatcher included these beds in the Claggett formation, although lithologically they are much more closely allied with the Judith River. In the Big Sandy field, however, the sandstone overlying the dark marine shale of the Claggett, although similar in lithologic character and stratigraphic position to the marine sandstone at the mouth of Judith River, is of fresh or brackish water origin. This is proved by the occurrence in it of fresh or brackish water shells and beds of carbonaceous shale. As there is no evidence of an erosion interval between the shale of the Claggett formation and these fresh-water beds, it is possible that these beds are the time equivalent of the marine sandstone at the mouth of Judith River, but to the writer it seems more logical that the name Claggett formation should be restricted in this field to the marine shale and that the overlying sandstone should be included in the Judith River formation.

JUDITH RIVER FORMATION.

The Judith River formation overlies the Claggett and is principally of fresh or brackish water origin. This formation was named by Hayden [1] in 1872, though its stratigraphic relation was not then understood. In their work on the Judith River formation [2] Stanton and Hatcher determined that the formation belongs in the Montana

[1] Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey of Wyoming and portions of contiguous Territories, Preliminary (Second) Rept. progress, p. 97, 1872.

[2] Stanton, T. W., and Hatcher, J. B., op. cit., 1905.

group and is the time equivalent of a part of the Pierre shale. Their conclusion was borne out by the work of the writer in this area.

The Judith River formation consists of light-colored alternating beds of sandstone and shale in which occur thin beds of carbonaceous shale and coal, the latter of little economic importance in this field. In some places the sandstones are cross-bedded and ripple marked and contain ferruginous and sandy calcareous concretions which have a general resemblance to the more sandy concretions of the Claggett. There is considerable lithologic variation in the beds, both horizontal and vertical, which renders it impossible to match up sections measured at separate localities. The thickness of the formation was not determined in this area because of lack of good exposures and uncertainty as to structure. However, in other areas in this part of the State the formation is about 500 feet thick.

The general distribution of the Judith River formation is shown on the map (Pl. XXI, p. 372), but as the formation is largely obscured by glacial drift, the boundaries shown are more or less hypothetical. The formation is believed to underlie different areas in the northern part of the field, but it is impossible from a surface study of the formation to draw the boundary between it and the younger rocks; in that part of the area, therefore, the rocks underlying the glacial drift are not represented on the map.

There is a narrow transition zone between the Judith River and the underlying Claggett, and the formation is also conformable beneath the Bearpaw shale. This normal relation exists over a small area in the northeast part of T. 26 N., R. 15 E., but elsewhere throughout the field the Judith River is cut off by igneous rocks or appears to be in fault contact with younger formations.

BEARPAW SHALE.

The Bearpaw shale was named by Stanton and Hatcher[1] "because it is well exposed in the area south, east, and north of the Bearpaw Mountains." This shale contains a fauna which elsewhere is regarded as typical of the Pierre. The Bearpaw is therefore the equivalent of the upper part of the Pierre and in areas to the southeast, between Missouri and Musselshell rivers, is directly overlain by the Lance formation.

The Bearpaw is a lead-gray marine shale, containing calcareous concretions which yield most of the fossils of the formation. In both lithologic and paleontologic characters the Bearpaw resembles the shale of the Claggett formation so closely that in many places the two can not be definitely distinguished except in their stratigraphic relations. As only a part of the formation is exposed in this field,

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[1] Stanton, T. W., and Hatcher, J. B., op. cit., p. 62, 1905.

its thickness was not determined, but in other localities it is known to be 1,000 to 1,100 feet thick.

In the northeastern part of T. 26 N., R. 15 E., a small body of marine shale appears to rest conformably on the Judith River formation and is therefore called Bearpaw. Another small mass of dark shale overlies beds which seem to belong to the Judith River in sec. 24, T. 27 N., R. 14 E., at the base of the Bearpaw Mountains. The only direct evidence of the age of this shale is its apparent stratigraphic position above the Judith River. The structure is doubtful, however, and steep dips and variable strikes in a few small exposures suggest fault relations; it may be, therefore, that the shale represents some other formation. In the vicinity of the Mackton coal mine there are several isolated exposures of similar marine shale which seems to underlie the coal-bearing formation (Fort Union) and to overlie undoubted Judith River beds. The fossils collected from this shale are regarded by Mr. Stanton as more nearly allied to those of the Bearpaw shale than to those of the Claggett. The structural conditions are uncertain at these places, but the apparent stratigraphic relation of the shale and the fossils it contains suggest that it is of Bearpaw age. The distribution of the Bearpaw in the vicinity of the Mackton mine can not be determined because the shale is exposed at only a few places and other evidence indicates the existence of faults by which the shale may in some places be entirely cut out. Its distribution, however, is probably greater than the exposures indicated on the map.

The Bearpaw is conformable above the Judith River, and apparently also underlies the Fort Union formation conformably, except in places where faulting has disturbed these relations. The Fox Hills, Lance, and Livingston formations, which at some localities in Montana occur between the Bearpaw (or Pierre) and the Fort Union, are not present in this or immediately adjacent fields. The absence of these formations indicates either a stratigraphic break or different conditions of deposition at the localities where these beds do not occur. Therefore, although there is apparent conformity between the Bearpaw and the overlying Fort Union formation, there may really be a time break.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The coal-bearing formation at the Mackton mine is classed as Fort Union on the basis of fossil plants collected from it at the mine and at a locality about 2 miles farther east. The stratigraphic position of these beds in the Fort Union has not been determined; their presence at this locality, far removed from all other known areas of Fort Union rocks, is due to faulting, which has brought the beds down to the level of older rocks.

The Fort Union consists of alternating layers of sandstone, sandy shale, and shale. The formation is of variable color, but light shades of buff, yellow, green, blue, and gray predominate. It contains one or more coal beds. A massive cross-bedded yellowish sandstone occurring near the base is relatively resistant to erosion and forms cliffs and ledges. The overlying beds weather down readily and are as a rule not exposed at the surface. The thickness of the formation at the Mackton mine is estimated as about 700 feet, although only about 350 feet are well exposed.

No accurate statement can be made of the distribution of the Fort Union formation in this field, because of the complex structure and the almost universal covering of drift. There is no clue as to the position of the southern boundary of the formation. On the north there are several small isolated exposures of a massive sandstone, similar in appearance to that near the base of the section at the Mackton mine. These exposures extend northeast from a point near the southwest corner of sec. 12, to the north quarter corner of sec. 1, T. 28 N., R. 14 E. If these outcrops represent the same sandstone as that at the Mackton mine, their positions should indicate approximately the northern limit of the formation, unless it is repeated still farther to the north by faulting. On the east the sedimentary rocks are all cut off by igneous intrusions of the Bearpaw Mountains.

QUATERNARY SYSTEM.

The Quaternary deposits comprise glacial drift, bench gravel, and alluvium; the drift is the most widespread of these deposits and covers the surface of almost all the area.

Over most of the district the drift consists of a heterogeneous mixture of sand, gravel, and bowlders, variable in size and in lithologic character. The most numerous and conspicuous erratics are granites, gneisses, and quartzites that obviously have been transported from distant regions, inasmuch as they are totally unlike any rocks occurring in place in this part of Montana. Along Missouri River and its tributaries, however, the bluffs are capped by a deposit of light-yellow, partly consolidated, loesslike sand and clay which is in places apparently stratified and as a rule contains a few small water-worn pebbles. This deposit is doubtless due to some phase of glacial action.

The drift covers almost all the field but does not occur in that part occupied by the Bearpaw Mountains. The boundary of the drift-covered area is shown on the map (Pl. XXI, p. 372).

Near the Bearpaw Mountains those areas that are not drift-covered are in most places overspread by gravel derived chiefly from the igneous rocks of the near-by mountains. In general, this gravel obscures the outcrops of the older formations as completely as does the drift.

The preglacial channel of Missouri River, crossing the northwest corner of the field, is occupied by alluvium. Similar deposits of smaller extent occur along the present channel of Missouri River and some of the small tributary streams.

IGNEOUS ROCKS.

The Bearpaw Mountains consist of igneous rocks of intrusive and extrusive origin and of both acidic and basic character. They have been briefly described by Weed and Pirsson.[1] Dikes and sills of these rocks radiate from the main mountain mass and some of them outcrop at a considerable distance from the mountains. These dikes and sills have had little effect on the inclosing strata, which are but slightly metamorphosed and have suffered no apparent displacement by the intrusion.

STRUCTURE.

Because of the general covering of glacial drift and alluvium, continuous exposures of the underlying formations are lacking and the structure is extremely obscure and difficult to interpret. Except locally where the drift cover is very thin, exposures of sedimentary rocks occur only along the streams and coulees, where erosion has removed the glacial material. A study of these exposures shows that the original attitude of the rocks has been disturbed locally by faulting, but because of the conditions described above the fault lines can not be traced, and in many places the existence of a fault can be inferred only by a pronounced change in the dip or strike of the strata at near-by exposures. Along Missouri River, however, where the best exposures occur, faults are plainly visible; different formations end abruptly against one another along the strike or are repeated in the direction of dip several times in succession, as at the mouth of Alkali Coulee. The location of a few of the most obvious faults is shown on the map. Suggestions of other faults are numerous, and it is probable that still others are entirely obscured by the surface covering.

THE COAL.

OCCURRENCE.

The best grade of coal and the thickest and most extensive beds occur in the Fort Union formation in T. 28 N., R. 14 E., as shown on the map (Pl. XXI, p. 372). Thin irregular beds of poor coal are found in the Eagle and Judith River formations in the southern part of the field. For convenience of discussion the coal beds are grouped

[1] Weed, W. H., and Pirsson, L. V., The Bearpaw Mountains, Mont.: Am. Jour. Sci., 4th ser., vol. 1, pp. 283-301 351-362; vol. 2, pp. 136-148, 188-199, 1896.

according to geologic formations and are so presented in this report. As the area occupied by the Fort Union formation, though not accurately determined, is known to be small, it follows that the commercially valuable coal of the field is restricted to a relatively small area.

COAL IN THE EAGLE SANDSTONE.

Exposures of coal in the Eagle sandstone are confined to the southwestern part of the field. The coal occurs in a zone 50 to 100 feet thick near the middle of the formation and above the white massive basal sandstone. Several coal beds of variable thickness and purity are present, the most important of which is immediately above a black shale containing large ironstone concretions at its base. It is 20 to 30 feet above the top of the white massive sandstone, and the outcrop of the coal bed therefore corresponds closely to that of the upper rim of the sandstone ledge. The coal sections[1] measured on these beds are shown in fig. 11 (p. 373), Nos. 17 to 32.

The lowest bed, here designated bed A, is the most important, ranging in thickness from 15 to 36 inches. It is shown in sections Nos. 22, 23, and 32, and is the lowest bed shown in sections Nos. 24, 25, and 26 (fig. 11). The bed is variable in character; in some places it consists of one unbroken bench, in others it is split by bone or shale partings into several benches, and at locality 23a it consists entirely of carbonaceous shale. At locality 32 there is 31 inches of coal in three benches separated by partings 3 inches thick. The following sections show the character of bed A at different localities:

Section at locality 23, near east quarter corner of sec. 5 (unsurveyed), T. 25 N., R. 18 E.

	Ft.	in.
Coal (section No. 23, fig. 11)	2	4
Shale	10	
Shale, carbonaceous	2	
Clay	10	
Shale, carbonaceous	5	
Clay	10	
Shale, bed A, carbonaceous, with coaly streaks	4±	
Clay, drab, with iron concretions in middle, to white, massive sandstone (estimated)	20	
	63	4

[1] The coal sections are referred to by numbers which correspond with those used on the map (Pl. XXI).

Section at locality 22, on east bank of Missouri River, sec. 9, T. 25 N., R. 13 E.

	Ft.	in.
Coal (section No. 22, fig. 11)		7
Shale and sandstone, alternating	5	9
Clay	9	
Shale, carbonaceous	1	
Coal, bony, bed A		6
Shale, carbonaceous	1	
Clay, black	19	
Shale, carbonaceous, with lenses of coal and carbonized wood		8
Clay	3	
Sandstone, white, massive.		
	40	6

The following sections were measured in the bluffs on the north side of Missouri River in T. 26 N., R. 12 E., which lies just west of the area shown on the accompanying map (Pl. XXI, p. 372):

Section at Coal Banks, on north side of Missouri River, near west side of T. 26 N., R. 12 E.

		Ft.	in.
Clay, gray		10	
Bed A	Shale, carbonaceous	1	
	Coal		3
	Clay		3
	Coal, with 3 inches of bone 6 inches above base	1	2
	Clay and brown shale	1	8
	Coal	1	
Clay, brown		1	3
Sandstone, argillaceous		5	
Clay		2	6
Shale, carbonaceous		1	
Clay			1
Coal			4
Bone			6
Clay		10	
Shale, brown		1	
Clay		5	
Bone			4
Clay			1
Coal			3
Clay			1
Bone			4
Clay		6	
Sand, yellow, loose		6	
Shale		1	
Sandstone, white, massive.			
		56	1

Section on north side of Missouri River, about 1½ miles east of Coal Banks.

		Ft.	in.
Clay, drab		10	
Bone			10
Coal			2
Shale		3	6
Bone			8
Clay		14	
Bed A	Coal		5
	Clay		6
	Coal		11
	Shale, carbonaceous	1	
Clay, black, with iron band at bottom		5	
Clay		2	
Coal		1	1
Clay		5	
		45	1

At an old prospect (now almost obliterated), 50 feet east of the last section, another measurement of bed A was made, as given below. The two sections show the variability of the bed within a short horizontal distance.

Section of coal bed A measured 50 feet east of the preceding section.

	Ft.	in.
Coal	1	5
Clay		2
Coal		7
Clay		6
Coal	1	
	3	8

The overlying coal beds are thinner than bed A, and in most places are less than 15 inches thick, though locally they may be 24 inches thick. Sections Nos. 17 to 31 (fig. 11, p. 373) show the thickness of these beds at the localities indicated on the map.

From the above description it will be seen that the coal beds in the Eagle sandstone in this field are thin and variable, and up to 1912 no attempt had been made to exploit and use the coal. The thinness of the beds and the variability in the quality of the coal militate against development at the present time, but as the country becomes more thickly settled the coal may, to a limited extent, serve the local needs of ranchmen and homesteaders.

COAL IN THE JUDITH RIVER FORMATION.

As shown by surface exposures, the Judith River coal beds are thin and of no economic importance. The few exposures in the eastern part of the field, at which sections Nos. 33, 34, and 35, given below, were measured, show that the beds are thicker in that locality than they are farther west. It is possible that the formation contains some workable coal in Tps. 25 and 26 N., R. 16 E., immediately east of the area here considered, and it is well known that still farther east, on and near Cow Creek, coal beds of considerable thickness occur in the Judith River.

Coal sections Nos. 36, 37, and 38 in the following table, measured on Big Sandy Creek, represent practically all that is known of the Judith River coal in the western part of the field. The formation is largely covered by glacial drift, and the few exposures do not extend through a very great vertical range; consequently it is possible that coal beds which are not exposed at the surface occur in the formation. There is a general absence of coal in the Judith River formation at all existing outcrops, however, and it seems probable that the formation contains no important coal beds in this area.

Sections of coal beds in Judith River formation.

No. on Pl. XXI.	Location.	Section.	Ft.	in.
33	NE. ¼ SE. ¼ sec. 1, T. 25 N., R. 15 E.	Coal		6
		Parting, sandy		1
		Coal, bony	1	3
		Coal	1	3
		Total	3	1
34	NE. ¼ NE. ¼ sec. 36, T. 26 N., R. 15 E.	Bone	1	
		Coal		4
		Bone		1
		Coal	1	
		Shale	3	
		Coal, bony in lower part	1	3
		Total	6	8
35	SW. ¼ NE. ¼ sec. 35, T. 26 N., R. 15 E.	Coal		9
36	SW. ¼ NE. ¼ sec. 12, T. 27 N., R. 13 E.	Coal, impure	1	
		Bone	1	
		Total	2	
37	SW. ¼ NW. ¼ sec. 7, T. 27 N., R. 14 E.	Coal		10
		Bone	1	
		Total	1	10
38	SW. ¼ NW. ¼ sec. 8, T. 27 N., R. 14 E.	Coal		6

COAL IN THE FORT UNION FORMATION.

The coal in the Fort Union formation is of better quality than that occurring in the other formations. The Fort Union occupies a small area in the northern part of the field; its presence in this locality, as stated on page 364, is believed to be due to faulting, by which the beds have been brought down to a relatively lower level stratigraphically than that which they normally occupy. For the sake of clearness in discussion, the coal bed on which the Mackton mine (locality 39) is operated will be called the Mackton bed, and that on which the Mack mine (locality 43) is operated, the Mack bed, although it has not been conclusively demonstrated, as will be seen from the following discussion, that these represent different beds.

The Mackton bed (section No. 39, fig. 11, p. 373) is about 350 feet above the base of that part of the Fort Union formation exposed in the Big Sandy field. This bed has been considered by the Mackton

Coal Co. to be represented farther northeast by the bed on which sections Nos. 40 and 41 were measured, because the sections of the beds are similar. The writer considers this correlation doubtful because all search for the coal bed between the two localities has been fruitless, and further because of the fact that the bed at the Mackton mine (locality 39) is about 200 feet above a massive gray sandstone, not far below which is marine shale, whereas at locality 40 the coal appears to be below a similar massive sandstone and is separated from the underlying marine shale by alternating thin beds of clay and sand. The extent of the Mackton bed itself is not definitely known. From a point about 500 feet north of the mine the bed can be almost continuously traced nearly to the south side of sec. 18, a distance of almost one-half mile. Throughout this distance it has a thickness of 7 to 8 feet. The abrupt ending of all surface indications of the bed at either end of this line of outcrop suggests the presence of faults. There is more or less evidence of this at the southern termination of the coal outcrop, but the evidence is not so apparent at the northern termination. The failure to find the bed beyond these supposed fault lines suggests the possibility that the coal occurs in a small fault block that has been dropped vertically downward into a non coal-bearing formation. The surface covering of drift makes it impossible to trace fault lines or work out fault relations from the surface, and the demonstration of the presence or absence of faults can be made only by underground development. One small fault has already been encountered in the mine, and it seems likely from the evidence at hand that others may be found and that the Mackton bed may prove to be small in extent in the direction of strike. In the underground workings, as far as they have been extended, the structure corresponds exactly with what would be expected from a study of the surface exposures, which show that directly south of the mine, near the southwest corner of sec. 18, the strike of the formation is almost at right angles to the strike at the mine entrance and the south entries of the mine show that underground a similar change in strike takes place in the coal bed. This discordance in strike is one of the strongest evidences of faulting south of the present workings.

The Mackton bed has a total thickness of 7 feet 8 inches at the Mackton mine. A persistent parting of bone and shale 15 to 24 inches thick separates the bed near the middle into two benches; and a 2-inch parting also occurs in the lower part of the upper bench. This necessitates sorting the coal before it is marketed and adds to the cost of mining.

The bed worked at the Mack mine (locality 43) is regarded by Pepperberg[1] as occurring about 35 feet above the Mackton bed. If

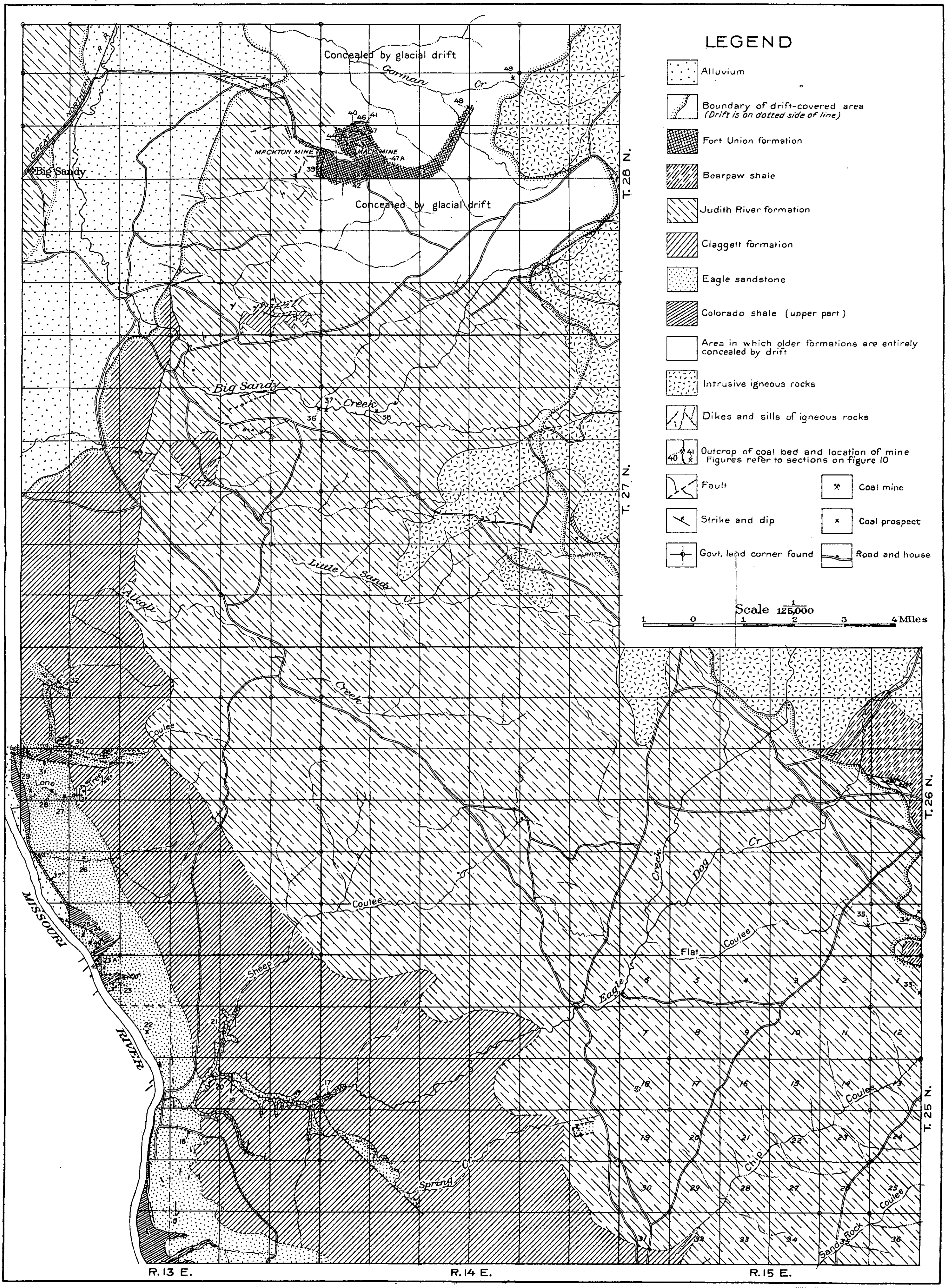
[1] Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, p. 103, 1910.

this is so, the Mack bed should be found above the Mackton mine, and the Mackton bed should be found below the Mack mine. However, no locality has ever been found in which both beds are exposed unless it can be proved that the bed at localities 40 and 41 is the Mackton bed. Both beds, moreover, occur a short distance above a massive sandstone. On the other hand, a comparison of sections Nos. 39 and 43, at the Mackton and Mack mines respectively, shows that there is no resemblance between the bed worked at the two localities. The evidence tending to show that they are one and the same bed consists therefore in the failure to find the two at the same locality and in the fact that each occurs above a massive sandstone; opposed to this is the dissimilarity in the sections of the two beds. The structure is so complicated and the authentic determination of faults so difficult in this area, owing to discontinuous exposures, that the writer does not attempt any correlation of the coal beds at the two localities. The bed represented by sections Nos. 42 and 44 to 47 is generally regarded as the Mack bed, owing to the resemblance in thickness and quality. A short distance southeast of locality 47 the bed is concealed by drift and can not be traced farther. However, on the dump of an old prospect entry, at locality 47a, there is perhaps a ton or more of slacked coal, which seems to indicate the presence of a bed similar in quality to that at locality 45. The entry at this prospect is now completely caved in and the outcrop of the coal bed is covered by drift, so that the bed could not be examined. About three-fourths of a mile southeast of this old prospect two sills of igneous rock appear nearly at the horizon of the coal bed, but there is no evidence of coal until locality 48 is reached, where a thin bed is exposed just below the lower sill. About 1 mile farther to the northeast, at locality 49, there is another exposure of coal at approximately the same horizon, in close association with a dike or sill, but the bed can not be traced and no other exposures of coal can be found in this part of the field.

The Mack bed is in all probability continuous and thick enough for mining under the drift-covered bench within the curve formed by the coal outcrop between localities 42 and 47. The eastward extent of the bed is not definitely known, but if, as seems probable, it is represented by sections 48 and 49, it is evident that locally at least the bed is considerably thinner to the eastward than in the vicinity of the Mack mine.

PROPERTIES OF THE COAL.

The coal in the Eagle and Judith River formations is black or brownish black in color, has a brown streak, and no pronounced woody structure. The Fort Union coal, as observed in the Mackton mine, has the following physical properties: Color pitch-black, streak brown to black, luster vitreous, structure bedded, jointing or cleavage



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF BIG SANDY COAL FIELD, CHOUTEAU COUNTY, MONTANA

By C. F. Bowen

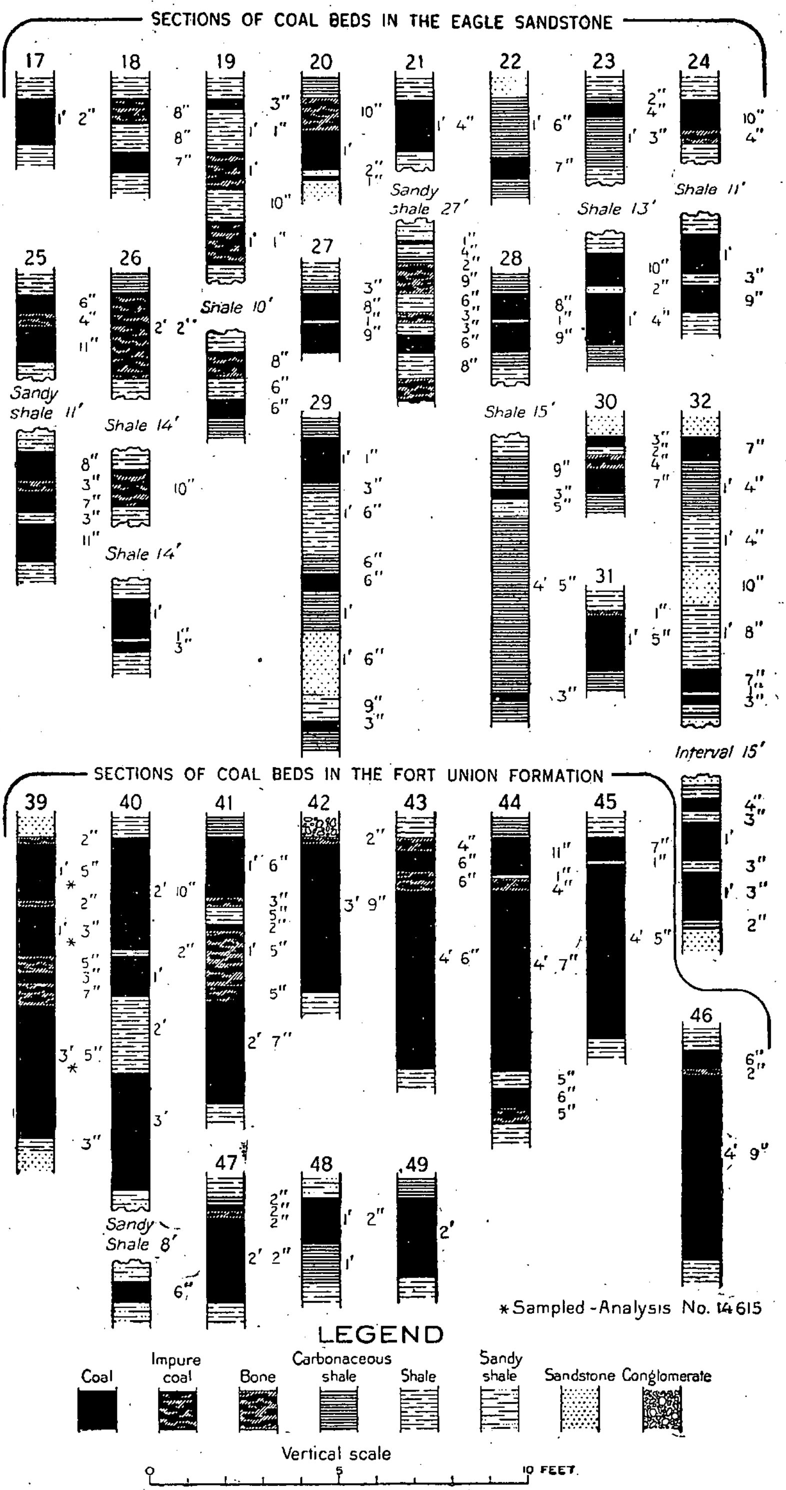


FIGURE 11.—Sections of coal beds in the Big Sandy coal field, Chouteau County, Mont.

in two directions, the coal breaking into subcubical blocks and smaller fragments when reduced, fracture conchoidal to uneven, texture dense, coherence brittle.

Two samples for analysis were taken from the bed at the Mackton mine. Sample 14615 came from the south entry of the first level, 250 feet from the mouth of the entry and 150 feet below the mouth of the slope. The bed at that point is represented by section No. 39 (fig. 11). Its total thickness is 7 feet 6 inches, but the sample, which includes only the coal, represents a thickness of 6 feet 1 inch. Sample 14613 was taken from the north entry of the second level, 140 feet north of the mouth of the entry and 335 feet down the slope. The bed at the place of sampling has the following section:

Section of Mackton coal bed at locality where sample shown in analysis 14613 was collected.

	Ft.	in.
Coal	2	5
Bone		2
Coal		6
Bone and coal (discarded in mining)	1	9
Coal	2	
	7	5

No mining had been done in the upper level for several months; hence this sample does not represent perfectly fresh coal. The other sample was taken from a fresh surface. The mine is dry throughout, so that the conditions under which the two samples were collected were the same except as to the length of time that the sampled surface had been exposed to atmospheric influences. In collecting the samples the face of the bed was first freed from all foreign matter and the bed was then trenched across from top to bottom. In order to compare the coal of the Big Sandy field with other coal with which it must compete in the market, analyses of representative samples of coal from the Havre district of the Milk River field and from Sand Coulee of the Great Falls coal field are also given.

These analyses, contained in the table below, are given in four forms marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. This form is not well suited for comparison because the amount of moisture in coal as it comes from the mine is largely a matter of accident and may vary widely. Analysis B represents the sample after it has been dried at a temperature of 30° to 35° C. 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 its condition after all moisture and ash have been theoretically removed. This form is supposed to represent the true coal substance, free from the most significant impurities. Forms

C and D are obtained from the others by recalculation. They represent theoretical conditions that never exist.

In making these analyses, the volatile matter in samples 14613 and 14615 from the Big Sandy field was determined by the modified method, whereas in all the other samples the volatile matter was determined by the official method. The difference between these two methods lies in the fact that in determining the volatile matter by the modified method the sample is first given a preliminary heating of 4 minutes over a small flame and a final heating of 7 minutes over a flame 20 centimeters high, whereas in the official method the preliminary heating is omitted. This preliminary heating allows the moisture to escape slowly and thus prevents the sputtering which occurs when coal that is high in moisture is placed directly over a hot flame. The mechanical losses due to such sputtering, though almost negligible in bituminous coal, may amount to as much as 25 per cent in some lignite. In such material the modified method, by reducing the mechanical loss caused by sputtering, has the effect of decreasing the percentage of volatile matter and increasing the percentage of fixed carbon. It is now customary to use this method in determining the volatile matter in lignite and subbituminous coal and all other coal which has a moisture content of more than 10 per cent.

The effects of the two different methods of analyses on the Mackton coal of the Big Sandy field, which is a high-grade subbituminous coal, may be seen by comparing analyses 14613 and 14615, made by the modified method, with analysis 6550, made by the official method. Analysis 14615, however, represents coal that may have been slightly weathered. It is consequently less valuable for purposes of comparison than analyses 14613 and 6550, both of which represent perfectly fresh coal taken in the Mackton mine. The differences in results between these two analyses are perhaps no greater than would be obtained from the analysis of any two samples taken from the same bed in different parts of the same mine and both analyzed by the same method. Furthermore, the differences which do occur are the opposite of what would be expected as a result of the methods of analysis employed. The volatile matter is 1.6 per cent lower and the fixed carbon about 1.6 per cent higher in analysis 6550, made by the official method, than in analysis 14613, made by the modified method. It is therefore evident that the slight differences in the results are to be accounted for by some other factor than the methods of analysis employed.

Analyses of coal samples from the Big Sandy and adjacent coal fields, Chouteau County, Mont.

[Made at the Pittsburgh laboratory of the Bureau of Mines, F. M. Stanton and A. C. Fieldner, chemists in charge.]

Laboratory No.	Locality.	Location.				*Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
		Quarter.	Sec.	T. N.	R. E.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
	BIG SANDY FIELD.																	
14615	Mackton mine	SW	18	28	14	1.9	A	12.4	36.9	35.8	14.9	0.70					5,050	9,090
							B	10.7	37.6	36.5	15.2	.71					5,150	9,270
							C		42.2	40.8	17.0	.80					5,765	10,380
							D		50.8	49.2		.96					6,950	12,510
14613	do	SW	18	28	14	1.8	A	13.0	36.3	40.1	10.6	.53					5,340	9,620
							B	11.4	37.0	40.8	10.8	.54					5,440	9,790
							C		41.7	46.1	12.2	.61					6,140	11,060
							D		47.5	52.5		.69					6,995	12,590
6550	do	SW	18	28	14	5.5	A	12.1	34.7	41.7	11.54	.80	5.30	55.85	0.71	25.80	5,330	9,600
							B	7.0	36.7	44.1	12.21	.85	4.96	59.10	.75	22.13	5,640	10,160
							C		39.5	47.4	13.12	.91	4.50	63.52	.81	17.14	6,065	10,920
							D		45.4	54.6		1.05	5.18	73.11	.93	19.73	6,980	12,560
	MILK RIVER FIELD.																	
6473	Havre district: Electric mine	SW	29	32	16	16.3	A	22.9	29.3	34.6	13.2	.80					4,390	7,900
							B	7.8	35.0	41.4	15.8	.95					5,245	9,440
							C		38.0	44.8	17.2	1.04					5,685	10,240
							D		45.9	54.1		1.26					6,865	12,360
6640	Clacks mine	NE	5	31	17	14.2	A	25.6	28.0	39.1	7.27	.58	6.19	49.08	1.03	35.85	4,605	8,290
							B	13.2	32.6	45.7	8.47	.68	5.39	57.20	1.20	27.06	5,370	9,670
							C		37.6	52.6	9.77	.78	4.50	65.96	1.38	17.61	6,190	11,140
							D		41.7	58.3		.86	4.99	73.10	1.53	19.52	6,860	12,350
	GREAT FALLS FIELD.																	
4119	Gerber mine at Sand Coulee.	NE	23	19	4	2.6	A	7.5	27.3	51.4	13.78	2.32	4.68	62.21	.88	16.13	6,115	11,010
							B	5.0	28.1	52.8	14.15	2.38	4.51	63.87	.90	14.19	6,280	11,300
							C		29.5	55.6	14.90	2.51	4.16	67.25	.95	10.23	6,610	11,900
							D		34.7	65.3		2.95	4.89	79.02	1.12	12.02	7,765	13,980

As the results obtained by the modified and the official methods of analysis are essentially the same for the samples representing the coal in the Big Sandy field, we may compare these results directly with the results of the analyses of the coals in the Milk River and Great Falls fields. The analyses of the air-dried samples show that on the average the coal of the Big Sandy field is about 2 per cent lower in retained moisture, 3 per cent higher in volatile matter, 3 per cent lower in fixed carbon, and about 400 British thermal units higher in heating value than the coal of the Havre district in the Milk River field. As received from the mine, the coal from the Big Sandy field is about 12 per cent lower in moisture than the coal from the Havre district. The essential difference between the Big Sandy and the Havre coal seems to lie in the excessive moisture of the latter. This affects the coal in two ways, first by lowering its heating value, and second by causing the coal to slack much more readily when exposed to the air.

As compared with the coal of the Great Falls field, the coal from the Big Sandy field is about 4.5 per cent higher in retained moisture, 10 per cent higher in volatile matter, 11 per cent lower in fixed carbon, 3.5 per cent lower in ash, and 869 British thermal units lower in heating value. As received from the mine the Big Sandy coal is about 5 per cent higher in moisture than the coal from the Great Falls field. The coal from the Big Sandy field is therefore of lower grade than that from the Great Falls field, with which it must compete in the open market.

The physical and chemical properties above enumerated, the general absence of well-defined cleavage planes, and the development of irregular fractures in the coal when exposed to the atmosphere show that the Fort Union coal in the Big Sandy field belongs to the subbituminous class, but because the coal will withstand weathering for a considerable length of time before crumbling to pieces, and because of its high heat value (nearly 10,000 British thermal units), it is regarded as a high-grade subbituminous coal. The high quality of the coal is perhaps the result of metamorphism and physical conditions produced by the thrusts that have taken place in this area.

DEVELOPMENT.

The Mackton mine consists of a slope about 350 feet long, extending S. 70° E. and inclined in accordance with the dip of the strata at an angle of 40°. At 130 feet down the slope there is an upper level consisting of a north entry 75 feet long and a south entry 250 feet long. About 335 feet down the slope there is a lower level consisting of a north entry 510 feet long and a south entry, having a somewhat devious course, 360 feet long. During the winter season the output is reported to be about 100 tons a day, but in the summer season, when the demand is light, the output is much less and only a few men are employed. The mine is connected with the Great Northern Railway by a narrow-gage railway owned and operated by the mining company. The coal is sorted and sold according to grade. The best grade sells readily at the towns along the railroad in competition with other coal and is preferred to most of the coal from the Milk River field.

The Mack mine supplies a small local trade; it has no shipping connections.

Years ago a mine was operated at locality 46, chiefly to supply the Fort Assiniboine military post; this mine has long since been abandoned.

The future of the district as a coal producer is dependent almost wholly on the Fort Union coals. Because of the complicated structure, the lack of surface exposures, and the small amount of underground development, no definite statement as to the extent of the productive area can be made. It is believed, however, from the evidence obtained, that the productive area is small and is confined to the immediate vicinity of the Mackton and Mack mines.

THE HORSESHOE CREEK DISTRICT OF THE TETON BASIN COAL FIELD, FREMONT COUNTY, IDAHO.

By E. G. Woodruff.

INTRODUCTION.

From time to time during the last six or eight years there have been persistent rumors that a large field of high-grade coal lies southeast of St. Anthony. As the development of such a field would be of great advantage to a large tributary region containing extensive mining and agricultural developments, and as samples from the field seemed to corroborate the rumor regarding the quality of the coal, the writer in 1912 made a hasty examination of the field to determine its prospective value. He found that the reports concerning the quality of the coal were substantially correct, but that the beds are so broken by faults and the area known to be underlain by the beds is so small that the field will probably never supply more than the local market and can not become a factor in the development of the general region of the Snake River valley.

The location and extent of the Teton Basin coal field and the position of the Horseshoe Creek district are shown on the index map (fig. 12). The area here described lies 25 miles southeast of St. Anthony, 10 miles southwest of Haden, a village on the Teton branch of the Oregon Short Line Railroad, and a little farther west of Driggs, a larger town on the same railroad. It embraces the upper part of Horseshoe Creek drainage basin and extends northward across the south fork of Packsaddle Creek. As shown on Plate XXII (p. 388) the district covers about 6 square miles in four townships as follows:

T. 4 N., R. 43 E., 1 square mile.
T. 5 N., R. 43 E., 3 square miles.
T. 4 N., R. 44 E., 1 square mile.
T. 5 N., R. 44 E., 1 square mile.

Only a small part of the 6 square miles, however, contains coal beds which the miners in the field consider thick enough to work under present conditions.

The Horseshoe Creek district has sometimes been called the St. Anthony coal field, because some of the coal has been marketed in that town, and also because prior to the construction of the railroad

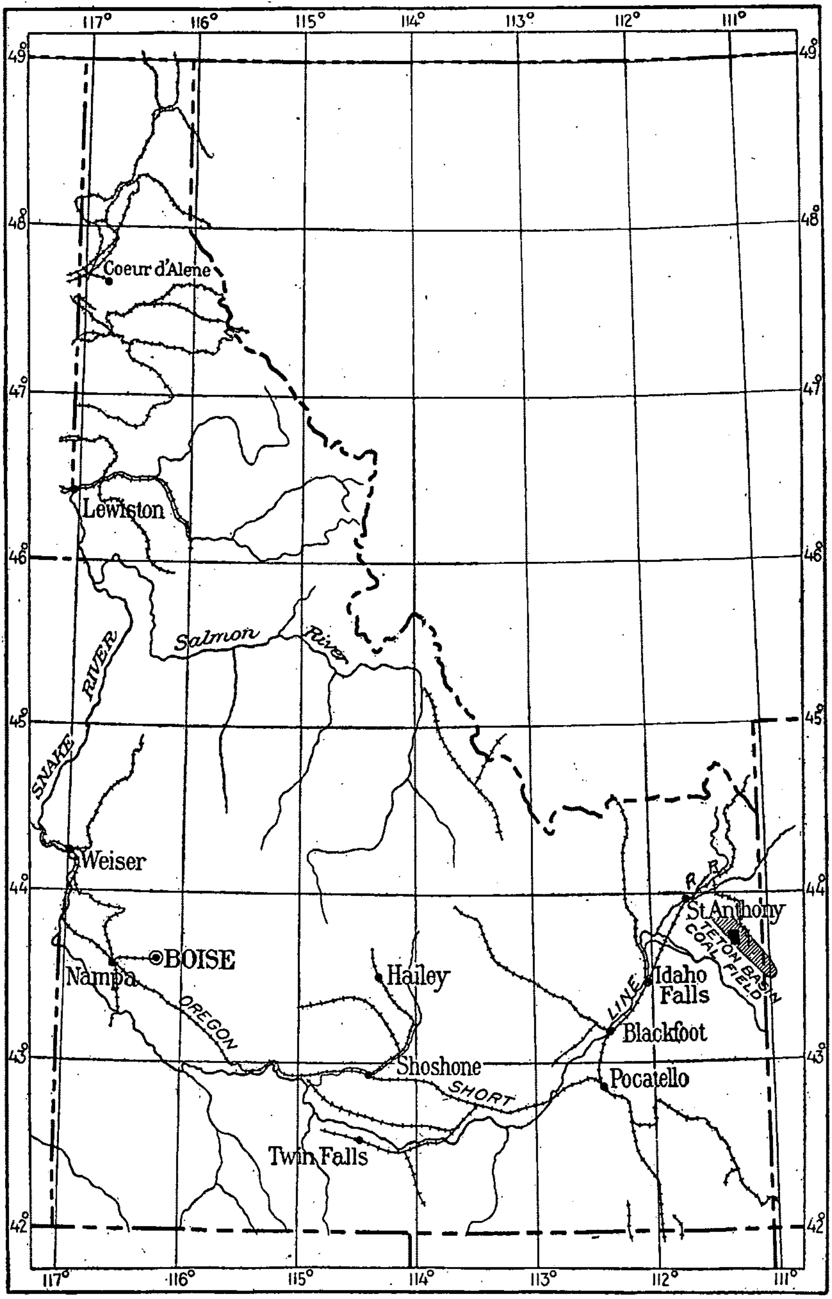


FIGURE 12.—Map showing location of the Horseshoe Creek district of the Teton Basin coal field, Fremont County, Idaho.

in the Teton Basin in the fall of 1912 St. Anthony was the gateway of the entire region. For two reasons this designation seems inappropriate—first, the area considered is only a small part of a large though indefinite field, and, second, the name applied to it is the name of a town 25 miles away. In this report the area is considered as a district of the Teton Basin coal field. This field embraces the western part of the Teton Basin and the western slope of the Big Hole Mountains. (See index map, fig. 12.) No coal has yet been found in the main part of the basin, which, however, must be considered as a possible coal field because rock formations that are coal bearing elsewhere underlie the basin and probably contain coal. It is believed that coal may be found by drilling or other means of deep prospecting. The Horseshoe Creek district is the only part of the field in which coal is now mined for market.

SURFACE FEATURES.

The surface of the district is characterized by steep slopes which are trenched by narrow steep-sided valleys. On the west the district is bounded by an escarpment which rises to a height of nearly 1,000 feet and trends north-south near the line of a great fault, shown by a broken line on Plate XXII. This escarpment is so steep that its ascent is difficult except at a few places where the rocks have broken down more completely than elsewhere and form a talus slope. From the foot of the escarpment the surface slopes northeastward to the valley of the north fork of Horseshoe Creek, in the main part of the district. From the floor of this valley there is an almost equally steep ascent to the top of a sharp crested ridge, shown by hachures on Plate XXII. From the summit of the ridge the surface slopes gently northeastward to the valley portion of the Teton Basin. The topographic features are in part shown in profile by the cross section in Plate XXII. These dominant features are modified in a minor way by streams that rise along the escarpment and flow northward in narrow steep-sided valleys, some of which are as much as 100 feet deep. Packsaddle Creek is the largest stream in the northern part of the district, and the two branches of the south fork of Horseshoe Creek are the largest in the southern part. The southern part of the district is also traversed by the main branch of Horseshoe Creek, which leaves the district through a narrow-bottomed, rather steep-sided valley. This valley affords a fairly easy grade for a wagon road into the field.

The coal-bearing part of the field is well watered, containing many small springs and perennial creeks. The surface is covered with a moderately thick growth of trees, mostly aspen and pine, which furnish an abundance of timber that is excellently suited for mine use.

GEOLOGY.

STRATIGRAPHY.

The rocks of the district comprise limestone, shale, and quartzite of Paleozoic age; sandstone, shale, and coal beds of Mesozoic age; and lava. In the Paleozoic rocks the limestone is mostly hard gray crystalline and locally somewhat fossiliferous; the quartzite is hard and light colored; and the shale is mostly soft and contains only a rather small quantity of sand. In the Mesozoic rocks the sandstone is only moderately hard and is either gray or buff colored; the shale is soft, generally very sandy, and locally carbonaceous. The coal beds are described later in this report. Lava forms the surface rock over the northern and northeastern part of the district.

No detailed stratigraphic section was measured, because neither the top nor bottom of the coal-bearing strata is exposed. The bottom of the formation lies in a valley where the older rocks are concealed by surface débris, brush, and timber, and the top, which lies along the fault, is effectually concealed by débris which falls from the escarpment. However, sufficient stratigraphic data were obtained to show that the Paleozoic strata occur mostly in thick beds, whereas some of the beds of the Mesozoic sandstone are thick and others are thin and shaly.

A determination of the age of the rocks is based on two collections of fossils, one from the top of the escarpment in the west half of sec. 36, T. 5 N., R. 43 E., and the other from the Brown Bear mine. G. H. Girty reports that the first collection contains zaphrentoid corals, Spirifer, and Compositæ, probably belonging to the Madison limestone. The collection from the Brown Bear mine, according to T. W. Stanton, includes Cardium, Lucina, and Corbula, which suggest a correlation of these strata with the Mesaverde formation of the Rock Springs field or possibly the Adaville formation of southwestern Wyoming. These identifications show that the rocks of the escarpment are Paleozoic and that the coal-bearing rocks in the center of the district belong to the Cretaceous system of the Mesozoic era. Fossils were not found in the eastern part of the district, but the stratigraphic position, thickness, and lithology of at least two of the beds exposed in the high ridge in the eastern part of the field are the same as those of beds in the escarpment; hence it is inferred that the strata at the two places are the same and that both are Paleozoic. The beds in the extreme eastern part of the field have the same lithologic character as some of the Mesozoic beds of this district.

The areal distribution of the Cretaceous is shown approximately on Plate XXII, but as the area was examined chiefly to determine the coal resources, the non coal-bearing rocks, which include both Paleozoic sedimentary beds and rather recent lava flows, were mapped as a unit and are represented by the cross-lined pattern on Plate XXII.

STRUCTURE.

As shown by the dip and strike symbols and by cross section on Plate XXII, the rocks in the main part of the district dip steeply to the southwest, whereas the strata on the east side are only slightly inclined and those on the west are horizontal. In the southern part of the district the structure is complicated, but in general the rocks dip steeply to the north. The structure of the sedimentary rocks in the northern part of the district is concealed beneath recent lava flows. The most probable interpretation of the very diverse structural phenomena is that a great fault lies along the western margin of the field (see Pl. XXII), with the downthrow on the east and the upthrow on the west, and that on the east side of the district there is a similar, perhaps equally profound, fault, along which the movement has been in the same direction. Between these two faults lies a large block of strata that is tilted downward to the west. (See cross section, Pl. XXII.) The existence of the western fault can be proved by unmistakable evidence. The amount of throw along the fault is great; according to one method of estimation it is as much as 10,000 feet. Though the fault in the eastern part of the field is concealed by débris, its existence is inferred from the fact that the dip of the rocks near the center of sec. 32, T. 5 N., R. 44 E., is much greater than that of those in the SE. ¼ sec. 28 of the same township. This difference in structure is especially noticeable when the discordance in dip is considered in connection with the relative ages of the strata at the two points. In sec. 32 the rocks are of Paleozoic age and at least 2,000 feet lower stratigraphically than those at the other locality. To reach their present relative positions the beds must have been very sharply bent upward a little west of location 15, then downward toward the west after considerable altitude was reached, or else they were faulted. It is believed that the space is too small to permit the necessary folding, and therefore it is thought that the strata have been faulted.

If there are two great faults in the district, as stated above, the rocks between them constitute a fault block which is sharply tilted to the west, as previously explained. In view of the evidence this seems probable, and the cross section on Plate XXII is drawn on that basis.

Besides the major breaks mentioned above there are many minor faults, which have been found wherever the strata are exposed over any considerable area. The abundance of the faults at some places is shown by the plan of the Brown Bear mine, presented at the bottom of Plate XXII. The horizontal extent of the minor faults ranges from a few rods to as much as half a mile and the amount of throw from a few inches to many feet. The effect of these structural movements on the coal beds is discussed later.

THE COAL.

CHARACTER AND DISTRIBUTION.

As shown on Plate XXII, the coal beds outcrop along the slope at the foot of the escarpment and extend downward to the fault in the western part of the field. As the beds are faulted and the outcrops badly covered, it is impossible to trace them for any considerable distance, but certain key rocks were found which assist in the correlation of the beds. A probable connection of the beds at the south end of the field with those exposed in the center and north end is shown on the map. In examining this map, however, it should be borne in mind that the line shows only approximately the position of the outcrop. The exact position can be determined only by a system of prospecting which will explore the bed below the surface. The coal beds occur in two groups about 1,100 feet apart stratigraphically, the lower group being represented at locations 5, 6, 7, 9, 10, and 13 on the map and the upper at locations 8 and possibly 1, 2, 3, and 11. It is probable that the so-called upper group contains only one bed and that the apparent occurrence of more than one bed is due to faulting, which has duplicated its outcrop. The lower group consists of three beds in the northern part of the field, one in the central, and two in the southern part. From the difference in the number of beds in the groups at different localities it is evident that the beds are not continuous. They also differ in thickness and character, but the data obtained do not show conclusively to what extent. The difference is indicated, in part, however, by a comparison of the two sections measured in the Brown Bear mine, 1,200 feet apart, one having a total thickness of 4 feet 5 inches and the other 5 feet 3 inches. These sections are presented on page 387 of this report.

The coal is black and hard, but, as would be expected in a region where so much faulting has taken place, it is badly broken. In mining a large percentage of it comes out fine, and even the larger pieces are so shattered that they do not stand handling well. The coal is bituminous and rather free from impurities, but noncoking, according to the agate-mortar test. The chemical properties of the coal are presented in the following table of analyses, which also shows analyses of samples from other fields for comparison.

The sampling was done according to the regulations of the Bureau of Mines,[1] which in brief requires that the face to be sampled must be cleared of weathered coal, powder stains, and the like, and then a channel cut across the bed to obtain the sample, at the same time large partings and lumps of impurities being rejected. The sample is collected on a sampling cloth, broken up to pass through a half-inch mesh sieve, mixed thoroughly, quartered, mixed again, and

[1] For a detailed discussion of the method of coal sampling, see Holmes, J. A., The sampling of coal in the mine: Bur. Mines Technical Paper 1, 1911.

finally the sample is placed in a sealed can, to be forwarded to the chemical laboratory.

Analyses of coal samples from the Horseshoe Creek district, Teton Basin coal field.

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

Locality.	Laboratory No.	Air-drying loss.	Form of analysis.[a]	Proximate.				Ultimate.					Heating value.	
				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Brown Bear mine	15115	8.3	A	11.5	37.2	47.0	4.30	0.54	5.94	68.09	1.40	19.73	6,720	12,090
			B	3.4	40.6	51.3	4.69	.59	5.47	74.25	1.53	13.47	7,325	13,190
			C	....	42.0	53.1	4.86	.61	5.27	76.89	1.58	10.79	7,590	13,660
			D	....	44.2	55.8	.....	.64	5.54	80.82	1.66	11.34	7,975	14,360
Horseshoe mine	15116	4.3	A	7.7	39.7	50.4	2.2	.38	.....	......	......	......	7,155	12,880
			B	3.6	41.5	52.6	2.3	.40	.....	......	......	......	7,475	13,460
			C	....	43.0	54.6	2.4	.41	.....	......	......	......	7,755	13,960
			D	....	44.1	55.9	.....	.42	.....	......	......	......	7,945	14,300
Union Pacific mine, No. 1, Rock Springs, Wyo.	5358	2.3	A	8.5	35.6	50.4	5.48	.78	5.36	66.15	1.19	21.04	6,575	11,830
			B	6.4	36.4	51.6	5.61	.80	5.22	67.71	1.22	19.44	6,730	12,110
			C	....	38.9	55.1	5.99	.85	4.82	72.32	1.30	14.72	7,185	12,940
			D	....	41.4	58.6	.....	.90	5.13	76.93	1.38	15.66	7,645	13,760
Diamondville No. 1 mine, Kemmerer, Wyo.	2284	1.3	A	5.1	40.5	49.8	4.61	.49	5.63	72.95	1.18	15.14	7,200	12,960
			B	3.9	41.0	50.4	4.67	.50	5.56	73.91	1.20	14.16	7,295	13,140
			C	....	42.7	52.4	4.86	.52	5.33	76.89	1.24	11.16	7,590	13,660
			D	....	44.9	55.1	.....	.54	5.61	80.82	1.31	11.72	7,980	14,360
Wasatch mine, Coalville, Utah.	2408	6.9	A	13.9	38.0	43.7	4.4	1.03	.....	......	......	......	6,080	10,940
			B	7.5	40.8	46.9	4.8	1.11	.....	......	......	......	6,530	11,750
			C	....	44.1	50.7	5.2	1.20	.....	......	......	......	7,060	12,710
			D	....	46.5	53.5	.....	1.27	.....	......	......	......	7,445	13,410

[a] The form of analysis represented by A, B, C, and D is as follows: A, coal as obtained in the mine; B, coal dried at a temperature of 30° to 35° C.; C, moisture-free coal; D, coal free from moisture and ash.

Sample No. 15115, from the Brown Bear mine, was taken from the end of the north entry, 950 feet from the portal, where mining had been done recently and where the coal was unweathered. The sample is believed to represent the coal in its normal condition. For section of coal bed where sampled see page 387.

Sample No. 15116, from the abandoned Horseshoe mine, was moderately weathered. It was taken at a point about 200 feet from the portal, from a face which had been exposed for more than a year. The surface was cleaned until apparently fresh coal was obtained, but it seems probable that some change, which did not alter the physical appearance of the coal, must have taken place, because the mine is in a dry climate and had remained open to the unrestricted circulation of the air for a long time. It seems most probable that this exposure to the air had resulted in partial oxidation which decreased the heat value below that of unaltered coal. Nevertheless the sample gave a higher calorific value than the unweathered coal from the Brown Bear mine. This is probably to be explained in part by the smaller amount of ash in the Horseshoe sample. For section of bed where sampled see page 387.

DEVELOPMENT.

There are two producing mines in the field, the Brown Bear mine (location 9) and the Boise (location 8).[1] Mining and prospecting have been done at other places but at present no development work is in progress. At the northern end of the field, along Packsaddle Creek, there are several abandoned openings, and in the southern part there are two abandoned mines.

Location 1.—At location 1 there is a caved drift. The bed is reported to be 9 feet thick and to terminate at a fault. It is probable that the report of the thickness is exaggerated or that it is abnormal, the coal being squeezed into a pocket. A bed exposed at one place near the portal of the drift is 14 inches thick, but this may not be the bed reported to have been encountered farther back.

Location 2.—At location 2 there is a dump composed in part of coal. The opening from which the coal came is caved, hence no data as to the character of the bed were obtained.

Location 3.—At location 3 there is a prospect pit 6 feet deep in which a coal bed is exposed. The coal occurs in two benches separated by 10 inches of shale, the upper bench being 19 inches thick and the lower 11 inches. The character of the bed is shown by section 3 on Plate XXII.

Location 4.—At location 4 there is an abandoned entry in which 40 inches of badly crushed coal is exposed. At this place the bed appears to have been distorted, hence the normal thickness could not be determined.

Locations 5, 6, and 7.—At locations 5, 6, and 7 there are prospect pits in which sections of the coal beds exposed are as follows: At location 5, 40 inches of coal; at location 6, 13 inches of coal; at location 7, in two benches of coal, 8 inches thick, separated by a 3-inch parting of very impure coal. Graphic sections of these beds are shown in Plate XXII.

The Boise mine (location 8).—The Boise mine consists of a rock tunnel 150 feet long, crosscutting the strata, and an entry 200 feet long extending along the bed from the point where the tunnel enters the coal. The bed (see section 8, Pl. XXII) is 38 inches thick and lies between beds of shale. It is cut by several small faults which displace the beds from 6 inches to 2 feet. At the time of examination no coal was being produced, though preparations had been made to mine a few tons daily.

Brown Bear mine (location 9).—The Brown Bear mine consists of a horizontal rock tunnel 325 feet long from the surface to the coal bed and two horizontal entries, one to the north and the other to the south, following the bed. The plan of this mine is presented in Plate

[1] Location numbers refer to corresponding numbers on Pl. XXII.

XXII. Stopes are worked above the entries and the coal is taken down through chutes into the mine cars. The Brown Bear, which is the chief producing mine in the field, has an output of a few tons a day during busy seasons in the fall and spring. Sections of the bed at opposite ends of the mine are as follows:

Sections of coal bed in Brown Bear mine.

North end of mine.

	Ft.	in.
Shale.		
Coal [1]	3	11
Shale		3
Coal [1]	1	1
Shale.		
	5	3

South end of mine.

	Ft.	in.
Shale:		
Coal	2	10
Coal, crushed	1	7
Shale.		
	4	5

Location 10.—At location 10 a bed of coal represented by section 10, Plate XXII, is exposed in a surface opening. This is believed to be the bed worked at the Brown Bear mine and is without doubt the one worked at the Horseshoe mine.

Locations 11 and 12.—At location 11 there is an abandoned entry 50 feet long and at location 12 a surface opening on the same bed. A section on this bed is as follows:

Section of coal bed at location 11.

	Ft.	in.
Sandstone.		
Shale, carbonaceous		2
Coal	2	2
Shale.		
	2	4

Location 13.—The Horseshoe (abandoned) mine (location 13, Pl. XXII) consisted of a single entry 500 feet long extending north from the side of a steep hill where the bed was exposed. Though badly caved, the mine can be entered for a distance of 200 feet. At that point the following section, shown graphically in Plate XXII, is exposed:

Section of coal bed exposed in the Horseshoe mine.

	Ft.	in.
Shale.		
Coal [1]	1	11
Sandstone		10
Coal, crushed [1]	3	4
Coal, bony	1	9
Coal, crushed [1]	3	3
Shale.		
	11	1

Location 14.—At location 14 there is a small prospect in some slump material which contains fragments of coal.

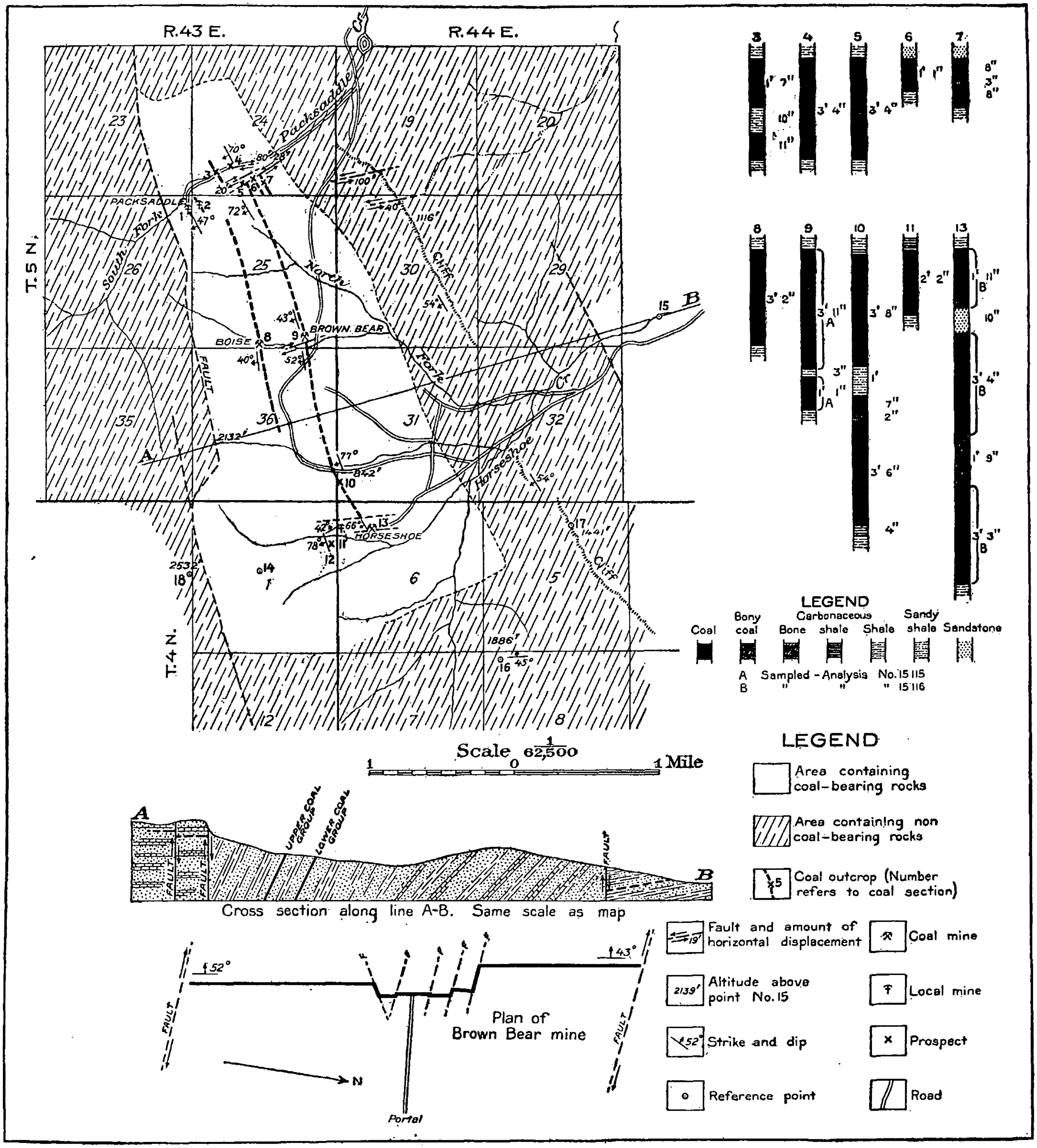
Location 15.—The extent of the coal encountered in the two prospects at location 15 was not determined, because the openings are

[1] A sample of these benches was analyzed with the results shown in the table on p. 385.

now caved and the coal is concealed. The size of the dumps indicates that considerable work has been done and some coal taken out. It is reported that the bed is thin, and the fact that this work was abandoned for locations farther from market and where the stratigraphic conditions were less favorable indicates that the prospect was not promising. This prospect lies in a valley with lava-covered hills to the north and débris-strewn hills to the south. About one-half mile east of the prospects lava caps the hills to the south also and forms the mountain slope on both sides of the creek. The exposed area of coal-bearing rocks is therefore small and confined to the valley of Horseshoe Creek.

CONCLUSIONS.

The Horseshoe district contains beds of excellent coal thick enough to be mined profitably if they were horizontal, but the steep dip of the beds and the numerous faults render mining expensive, difficult, and uncertain. The beds are irregular in thickness and extent. One of them most probably extends throughout the district, but others are certainly less extensive. Timber and water are abundant, especially water, the supply of which far exceeds the requirements for mining. The district is situated in a region where there is considerable local demand for coal for domestic fuel that now is supplied from mines at a distance. From the data obtained the writer concludes that this district can profitably supply a domestic trade for a long time, but that it can not be reckoned as a factor in the great coal trade of the Rocky Mountain region.



MAP AND SECTIONS OF THE HORSESHOE CREEK DISTRICT OF THE TETON BASIN COAL FIELD, FREMONT COUNTY, IDAHO, AND PLAN OF BROWN BEAR MINE.

By E. G. Woodruff.

THE GLACIER COAL FIELD, WHATCOM COUNTY, WASHINGTON.

By E. G. Woodruff.

INTRODUCTION.

The Glacier coal field of Whatcom County is not a producing field but has attracted considerable attention because it contains anthracite in at least one place and thin beds of bituminous coal in several other places. The information upon which this report is based was

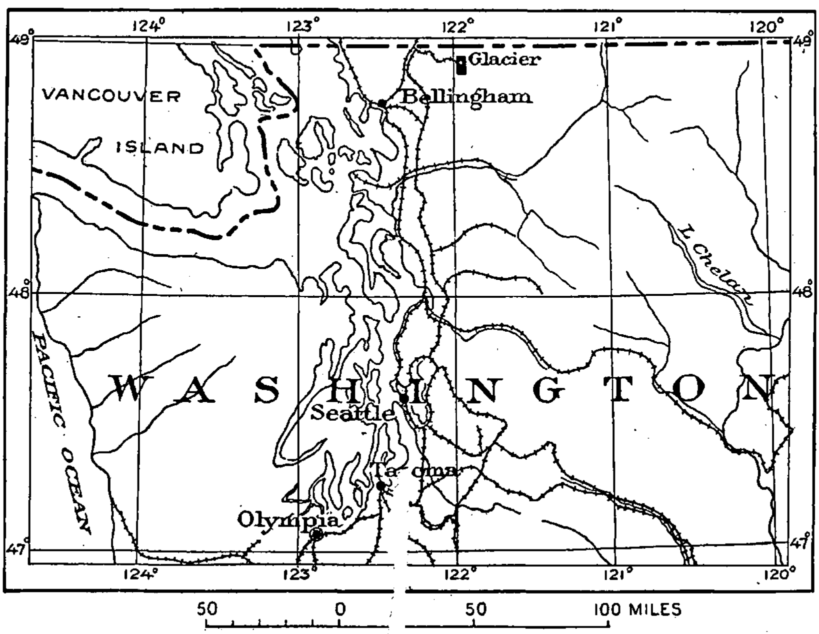


Figure 13.—Map showing location of the Glacier coal field, Whatcom County, Wash.

obtained by the writer in the fall of 1912, but the data for the map (Pl. XXIII, p. 398) were supplied chiefly by Prof. Henry Landes, director of the State Geological Survey of Washington, who also advised the writer concerning the geology of the area and the field methods best adapted to the work.

The Glacier coal field lies in the north-central part of Whatcom County, Wash., in the vicinity of the village of Glacier, which is the terminus of the Bellingham Bay & British Columbia Railroad. (See fig. 13.) The coal-bearing rocks are reported to extend westward from Glacier toward Bellingham Bay, but it was not practicable to extend the present survey in that direction as far as the boundary of the field; consequently the report was not verified. The area considered here embraces about 25 square miles in the western part of T. 39 N., R. 7 E., Willamette base and meridian, and sec. 24 of the township to the west and sec. 31 of the township to the north.

SURFACE FEATURES.

The Glacier coal field lies on the west face of the Cascade Range, where the slope rises at the rate of nearly 1,000 feet to the mile. The lowest point in the field is on North Fork of Nooksak River near the northwest corner of the field, at an altitude of about 900 feet, and the highest point is on the southern border at an altitude of about 5,000 feet. In the part of the field described in this paper the difference in altitude is about 4,000 feet. The only level ground is the narrow, bowlder-strewn valleys of Nooksak River and Glacier Creek; elsewhere the slopes are steep and cliffs are not uncommon. The mountain sides are so steep and uneven that they can be traversed only on foot or with pack animals along a few trails.

The area is drained by North Fork of Nooksak River, which crosses the northern edge, and by Glacier Creek, which enters near the southeast corner, follows the east side for a distance of 4 miles, then turns northwest to its junction with the main stream near the village of Glacier. Normally these streams are perennial and contain a moderate quantity of swiftly flowing, clear, cold water, but at times of freshet they become torrents. Numerous brooks rise high on the mountain slopes and flow in steep-sided valleys and over cascades at short intervals.

Except where the timber has been cut the mountain slopes are covered by a thick growth of splendid trees, some of which are as much as 5 feet in diameter and 250 feet high. These trees are so large and have grown so closely together that the traveler can seldom see more than a few hundred feet. The ground is covered by vegetable matter composed of fallen twigs, cones, and needles from the trees, and fragments of underbrush.

GEOLOGY.

GENERAL CONDITIONS IN THE AREA.

The dense forests which cover most of the field, together with the thick layer of vegetable mold, render geologic examination difficult. The problem is additionally complicated by the prevalence of landslides, which constitute a large part of the surface débris. These slides are not, as is sometimes popularly supposed, masses of rocks which have been loosened from the mountain side and precipitated into the valley below, but they are large masses of rock which have moved slowly and are now at rest or are very slowly moving down the mountain side. In some of these slides the rocks have been broken up and the fragments intermingled, whereas in others the mass has moved as a unit and in many places it is impossible to tell whether the rocks in an outcrop are in place or not.

A satisfactory study of the geology of the field is impossible on account of the dense forests, thick vegetable mold, and rock débris concealing the beds, except on the steep slopes and along the stream channels; hence conclusions must rest mainly on inference.

STRATIGRAPHY.

During the examination here described no new stratigraphic information was obtained. Smith and Calkins, in 1901, made a reconnaissance across the Cascade Range and published the earliest report[1] on this general region. A good collection of Eocene fossils had been obtained at Keese, about 8 miles down the river from Glacier, and they therefore referred the strata in that locality to the Eocene. They state that the strata on the river a few miles above Glacier do not resemble the Eocene rocks lithologically, but are very similar to the Cretaceous strata to the west, and on these grounds they doubtfully referred them to the Mesozoic. They collected no fossils in the immediate vicinity of Glacier, but have stated to the writer that the coal-bearing strata closely resemble the Eocene beds farther down the river. Landes,[2] however, states that Upper and Lower Cretaceous fossils were found on the Mount Baker trail at a point about 4 miles southeast of Glacier. This place is about a mile east of the coal field and directly on the strike, so that unless a fault intervenes the coal-bearing strata would seem to be Cretaceous. If they are Cretaceous, however, the Glacier field is the only one known in Washington in which the coal is older than Eocene, and furthermore it is reported that the coal-bearing rocks extend from Glacier southwestward, probably at least as far as the area in which the rocks are definitely known to be Eocene. Finally, despite the presence of Cretaceous fossils a short distance from the coal field, the lithologic resemblance between the actual coal-bearing strata and the beds known to be Eocene must also be considered. Owing to the complexity of the geologic structure in this area and to the probability of faulting, it is impossible definitely to assign the coal-bearing rocks either to the Eocene or to the Cretaceous, although the evidence seems to indicate that they are Eocene.

The coal-bearing rocks are sandstone and shale, which rest on crystalline igneous rocks or schists. The sandstone is by far the

[1] Smith, G. O., and Calkins, F. C., A geological reconnaissance across the Cascade Range near the forty-ninth parallel: U. S. Geol. Survey Bull. 235, 1904.

[2] Landes, Henry, Notes on the Glacier coal field: Pacific Min. Jour., vol. 2, No. 4, p. 61, 1913.

most abundant. A few measurements made by the writer in the coal-bearing portion of the formations showed about 90 per cent of the strata to be composed of sandstone and 10 per cent of shale. These measurements, however, were not extensive and possibly did not encompass representative sections of the strata. Prof. Landes has done considerable work in the region and estimates the shale to comprise about 60 per cent and the sandstone 40 per cent of the different formations. The sandstone occurs in massive beds, which are separated from one another by thinner beds of shale containing coal at some places. This relation of thick beds of sandstone and thinner beds of shale has had an important bearing on the metamorphism of the coal and the deformation of the bed as explained on a later page. The shale is generally very sandy, but some of it has evidently been derived from fine silt intermingled with vegetable débris and is therefore very carbonaceous and consequently brown or black. At some places the black shale has been mistaken for coal or "coal blossom" or "leads" and the bed prospected. In fact, many of the prospects in the field have followed these so-called coal leads, but have found no coal.

STRUCTURE.

The field lies on the north flank of the mountain ridge which extends westward from Mount Baker. The general dip of the beds is northwest in the eastern part of the field but is slightly east of north in the western part. The dip is steep, being about 45°, except on the extreme west edge of the field, and locally is as much as 68°. Measurements at different places are shown in Plate XXIII. No faults or local folds were worked out, but undoubtedly some exist, though probably none are very extensive. The coal-bearing strata are so concealed that it is impossible to determine the details of structure, but the discordance in the dip and strike in secs. 18, 19, and 20 points to the conclusion that the beds are probably faulted at several places. Unquestionably, however, great movements of the strata have taken place in the region, and there has been profound folding and faulting. These disturbances were not produced by a sudden heaving, twisting, and breaking of the strata, but by movements continued through a considerable time, during which the coal beds were squeezed and distorted and the coal transformed from low to high grade.

THE COAL.

GENERAL CHARACTER OF THE BEDS.

The field contains a large number of thin beds of coal that is mostly dirty, though locally free from impurities. During the movements of the strata discussed above the coal beds have been pinched out at some places and forced into abnormal shapes at others, and the coal has been fractured or crushed. In fact, at some places the beds seem to have been subjected to a kind of kneading action, as indicated by the directions of the slickensiding. This variety in direction of movement is shown at Discovery tunnel, where on a few square feet of exposed surface the slickensides are horizontal in some layers, inclined 70° from the horizontal in other layers, and 30° in the opposite direction in others. Within a space of a few square yards almost every direction is indicated by the striæ in the coal or shale. The effects of the compression seem to have been concentrated or accentuated in the more plastic shale and coal because they are soft and yielding and comprise a minor part of the strata. As a result of the preponderance of sandstone, as determined by the writer, the shale and coal beds have been forced to conform to new spaces between the more resistant beds because the shale and coal are softer than the inclosing rocks, and consequently the coal has been squeezed into pockets, some of which have considerable thickness but small extent, whereas at other places the beds are pinched and broken.

CHARACTER OF THE COAL.

The coal of this field ranges in quality from subbituminous to anthracite. At a few places there are thin seams of subbituminous coal and at others beds of bituminous coal and anthracite, but both the low and high grades are not found in the same strata. Only the bituminous and anthracite are abundant enough to be considered. Complete chemical analyses have not been made because unweathered material could not be obtained, but from physical appearance the coal at the Discovery and No. 2 tunnels is a good grade of anthracite. Elsewhere in the field, however, it is bituminous, generally impure, and almost everywhere badly crushed and slickensided. Selected specimens are reported to compare favorably with the best grade of Pennsylvania anthracite, but it is the opinion of the writer that a representative sample of any bed will fall considerably below that standard in calorific value, because the amount of impurities is greater than in Pennsylvania anthracite. Three partial analyses with a field chemical testing outfit showed the ash to be 35 per cent in one sample, 54 per cent in another, and 74 per cent in another. The strata are saturated with water, which has prevented atmospheric weathering from extending to any considerable depth.

As the coal differs from place to place, further details of its character are presented under the description of the prospects.

PROSPECTS.

Considerable prospecting and some fairly deep exploration work have been done in the field, but as previously explained the surface in many places is composed of slide material which covers and conceals the rocks in place. This disturbed condition of the surface causes prospecting to be uncertain. Some of the tunnels have been started in regularly bedded rocks, which were erroneously thought to be in place, and have terminated in zones of broken rock at the bottom of the slide or entered entirely different strata, over which the prospected beds are found to have slid. Some of these unbroken masses include coal beds which seem to the superficial observer to be in place, but prospecting shows that the bed terminates a short distance below the surface. This condition has led to the unsuccessful ending of several prospect tunnels. In considering this field it should be borne in mind that drill holes or even prospect tunnels can not determine the coal resources, because the beds are so irregular that a test at one place does not indicate the conditions that may be found a short distance away.

As a result of the steep dip of the strata prospects have been opened to follow the beds, which are highly inclined from the horizontal, as in most metalliferous veins. Entries have been driven along the beds and stopes opened or crosscuts dug at promising points.

The following detailed description of prospects begins with those in the northeast corner of the field and proceeds southward by tiers of sections, each tier being considered from east to west. The location of each prospect is shown by the corresponding number on Plate XXIII (p. 398).

Hurst prospect.—The Hurst prospect (location 1), in the southeastern part of sec. 31, T. 40 N., R. 7 E., is about a mile from Glacier. It consists of a prospect rock tunnel 200 feet long and a slope 75 feet deep, which starts in a coal bed about midway of the tunnel. It is possible that the tunnel penetrates only an unbroken rock slide and terminates in country rock at the back. At any rate, the tunnel ends in non coal-bearing rock. A possible explanation for this condition is that the coal-bearing strata are cut off by a fault. The coal bed lies between two thick-bedded sandstones dipping 35° N. It is extremely irregular, occurring in small lenses, the largest being 6 inches in greatest thickness and 10 feet in length. The bed followed by the slope consists mainly of shale, but contains some coal. The coal is bituminous. At the time of examination no work was in progress, and apparently the prospect had been abandoned.

Hinton prospect.—The Hinton prospect (location 2), in the NW. ¼ sec. 6, T. 39 N., R. 7 E., comprises a tunnel 250 feet long, entirely in thick-bedded sandstone, except through about 8 feet of its length, which is in soft slickensided shale. This shale contains a lens of bituminous coal 4 inches thick and less than 10 feet long. The bed dips 45° N., and strikes N. 75° E. At the time of examination this tunnel was abandoned.

Location 3.—At location 3 there is a tunnel which penetrates surface débris to a depth of 125 feet and terminates in a distorted bed of slickensided shale and bituminous coal 5 feet 2 inches thick. The bed is so much distorted that its normal condition can not be fairly inferred. A most liberal interpretation of the indications of coal, however, points to the conclusion that the bed is valueless.

Armstrong prospect.—The Armstrong prospect (location 4) consists of a tunnel penetrating loose débris to a depth of 75 feet and terminating in a bed of carbonaceous shale 2 feet thick. No coal was found.

Brooks prospect.—At the Brooks prospect (location 5) there is an entry 125 feet long on a coal bed between beds of sandstone which dip 45° S. The following section is exposed at the end of the entry:

Section of beds exposed at the end of Brooks entry.

	Ft.	in.
Top, sandstone.		
Shale, carbonaceous, badly crushed	4	5
Coal, badly crushed	1	8
Sandstone, thick bedded.		
	6	1

The coal appears to be of good quality, but contains impurities disseminated through it. A determination with the field-testing outfit showed 54 per cent of ash. If the coal in this bed were good and the bed easily accessible, or if the bed were moderately impure and the impurities associated with the coal in such a way that they could be washed out, the bed might be mined, but as such conditions do not exist, and as the coal is in pockets, it is believed that systematic and economic mining can not be carried on.

Powers prospect.—The Powers prospect (location 6) consists of an entry 115 long in strata that dip 65° N. The prospect presents an excellent sample of the pockety character of beds and the crushed condition of the coal in this field. At one place in the entry the bed reaches a maximum thickness of 23 inches, but 2 feet from that point it is 17 inches thick, and 5 feet away only 13 inches. Thus, in a distance of 7 feet, the bed has decreased from 23 inches to 13 inches. The coal is very much crushed and slickensided, and contains 35 per cent of ash, some of which is not intimately mixed with the coal. Probably the coal could be improved to a marketable grade by washing if the bed were thick enough and continuous enough to be mined.

Location 7.—At location 7 there is a tunnel 250 feet long, in which an 18-inch bed of shale, containing some crushed coal, is exposed.

Location 8.—At location 8, on the opposite side of the creek and a little to the south from location 7, a tunnel 125 feet long exposes a bed of crushed coal 20 feet long with a maximum thickness of 6 inches. The coal lies between thick beds of sandstone.

Location 9.—A test hole was sunk with a diamond drill at location 9 to a depth of 500 feet. It is reported that no coal was found. The drill, which was vertical, formed an angle of 25° with the bedding planes and thus went diagonally instead of directly through the strata. Consequently the hole, although drilled to a depth of 500 feet, tested only a little more than 200 feet of strata.

Location 10.—At location 10, near the middle of the north line of the NW. ¼ sec. 20, a tunnel runs S. 20° W. for a little more than 150 feet and then southeast 100 feet. In this tunnel are exposed two lenses of black carbonaceous shales and one bed of carbonaceous shale in which there is a seam of crushed lignite 2 inches thick.

Location 11.—At location 11 a tunnel 50 feet long has been driven chiefly in sandstone. A few feet from the portal a 4-inch seam of highly carbonaceous shale has been altered locally to an impure graphite. About 100 feet southwest from the portal of the tunnel in the bottom of the valley, a small prospect in lower strata contains a very irregular pocket of crushed bituminous coal less than 3 feet in greatest thickness. Elsewhere along the outcrop of this bed the maximum thickness was found to be 3 inches, but the coal bed appeared to have been squeezed below its normal thickness.

Location 12.—The following section of strata is exposed at location 12:

Section of strata exposed in the SE. ¼ sec. 19.

	Ft.	in.
Top, sandstone, gray, massive; contains impressions of plants.		
Shale, carbonaceous, slickensided	1	2
Sandstone, black, shaly; contains impressions of plants; greatest thickness	1	8
	2	10

Location 13.—An entry has been dug to a depth of 45 feet at location 13. In this prospect a bed of crushed carbonaceous shale contains seams of coal. The thickness of the shale bed is very irregular. It is thin near the portal, increases to 36 inches at a depth of 30 feet, decreases to 14 inches 9 feet from that place, and is absent at the end of the entry. The thickest seam of coal in the bed has a maximum thickness of 4 inches, but even that appears to be in a pocket. The coal is bituminous.

Location 14.—At location 14, in sec. 19, a tunnel 40 feet long cuts the edge of a lenticular pocket of coal. A cross section of the tunnel is a broad oval in outline, about 6 feet high and 4 feet broad. The coal bed cuts diagonally across the face of the tunnel. Near the floor the coal seam is less than 1 inch thick, but it increases to 8 inches at the top of the tunnel. In a distance of a little more than 6 feet the bed changes from 6 inches in thickness to 1 inch. The coal, which lies between beds of massive sandstone that are much more resistant than the coal, is badly slickensided and appears to have been squeezed into its present form. A partial analysis of the coal showed it to contain 74 per cent of ash.

Hinton's prospect.—The Hinton prospect (location 15) consists of two entries, one 50 feet above the other, on a bed of coal lying between thick beds of sandstone which dip 56°. The lower entry is 15 feet long and contains a stringer of slickensided coal which ranges from a feather edge to 6 inches thick. The upper prospect is 50 feet long and contains crushed shale but no coal.

Bellingham Bay & British Columbia mine.—The Bellingham Bay & British Columbia mine (location 16), is reported to have been extended more than 1,000 feet along the strike of a coal bed before it was abandoned, but only the first 150 feet was examined by the writer. At the portal the following section is exposed:

Section of strata exposed at the portal of the Bellingham Bay & British Columbia tunnel.

	Ft.	in.
Sandstone.		
Shale, shattered	2	
Coal, slickensided, bituminous	1	5
Shale, crushed	3	6
Coal, slickensided, bituminous		6
Shale, crushed.		
	7	5

At two other places carefully examined, namely, 50 feet and 150 feet from the portal, no coal was found. On the mountain side, about 100 feet above the portal, the bed is thinner; 200 feet above the portal its thickness is still more diminished; and a little higher up it has disappeared. Evidently the bed consists of a small lens or pocket. This coal is fairly good. A partial analysis gave 5.3 per cent ash.

Tunnel No. 2.—Tunnel No. 2 (location 17) is reported to be 700 feet long. The writer examined the first 325 feet, which is believed to fairly represent the whole entry. In that distance the beds are crushed, slickensided, distorted, and locally metamorphosed. The thickness of the bed differs so that measurements do not represent conditions 100 feet away. At a point 325 feet from the portal the coal appears to lie in a pocket 3 feet thick, containing bright anthracite in the upper part and finely crushed bituminous coal in the lower part. Because the strata are badly disturbed no good dip measurement could be obtained, but a fairly reliable reading gave 69°. At the time of the examination the entry was deserted and workmen were starting a new one a short distance to the west but had not passed through the thick surface débris.

Discovery tunnel.—Discovery tunnel (location 18), reported to be between 750 and 780 feet long, is the most promising prospect in the field. At the time of examination the tunnel was closed and was filled with inflammable gas. It is said that the following section is exposed at the end of the tunnel:

Section of coal bed reported to be exposed in Discovery tunnel.

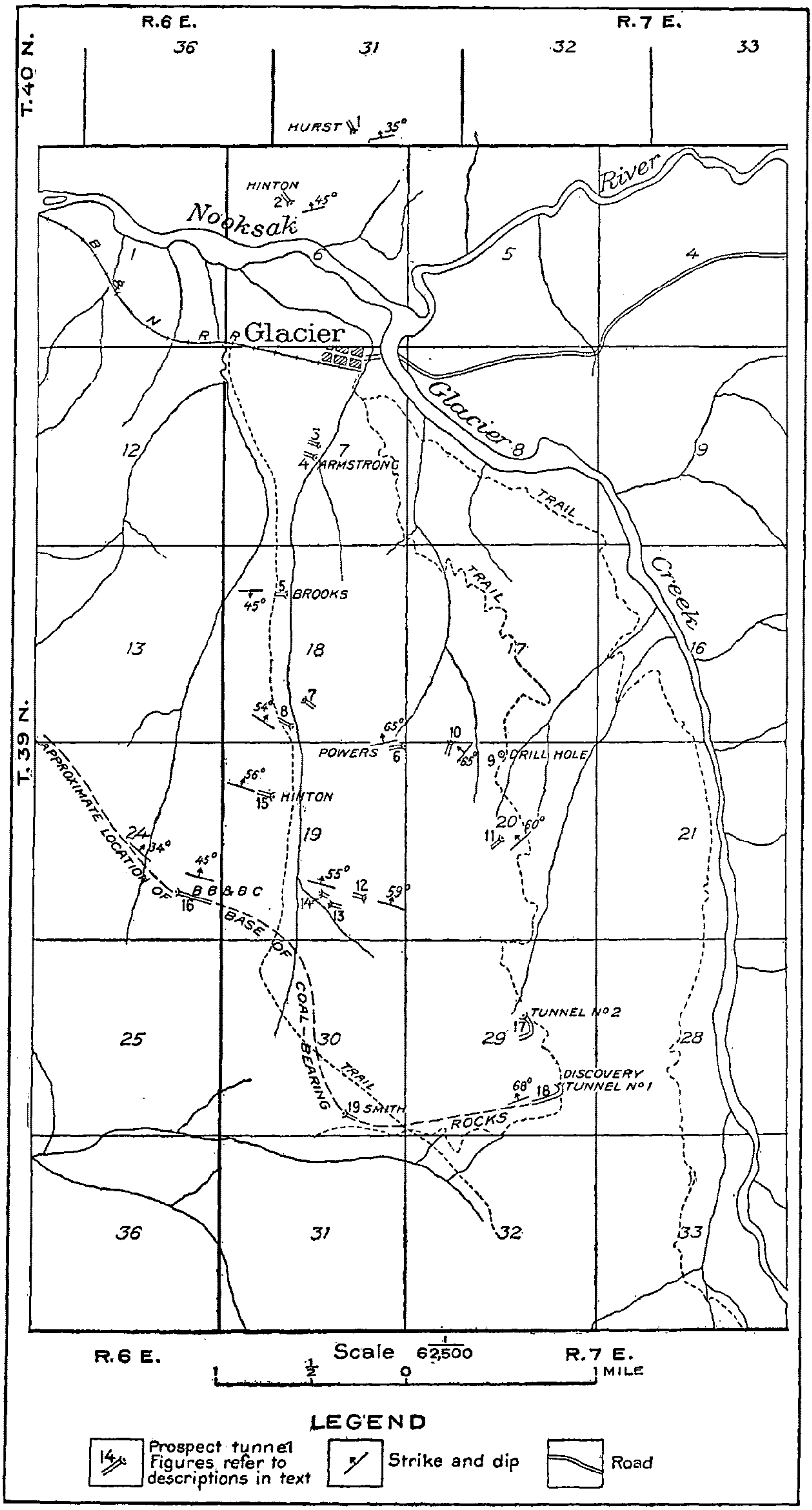
	Ft.	in.
Slate.		
Coal	2	2½
Bone	1	1
Coal	6	9
Slate.		
	10	½

Along the outcrop, about 100 feet from the tunnel, the bed is thinner than in the tunnel, but in the short distance that it is exposed it seems to increase abruptly downward, indicating that the tunnel enters a pocket. The coal, which is anthracite, is badly crushed and slickensided and in general breaks into small, irregular lumps. It is estimated that more than 50 per cent of the coal is crushed into pieces less than 1 inch by 3 inches. Some pieces are 6 or 8 inches in diameter and a few are as much as 1 foot. It is believed that this tunnel enters an exceptionally thick lens of coal, but it is inferred that the lens is not extensive, because 100 feet above the tunnel it is thinner than it is reported to be in the tunnel and it seems to decrease in thickness upward. This conclusion is strengthened by the fact that there is only a little coal in the Smith tunnel a mile west at the same stratigraphic horizon.

Smith tunnel.—The Smith tunnel (location 19) is about 300 feet long in rocks which are so badly disturbed that a fair estimate of the amount of coal can not be made. The coal is found in a distorted bed of shale which ranges from 4 feet to a feather edge within a horizontal distance of 100 feet and in general is less than 6 inches thick.

CONCLUSIONS.

The field has been prospected extensively but contains no mine except Discovery No. 2 and the Bellingham Bay & British Columbia mine, abandoned some years ago. The beds have been tested by prospects at various stratigraphic horizons, especially in the lower part of the sedimentary rocks, which seem to contain the most coal. These prospects have shown that the coal occurs in pockets that differ greatly in size. The largest pocket found is at Discovery tunnel No. 1, but it is probable that even larger ones may be found. The coal is mostly anthracite or high-grade bituminous, but some of it is lower grade. Generally the percentage of ash in the coal is very high, especially when the whole of the bed is considered. From the data obtained the writer concludes that the field contains coal in pockets, some of which are large enough to furnish a small supply of fuel, but as yet the prospecting has not developed coal enough to warrant the expectation that the field will produce coal in commercial quantities.



MAP OF THE GLACIER COAL FIELD, WHATCOM COUNTY, WASH.

By E. G. Woodruff.

THE EDEN RIDGE COAL FIELD, COOS COUNTY, OREGON.

By C. E. Lesher.

INTRODUCTION.

It has long been known that Eden Ridge, Oreg., is underlain by coal, and a large amount of prospecting has been done on the ridge and more recently in the Squaw Basin, immediately to the south. The beds first discovered are so bony that their ultimate workability has been questioned and considerable litigation has resulted because of their doubtful value. Furthermore, owing to the fact that the Eden Ridge coal occurs in the same formation as that of the neighboring and better-known Coos Bay field, which is subbituminous in grade, the United States Geological Survey and others have incorrectly assumed that the Eden Ridge coal is also subbituminous and that, being thus of low grade and also bony in character, it is probably of little value. In 1912 M. R. Campbell, of the Geological Survey, made a brief examination of the coal and his work showed that, contrary to the previous assumption, it is bituminous in grade. In view, however, of the recent extension of prospecting and the discovery of less bony coal beds in the Squaw Basin district, the writer made the examination here described. This work was detailed in character and was undertaken for the purpose of ascertaining the extent and character of the field and of classifying the land as coal or noncoal. The field work has not been completed, but the results obtained are published in this preliminary report partly in order to aid in the prospecting now in progress and partly because of the interest attaching to this field as the only area, so far as known, of bituminous coal of commercial importance in Oregon.

The field lies wholly within the Siskiyou National Forest. It is 35 miles west of the station of West Fork (Dothan post office), on the Southern Pacific Railroad, and 35 miles south of the terminus of the Coos Bay, Roseburg & Eastern Railroad at Myrtle Point. The field is not easily accessible at the present time, travel from these railroad points being confined to saddle horses and pack trains. Figure 14 shows the geographic position and known extent of the field.

The Eden Ridge field is comparatively free from complicated structure, and the field work consisted principally in determining the areal distribution and stratigraphic position of the various coal beds. Because of the dense underbrush and heavy timber locations could be made only by compass traverse, either paced or measured with tape, and tied to established land corners. Altitudes were determined with the aneroid barometer. In the unsurveyed portion of the field corners established by private surveys were used for horizontal control. Every prospect was visited and the section of the coal bed measured; 26 prospects were sampled. Twenty-six float and sink tests and 80 ash determinations were made in the field with

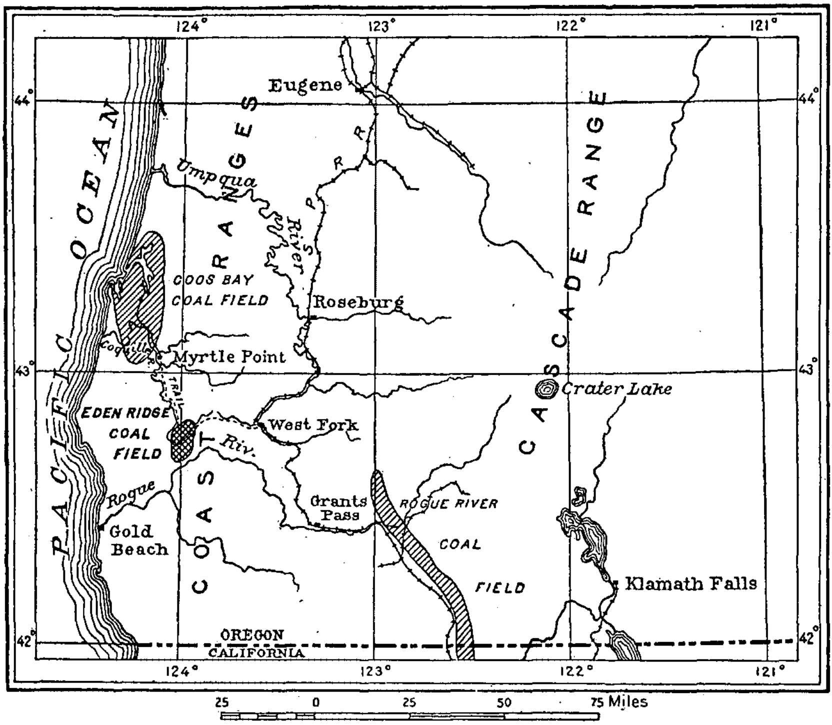


FIGURE 14.—Map of southwestern Oregon, showing location of the Eden Ridge and neighboring coal fields.

a portable analytical outfit. Five samples were taken for check analysis by the Bureau of Mines.

The field examination on which this report is based occupied six weeks during the summer of 1913. Assistance in the field was rendered by M. J. Anderson throughout the examination and by Harry Hillis for a week at the end of the season. The writer wishes to acknowledge his indebtedness to W. B. Meyers, Timothy Billings, Lee Emerson, and others for aid and many courtesies during the field work, and to M. R. Campbell and G. H. Ashley, of the United States Geological Survey, for advice and counsel in preparing the data.

SURFACE FEATURES.

The Eden Ridge field is characterized by a very uneven surface. Eden Ridge, Squaw Basin, and the area between Ash Swamp and the Bluff constitute three distinct topographic units, all drained by South Fork of Coquille River. (See Pl. XXIV, p. 404.)

Eden Ridge has a general northeast-southwest direction. Its highest point, about 3,500 feet above sea level, is 1,300 feet above the river at the mouth of Bear Creek on the east and 2,900 feet above the river at the mouth of Delta Creek on the west. The slopes of the ridge are very steep and are incised by the sharp canyons of the smaller streams. At the southern end of the ridge a vertical sandstone cliff 100 feet high and half a mile long is known as the "Big Slide," as it is the result of comparatively recent slumping. Another prominent escarpment, known as the "Bluff," is 150 to 200 feet high and extends from Forty Foot Falls on South Fork of Coquille River eastward to the Rogue River divide. Between Ash Swamp and the "Bluff" the surface has a more or less uniform slope from the same divide to Coquille River. (See Pl. XXIV.) Squaw Basin comprises the area south of the "Bluff" and east of Squaw Creek, extending from Coquille River to the Rogue River divide. Here the topography is rougher and dissection is well advanced; the smaller streams have cut sharp canyons 50 feet to 100 feet deep.

The possibility of developing water power under high head on South Fork has long been recognized. The water might be taken from the south side of the ridge near the Billings homestead either by tunnel through the ridge or by flume or high pressure pipe around it to the mouth of Delta Creek on the north side. It is estimated that with the excellent storage facilities offered by Ash Swamp, in which the river might be impounded and the flow of water thus equalized, not less than 7,000 continuous horsepower could be generated.

The area is heavily forested and contains much merchantable timber. The common varieties, named in the order of their value, are Port Orford white cedar, Douglas fir, and hemlock. The quantity of timber is said to range from 50,000 to 200,000 board feet to the acre. Madrona, salal, vine maple, tanbark oak, ferns, chinquapin, and buck brush are common and abundant forms of undergrowth. The climate is that typical of the west slope of the coast ranges, a rainy season lasts from October to June and a comparatively dry season from July to September. The total precipitation in 1912 is reported to have been 112 inches, but this is probably much higher than the yearly average.

GEOLOGY.

STRATIGRAPHY.

ARAGO FORMATION.

The rocks that outcrop in the Eden Ridge field are conglomerate, coarse yellowish sandstone, dark-colored shale, in part carbonaceous, and coal. They were studied by J. S. Diller in connection with the geologic mapping of the Port Orford quadrangle,[1] which includes the west half of Eden Ridge. According to Diller these rocks, to which he has applied the name Arago formation, are characterized by Eocene marine fossils. The coal-bearing rocks of the Coos Bay field belong to the same formation, but in that field the coal is of lower grade. The Arago lies unconformably on the Myrtle formation, of Lower Cretaceous age, which contains no coal.

Exposures in the Eden Ridge field are insufficient to afford a complete detailed stratigraphic section of the Arago formation. The strata above a blue conglomerate, which is a conspicuous horizon marker, are fairly well exposed on the slopes of the ridge, but relatively little is known of the character of the rocks which underlie it or of the positions of the coal beds. The following is a generalized section of the rocks above the blue conglomerate:

Generalized section of rocks above the blue conglomerate exposed in the Eden Ridge coal field.

	Feet.
Sandstone and shale	400
Sandstone	50
Shale	5
Coal bed, Lockhart	4-6
Shale	2
Sandstone, gray	8
Shale, in part carbonaceous	10
Sandstone, yellow	22
Shale	10
Coal bed, Carter	5-13
Shale	15
Sandstone and shale	240
Shale, some sandstone	50
Sandstone, massive	100
Shale	10
Coal bed, Anderson	6
Shale	25+
Coal bed, Meyers	9
Shale	10
Sandstone and shale	150
Sandstone, massive, conglomeratic near middle	100
Shale, green	10
Conglomerate, blue	40
	1,287+

[1] Diller, J. S., U. S. Geol. Survey Geol. Atlas, Port Orford folio (No. 89), 1903.

The above section is compiled from measurements made at several places in the field, and inasmuch as the strata overlying the conglomerate are known to differ in thickness and character the section can not be considered as representing correctly all the strata at any one locality.

The blue conglomerate is the only characteristic horizon marker in the field. It is about 40 feet thick and is composed of small pebbles of altered volcanic rock, chiefly andesitic in character, and fragments of fine-grained quartzites and slates ranging in size from one-eight of an inch to 2 inches in diameter. Outcrops of the conglomerate above water level along the river in the N. ½ sec. 33 are light gray, although some fragments are red and others are light green. Wherever it is thoroughly wet, as in stream beds, it has a characteristic bluish color, and for this reason it is here referred to as the blue conglomerate.

STRUCTURE.

The strata in this field dip toward a point near its center, thus forming an ellipitcal basin. The longer axis of the basin has a general north-south direction and the shorter axis is at right angles and has a slight pitch to the east. On the west side of the field the dip is 10°–17° E. and on the east side there is a similar dip to the west. The north-south axis of the basin passes through the center of secs. 20, 29, and 32, T. 32 S., and to the east of Squaw Camp in T. 33 S. On the north side of the field a southerly dip of 5°–15° prevails. Along Squaw Creek in T. 33 S. the rocks dip 12°–15° NE., and in the east half of the Squaw Basin district the dip is to the northwest at slightly greater angles.

Four faults were mapped. The Ash Swamp fault in secs. 22 and 23 has a vertical displacement of 800 feet. South of the fault the blue conglomerate is 800 feet above the river on the slope of Eden Ridge, and north of the fault it is at river level. The Bear Creek fault crosses secs. 31, 32, 33, and 34. At the mouth of Bear Creek in the north half of sec. 33 the displacement is 300 to 400 feet, with downthrow on the south side; in the west half of sec. 31 the displacement is 150 feet, with downthrow on the north side. The fault in sec. 28 has a vertical displacement of 200 feet, with downthrow on the south side. The fault south of sec. 32, at Little Falls, is of small but undetermined extent. A small fault in the NE. ¼ sec. 29 was not mapped.

As shown on the map (Pl. XXIV, p. 404) the outcrop of the blue conglomerate has been greatly displaced by these faults. South of the Bear Creek fault the outcrop of the conglomerate crosses Boulder and Bear creeks, forms the face of the "Bluff," crosses the river at the Forty Foot Falls, and swings around the south end of Eden Ridge. Between the Bear Creek fault and the fault in sec. 28 the conglomerate is exposed on both sides of the river near water level, and north of the fault in sec. 28 and on the north side of Eden Ridge it outcrops on the side of the ridge. In the SW. ¼ sec. 23 it is brought to river level by the Ash Swamp fault, but northward it rises and forms a rim rock possibly surrounding Ash Swamp.

THE COAL.

GENERAL CHARACTER.

The coal in the Eden Ridge field is bituminous in grade, and some of it is believed to possess coking qualities. It does not slack on exposure to the air, and when fairly pure has a heating value of over 11,000 British thermal units.

Three beds, the Lockhart, Carter, and Anderson, are known to underlie Eden Ridge, and the Anderson bed is also found in a portion of the area south of the river. (See map, Pl. XXIV.) The Meyers bed has been found only south of the ridge, although it may be coextensive with the Anderson bed. In the Squaw Basin district three coal beds outcrop but were not mapped. They are believed to be stratigraphically lower than the beds on Eden Ridge, but this fact has not been definitely established. If lower than the Anderson bed they underlie all of Eden Ridge, Ash Swamp, and probably a large part of the area between Ash Swamp and the Bluff.

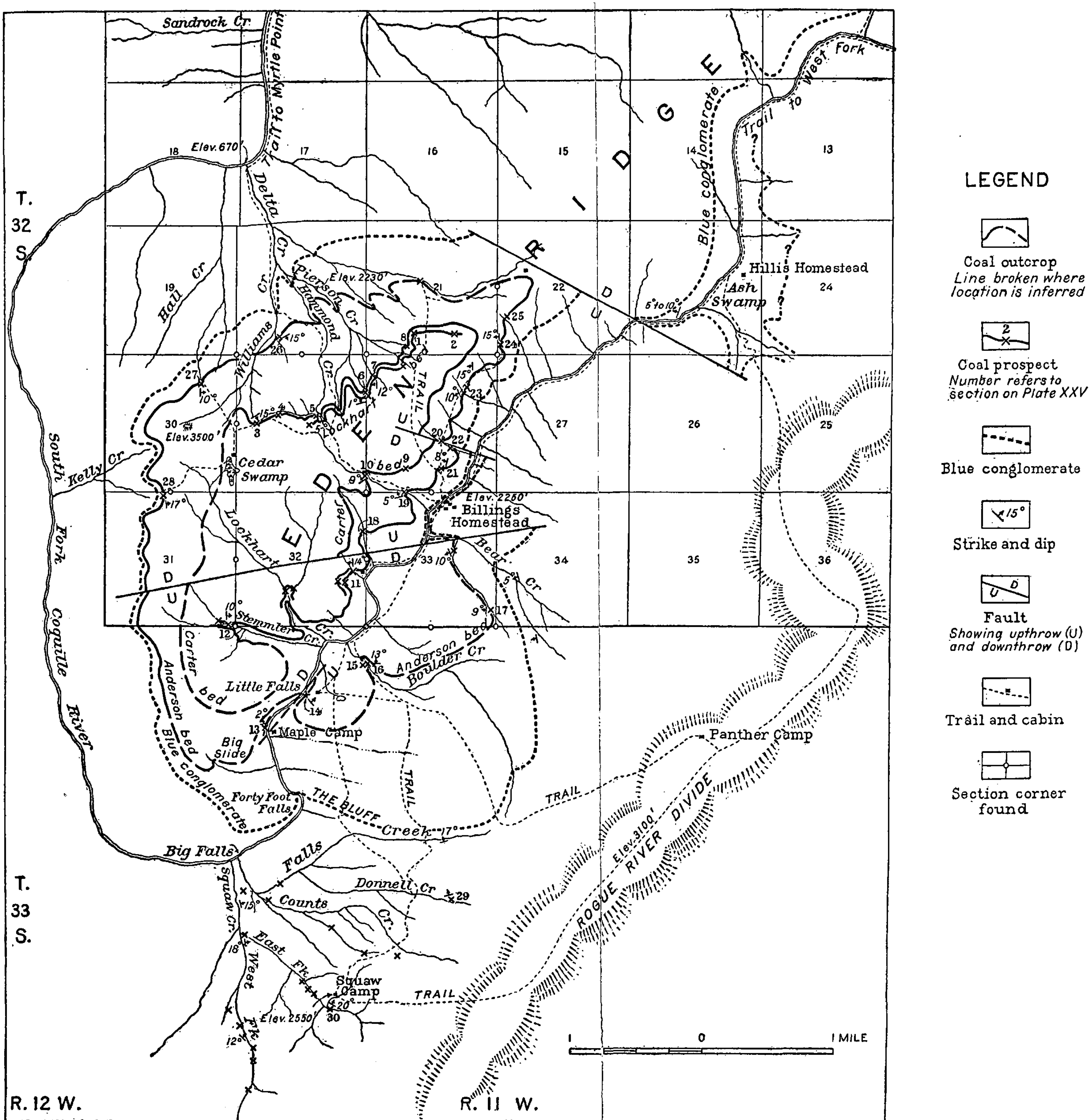
As shown by the graphic sections on Plate XXV [1] (p. 408), all these beds are badly broken by shale and bone partings. Moreover, in nearly all the sections measured in the field the bed contains numerous lenses of dirty coal or bone, so that it is impossible to state accurately the thickness and value of the bed in general terms. In the following descriptions of the occurrence and distribution of these beds frequent reference will therefore be made to the graphic sections, the character and purity of the coal being more extendedly discussed afterward.

The Lockhart bed is mainly carbonaceous shale and bone with layers of coal of a maximum thickness of 3 inches. A sample from location 1 of all this bed except the clay partings was analyzed in the field and found to contain 54 per cent of ash. The Squaw Creek beds, on the contrary, are mainly coal, with a few thin layers of bone. The Carter, Anderson, and Meyers beds are intermediate in quality between the Lockhart and Squaw Creek beds. The quality of the Anderson and Carter beds is very much better at the south end of the field than it is at the north end.

DISTRIBUTION.

The Anderson bed may be readily identified by its position 300 feet stratigraphically above the blue conglomerate and by the presence near its middle of a characteristic white clay parting. (See

[1] All the prospects at which sections were measured are numbered on the map (Pl. XXIV), and the sections measured at these points are numbered correspondingly on Pl. XXV and in the text.



MAP OF THE EDEN RIDGE COAL FIELD, COOS COUNTY, OREG.

By C. E. Lesher.

secs. 14 and 15, and 17 to 28, Pl. XXV, p. 408.) The outcrop of this bed is clearly marked on the north side of the ridge and on the south side from sec. 22 to the Bear Creek fault. In sec. 21, in the S. ½ sec. 33, T. 32 S., and in T. 33 S., the location of the outcrop, as shown on Plate XXIV, is only approximate. Prior to the examination by Mr. Campbell in 1912 the Anderson bed had not been found on the north and west sides of the ridge, and it was generally supposed that it was not continuous under Eden Ridge. It now seems certain, however, that the Anderson bed underlies about 5 square miles of Eden Ridge and approximately 1 square mile south of the river adjacent to the ridge.

The Carter bed is 400 feet stratigraphically above the Anderson bed. It has been opened in six places on the north side of the ridge, and the position of its outcrop for a distance of 2 miles is well established. On the south side of the ridge two openings have been made on this bed north of the Bear Creek fault and three south of the fault. Approximately 3 square miles along the crest of Eden Ridge are underlain by the Carter bed. The greatest thickness measured on this bed is about 8 feet, at location 7, and the smallest is 3 feet 7 inches, at location 12. Just above the section measured at location 9 (Pl. XXV) there is between 7 and 8 feet of bone and carbonaceous shale with numerous layers of clean coal one-fourth to one-half inch thick. If this material be considered part of the bed, the thickness here is nearly 13 feet. Location 4 is a shallow pit with several feet of water in the bottom, so that the lower part of the section and the total thickness could not be measured.

The Lockhart bed is 50 feet above the Carter. It is exposed in five prospects on the north side of the ridge in secs. 21, 28, and 29, and in three on the south side in sec. 32. The bed is everywhere composed of carbonaceous shale and bone with numerous thin layers of clean coal from a fraction of an inch to 3 inches thick. At locations 1 and 2 this bed is about 6 feet thick and it is probable that it is of equal thickness elsewhere. (See secs. 1 and 2, Pl. XXV.) The distinctive character of the bed and its stratigraphic position with reference to the Carter bed render it easily recognizable in the field. The bed has been prospected only in the areas noted above, and its outcrop was not mapped elsewhere, but the bed is believed to be coextensive with the Carter bed.

The Meyers bed has been opened at only two prospects, locations 13 and 16. It is 9 feet thick at location 16. (See sections on Pl. XXV.) Owing to the fact that the coal-bearing shale south of the river is badly slumped, except possibly at these prospects, the exact stratigraphic position of the bed is doubtful. The Anderson bed at location 15 is about 25 feet above the horizon of the Meyers at location 16, but the distance between these beds at locations 13 and 14 could not be determined, owing to the Little Falls fault. On the other hand coal which may represent the Meyers bed is exposed on Eden Ridge about 50 feet below the Anderson, so that the true distance between these beds may be 50 feet instead of about 25 feet.

In Squaw Basin 18 exposures of coal were observed. Only 2 of them, at locations 29 and 30, had been sufficiently prospected in August, 1913, to permit the determination of the thickness and character of the coal. At these two places the bed is 5 feet and 8 feet thick, respectively, but it is reported that on the Rogue River side of the divide south of Squaw Camp a prospect has recently been opened in which the bed is 13 feet thick. The prospecting is not sufficiently advanced to admit of satisfactory correlations of these exposures, but it is probable that there are at least three beds, the two lowest of which are not over 75 feet apart and the third or uppermost several hundred feet higher. The exact relation of these beds to those on Eden Ridge could not be positively determined. It is certain, however, that, unless there is a fault of greater magnitude than any now known in the area between Big Falls and the outcrop of the blue conglomerate immediately to the north, the Squaw Basin coal beds are 600 to 800 feet stratigraphically lower than the Anderson bed. No surface indications of such a fault have yet been observed, and it is believed that these coal beds are in reality lower than the Anderson bed. If they are lower, they must, if continuous, underlie all of Eden Ridge, Ash Swamp, and the greater part of the area between Ash Swamp and the bluff. The rocks exposed in Squaw Basin outcrop on the south slope of Rogue River divide, and this divide, therefore, marks the approximate limit of the coal field on the south.

QUALITY.

The coal in the Eden Ridge field is bituminous, and in the Squaw Basin district is believed to have coking qualities. It commonly has a bright luster, though in places it is somewhat dull. There is a poor vertical cleavage, but no pronounced lamination parallel to the bedding. The coal does not slack or disintegrate on exposure to the air, and, though thoroughly wet in many of the outcrops of the field, it does not appear to be readily affected by the weather. These physical properties, together with the low moisture content, averaging 4 per cent, the high heat value, about 12,000 British thermal units for coal with 10 per cent or less ash, and the possible coking quality, warrant the classification of the Eden Ridge coal as bituminous.

LOCAL FEATURES OF COAL BEDS.

The coal beds in this field (see sections on Pl. XXV) contain material of all grades from clean bituminous coal with ash as low as 10 per cent to bone with 60 per cent ash and carbonaceous shale. The lenses of coal, bony coal, and bone[1] are from a fraction of an inch to several inches in thickness and grade into one another both vertically and horizontally. The gradation from coal through bony coal and bone to carbonaceous shale is in most places almost imperceptible. Although in the graphic sections (Pl. XXV) parts of a bed as much as 3 feet thick are shown as coal, it should be understood that at no place is there so much as 1 foot of coal that does not contain at least a perceptible amount of bone or bony coal. Much of the material can not be accurately classified without a determination of its ash content, and the same portion of the bed may be differently described and classified by different observers. In addition to the difficulty of determining in the field what should be the designation of the different parts of a bed is the difficulty of showing the condition of the bed graphically. For instance, in the middle of the section at location 3 (see Pl. XXV) is a layer 1 foot 9 inches thick which is a mixture of carbonaceous shale, bone, and bony coal that can not be differentiated. This has been shown graphically by the symbol of bone superimposed upon that for carbonaceous shale.

So great is the variability of the beds that no two sections of a bed exactly agree, even though measured in the same opening, and the same section measured by different observers may be classified differently. To illustrate this difficulty, several sections measured by M. R. Campbell in the same prospects measured by the writer are given on Plate XXV. For purposes of discussion the sections of the Carter bed at location 7, measured by Mr. Campbell and the writer, may be taken as a typical example. These sections were measured at the face of a prospect drift 110 feet long at points not over 10 feet apart. Comparison of the sections measurement by measurement indicates that in the upper 5½ feet, although each section shows approximately the same total number of inches of coal—45½ inches and 47 inches, respectively—the coal is differently distributed, and where one section shows three layers of carbonaceous shale the other shows bone. Furthermore, the total thickness of the bed between shale roof and floor in one section is 8 feet 1½ inches and in the other 6 feet 1½ inches. Perhaps a more striking example of the irregularity of the beds is derived from a comparison of the sections of the Anderson bed measured by Mr. Campbell and the writer at location 21. These sections were measured at the face of a prospect drift 103 feet long at points about 5 feet apart. One section shows a total of 45 inches of coal in nine layers which range in thickness from 2 inches to 10 inches; the other has but one stratum of coal, and that is 14

[1] The material here described as bone is a black compact and coherent mixture of carbonaceous and noncarbonaceous material and is not considered a fuel in the ordinary sense of the term. It contains 33 per cent or more of ash; its luster is dull; its streak is dark brown; its texture is dense; its fracture is even; and it is usually harder and decidedly heavier than the coal with which it is associated. It is generally tough and when struck with a hammer gives a dull impact. "Bony coal" is a coal containing a large percentage (less than 33) of ash, either as a coherent mixture or as thin alternating layers of coal and bone.

inches thick. The 10-inch and 5½-inch layers of coal above the parting in the section measured by Mr. Campbell are represented by 11 inches and 5½ inches of bony coal in the section measured by the writer. The 11-inch and 5½-inch layers of bony coal were sampled separately and found to contain 30 per cent and 29 per cent of ash, respectively.

Under such conditions it is manifestly impossible properly to determine the true character and quality of a coal bed except by making chemical analyses of numerous samples. Accordingly, the beds at all prospects, with the exception of those at locations 2, 4, 8, and 24, were sampled for analysis.[1] Fifteen samples of coal from this field have been analyzed by the Bureau of Mines and the heat value of the coal experimentally determined. Five of these samples were taken by W. M. Stephens, mineral examiner of the Forest Service, five by M. R. Campbell, of the Geological Survey, and five by the writer. Analyses Nos. 9151 and 9187 of two samples taken by M. A. Pishel in the Coos Bay coal field are also given.[2]

On Plate XXV the parts of each bed sampled are bracketed and lettered, and the corresponding analyses in the table (pp. 411–413) are denoted by a combination of the number of the prospect and the letter showing the part sampled. Thus one sample was taken of the bed at location 6 and its analysis is designated in the table as 6A; No. 22 was sampled in two parts, of which the analyses are represented by 22A and 22B; No. 27 was sampled by both the writer and Mr. Campbell and the analyses are numbered 27A and 27B. The sections of the Anderson bed represented by samples 23B and 23C are not shown on Plate XXV but are given below, as are also the sections measured by W. M. Stephens, the corresponding samples being numbered 5C, 10B, 18D, 21B, and 21C (laboratory Nos. 14048, 14049, 14047, 14045, and 14046, respectively).

Sections of Anderson coal bed at location 23, NE. ¼ sec. 28, T. 32 S., R. 11 W.

Section measured 20 feet from section 23 shown on Pl. XXV.

	Ft.	in.
Shale.		
Coal and bone mixed[3]	2	6
Clay, white		3
Coal and bone mixed[3]	2	10
Shale.		
	5	7

Section below white clay parting, measured 5 feet from preceding section.

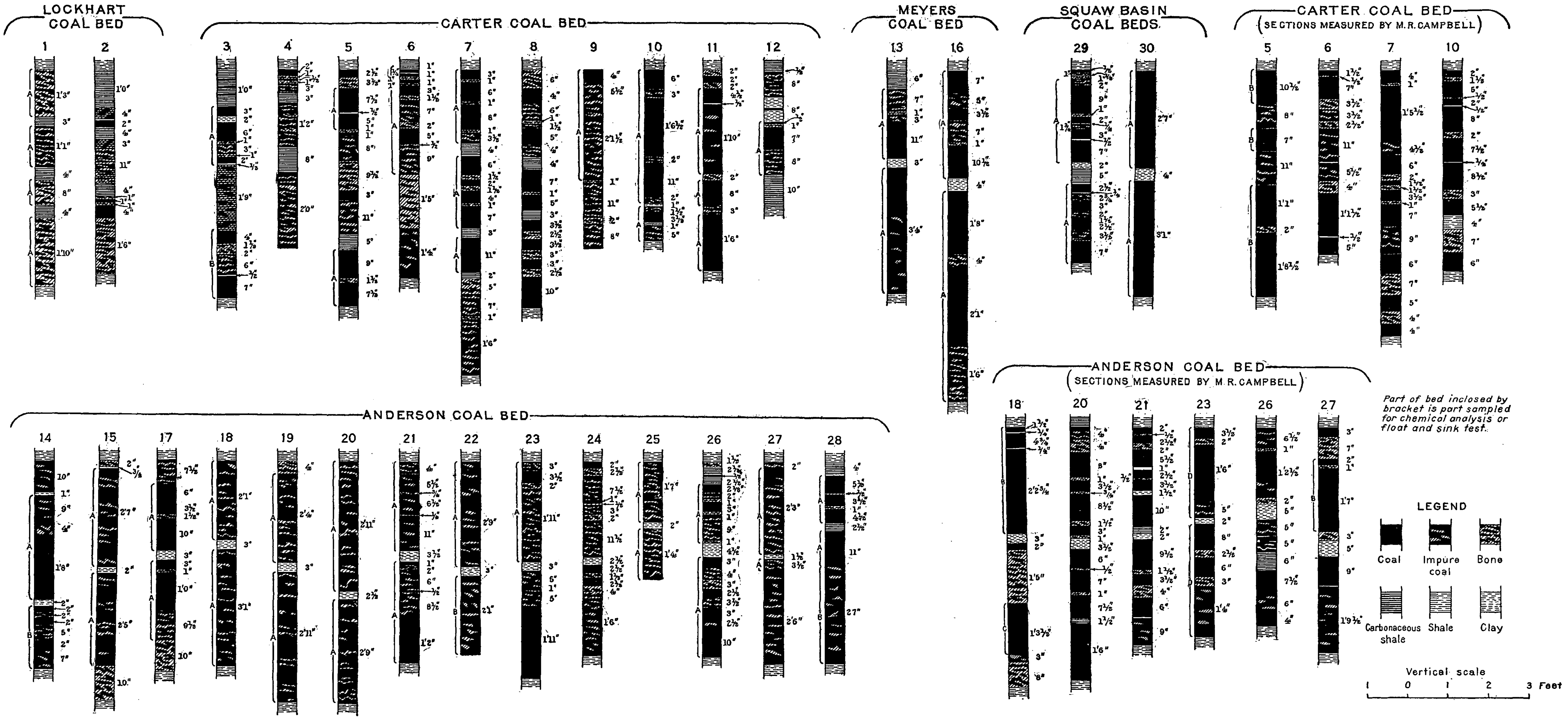
	Ft.	in.
Clay, white.		
Coal[4]		9
Bone[4]		3
Coal[4]	1	4
Shale.		
	2	4

[1] The samples for analysis were taken according to the standard method of the United States Geological Survey, which briefly is as follows: The face to be sampled is cleaned and squared up and a cut made across that part of the bed to be sampled of such size as to yield about 6 pounds of coal to the foot of thickness of bed, all partings of clay over three-eighths of an inch thick being rejected and the whole sample being caught on a piece of oilcloth. The sample is then reduced in size to pass a screen with openings one-half inch square and cut down by quartering to a final sample of 3 to 4 pounds, which for transmission to the Bureau of Mines is sealed in a galvanized-iron can.

[2] Diller, J. S., and Pishel, M. A., Preliminary report on the Coos Bay coal field, Oregon: U. S. Geol. Survey Bull. 431, p. 190, 1911.

[3] Included in sample 23C (float and sink test, p. 417).

[4] Included in sample 23B (float and sink test, p. 417). A sample of the 9 inches of coal in this section was analyzed separately and found to contain 22 per cent of ash.



SECTIONS OF COAL BEDS IN THE EDEN RIDGE COAL FIELD, COOS COUNTY, OREG.

Sections of Anderson coal bed at locations 18 and 21.

[Measured by W. M. Stephens.]

Location 18, NE. ¼ sec. 32, T. 32 S., R. 11 W.

	Ft.	in.
Sandstone, shaly.		
Shale and bone		4
Coal, hard, some bone		7
Bone		1
Coal, hard, bony		9
Bone		1
Coal, bright		3
Coal, bony		3
Coal, hard, bright		6
Shale, carbonaceous		1
Coal, bright		3
Shale, carbonaceous		1
	3	3
Shale, light sandy, main parting[1]		2-3
Coal, bright		2
Coal, shaly		2
Coal, hard, bright		4
Shale, carbonaceous		3
Coal		2
Shale, carbonaceous		3
Coal, some bone		8
Shale, soft carbonaceous		2
Coal, hard, bony		5
Clay, dark, soft		2
Sandstone, shaly.		
	2	9
	6	2-3

Location 21, SW. ¼ SE. ¼ sec. 28, T. 32 S., R. 11 W.

	Ft.	in.
Sandstone, shaly.		
Shale, carbonaceous		1¾
Coal, bright		3½
Shale, carbonaceous		¾
Coal		7
Shale and bone		1
Coal		3
Coal and shale interbanded		1
Coal		3
Shale, brown		1
Coal with shale bands		11
	2	9
Shale, main parting, light sandy[2]		2-3
Coal and shale		9
Shale, carbonaceous		2
Coal		4
Shale and bone		3
Coal		5
Coal and shale, soft		10
Shale		1
Sandstone, shaly.		
	2	10
	5	9-10

Sections of Carter coal bed at locations 5 and 10.

[Measured by W. M. Stephens.]

Location 5, SW. ¼ NE. ¼ sec. 29, T. 32 S., R. 11 W.

	Ft.	in.
Sandstone, shaly.		
Coal, bony, and shale interbanded[3]	3	
Coal, bright		7
Shale, parting		2
Coal		6
Bone		2
Coal		12
Coal, bony		3
Coal		12
Coal, bony		1
Coal		6
Shale, sandy.		
	7	6

Location 10, SE. ¼ SE. ¼ sec. 29, T. 32 S., R. 11 W.

	Ft.	in.
Shale and shaly sandstone.[4]		
Shale and bone		10
Coal		5
Coal, shaly		3
Coal, hard and bony		28
Coal, bony		5
Shale, light		½
Coal		7
Shale, soft		3
Coal, shaly, and shale, soft		12
Shale, sandy.		
	6	1½

[1] All of bed between roof and floor except this parting was included in sample 18D (laboratory No. 14047).

[2] Portion of bed between roof and this parting was included in sample 21B (laboratory No. 14045), and portion of bed between this parting and floor was included in sample 21C (laboratory No. 14046).

[3] All of bed between this bony coal and interbanded shale and the shale floor was included in sample 5C (laboratory No. 14048).

[4] All of bed between roof and floor was included in sample 10B (laboratory No. 14049).

CHEMICAL ANALYSES.

In the accompanying table 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 to general comparisons. 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 represent theoretical conditions that do not actually exist, are obtained from the others by recalculation.

In the analytical work chemists generally recognize that 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. It is also understood that calorific determinations to individual units are 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, as the value of a British thermal unit is about one-half that of a calorie.

Analyses of coal samples from the Eden Ridge and Coos Bay coal fields, Coos County, Oreg.

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

Eden Ridge coal field.

Name of prospect or mine.	Collector.	Coal bed.	Location.				Thickness.		No. on Pl. XXV.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Sulphur.	Heating value.	
			Quarter.	Sec.	T. S.	R. W.	Coal bed.	Part sampled.					Moisture.	Volatile matter.	Fixed carbon.	Ash.		Calories.	British thermal units.
							Ft. in.	Ft. in.											
Hammond	W. M. Stephens	Carter	SW. ¼ NE. ¼	29	32	11	7 6	4 6	5C	14048	3.3	A	8.1	32.5	29.2	30.2	0.35	4,610	8,300
												B	5.0	33.6	30.2	31.2	.36	4,765	8,580
												C	....	35.4	31.8	32.8	.38	5,015	9,030
												D	....	52.7	47.3	....	.57	7,470	13,440
Do	M. R. Campbell	do	SW. ¼ NE. ¼	29	32	11	6	4 3	5B	14831	3.7	A	8.0	35.0	37.1	19.9	.58	5,460	9,830
												B	4.5	36.3	38.6	20.6	.60	5,670	10,210
												C	....	38.0	40.4	21.6	.63	5,940	10,690
												D	....	48.5	51.5	....	.80	7,575	13,630
Reeves	C. E. Lesher	do	NW. ¼ NW. ¼	28	32	11	8 1½	4 9½	7A	17704	2.9	A	8.3	26.7	27.7	37.3	.57	3,900	7,020
												B	5.6	27.5	28.5	38.4	.59	4,015	7,230
												C	....	29.2	30.1	40.7	.62	4,255	7,660
												D	....	49.2	50.8	....	1.05	7,175	12,910
Johnson	W. M. Stephens	do	SE. ¼ SE. ¼	29	32	11	6 1½	6 1½	10B	14049	2.5	A	7.2	34.1	28.9	29.8	.81	4,720	8,500
												B	4.8	34.9	29.7	30.6	.83	4,840	8,720
												C	....	36.7	31.2	32.1	.87	5,090	9,160
												D	....	54.1	45.9	....	1.28	7,500	13,500
Everett Association.	C. E. Lesher	Meyers	....	....	[a]33	11	5 11	5 2	13A	17708	12.0	A	15.1	33.2	31.4	20.3	1.29	5,020	9,040
												B	3.5	37.8	35.6	23.1	1.47	5,705	10,270
												C	....	39.2	36.9	23.9	1.52	5,910	10,640
												D	....	51.4	48.6	....	2.00	7,770	13,990
W. B. Meyers	do	do	....	....	[a]33	11	8 9	8 5	16A	17705	5.5	A	9.2	34.2	32.3	24.3	1.68	5,110	9,190
												B	4.0	36.2	34.2	25.6	1.78	5,400	9,720
												C	....	37.7	35.6	26.7	1.85	5,625	10,130
												D	....	51.5	48.5	....	2.52	7,675	13,810
O. L. Hillis	W. M. Stephens	Anderson	SE. ¼ NE. ¼	32	32	11	6 3	6	18D	14047	3.7	A	7.6	36.0	25.8	30.6	1.24	4,700	8,460
												B	4.0	37.3	26.8	31.9	1.29	4,880	8,780
												C	....	38.9	27.9	33.2	1.34	5,080	9,150
												D	....	58.2	41.8	....	2.00	7,605	13,690

Analyses of coal samples from the Eden Ridge and Coos Bay coal fields, Coos County, Oreg.—Continued.

Eden Ridge coal field—Continued.

Name of prospect or mine.	Collector.	Coal bed.	Location.				Thickness.		No. on Pl. XXV.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Sulphur.	Heating value.	
			Quarter.	Sec.	T. S.	R. W.	Coal bed.	Part sampled.					Moisture.	Volatile matter.	Fixed carbon.	Ash.		Calories.	British thermal units.
							Ft. in.	*Ft. in.*											
O. L. Hillis	M. R. Campbell	Anderson.	SE. ¼	32	32	11	6 10	1 3½	18C	14827	6.7	A	10.0	38.5	36.3	15.2	0.63	5,850	10,530
			NE. ¼									B	3.5	41.2	39.0	16.3	.68	6,270	11,280
												C	....	42.7	40.4	16.9	.70	6,495	11,690
												D	....	51.4	48.6	......	.84	7,820	14,070
Do	do	do	SE. ¼	32	32	11	6 10	2 9½	18B	14830	3.3	A	6.7	35.5	27.4	30.4	2.2	4,750	8,550
			NE. ¼									B	3.5	36.7	28.4	31.4	2.3	4,910	8,840
												C	....	38.1	29.4	32.5	2.4	5,090	9,170
												D	....	56.4	43.6	......	3.5	7,550	13,590
Gant	W. M. Stephens	do	SW. ¼	28	32	11	5 10	2 9	21B	14045	3.6	A	7.3	33.5	26.1	33.1	2.5	4,530	8,160
			SE. ¼									B	3.9	34.7	27.1	34.3	2.6	4,700	8,460
												C	....	36.1	28.2	35.7	2.7	4,890	8,800
												D	....	56.2	43.8	......	4.2	7,605	13,690
Do	do	do	SW. ¼	28	32	11	5 10	2 10	21C	14046	6.2	A	10.2	33.3	26.0	30.5	1.1	4,485	8,070
			SE. ¼									B	4.2	35.5	27.6	32.7	1.2	4,780	8,610
												C	....	37.0	28.9	34.1	1.2	4,990	8,990
												D	....	56.2	43.8	......	1.9	7,580	13,640
J. H. Flanigan	M. R. Campbell	do	NW. ¼	28	32	11	5 6	5 4	23D	14828	6.2	A	10.1	31.3	24.9	33.7	1.1	4,150	7,470
			NE. ¼									B	4.2	33.4	26.5	35.9	1.2	4,420	7,960
												C	....	34.8	27.7	37.5	1.2	4,615	8,310
												D	....	55.7	44.3	......	2.0	7,375	13,280
Vanderpool	do	do	NW. ¼	30	32	11	5 10½	1 10	27B	14829	3.3	A	7.3	37.6	27.6	27.5	2.6	4,915	8,850
			NE. ¼									B	4.1	38.9	28.5	28.5	2.7	5,085	9,150
												C	....	40.6	29.7	29.7	2.8	5,305	9,550
												D	....	57.7	42.3	......	4.0	7,540	13,580
G. W. Donnell	C. E. Lesher	(?)	....	....	a33	11	5 1½	4 3½	29A	17706	6.8	A	10.8	30.9	31.8	26.5	1.0	4,820	8,680
												B	4.3	33.2	34.1	28.4	1.1	5,170	9,310
												C	....	34.7	35.6	29.7	1.1	5,405	9,720
												D	....	49.3	50.7	......	1.6	7,690	13,840

Squaw Creek	do	(?)	....	....	a33	11	6		5 8	30A	17707	9.3	A	12.6	35.0	37.7	14.7	1.3	5,750	10,350
													B	3.6	38.7	41.5	16.2	1.4	6,340	11,410
													C	....	40.0	43.1	16.9	1.5	6,575	11,830
													D	....	48.2	51.8	......	1.8	7,910	14,230
Coos Bay coal field.																				
Beaver Hill mine	M. A. Pishel	....	NE. ¼	17	27	13	6 3		5 5	....	9151	7.0	A	14.3	34.4	43.2	8.1	.74	5,350	9,630
													B	7.8	37.0	46.5	8.7	.80	5,750	10,350
													C	....	40.2	50.4	9.4	.86	6,240	11,230
													D	....	44.4	55.6	......	.96	6,885	12,400
Smith & Power mine.	do	....	SE. ¼	36	26	13	3 3		2 11	....	9187	8.6	A	18.9	28.6	35.4	17.1	.54	4,315	7,770
													B	11.3	31.2	38.8	18.7	.59	4,720	8,500
													C	....	35.2	43.7	21.1	.67	5,325	9,590
													D	....	44.6	55.4	......	.85	6,750	12,150

a Unsurveyed.

The analyses illustrate the great variability of these coals from place to place. Sulphur determinations by the Bureau of Mines on 26 samples from all the beds in the field show a minimum of 0.36 per cent, a maximum of 3.51 per cent, and an average of 1.26 per cent. In 25 samples the moisture in the air-dried condition ranged from 2.9 to 7.3 per cent, the average being 4 per cent. In 15 samples of the Anderson bed the ash ranged from 16.3 to 40.2 per cent, the average being 31 per cent. In 9 samples of the Carter bed the ash ranged from 20.6 to 45.9 per cent, the average being 34.5 per cent. The Meyers bed contains about 24 per cent ash; the two analyses of Squaw Basin coals show 16 and 28 per cent ash.

The analyses differ widely in respect to ash content and heating value, as stated above. A study of form D, however, which represents the coal material free from moisture and ash, shows that the heating value of the material itself is very uniform and averages over 13,000 British thermal units. This suggests that if coal beds containing less bone and shale could be discovered in the field, or if the coal in the beds here discussed could be mechanically purified, the resulting fuel would be of high grade.

Comparison of the analyses with those of the Coos Bay coals shows that the latter are lower in ash and in heat value and higher in moisture than the coals in the Eden Ridge field. The Coos Bay coals contain on an average less than half the amount of ash and from two to three times the amount of moisture found in the Eden Ridge coals. The heat value of the coals calculated on the ash and moisture-free basis, form D, shows that the Coos Bay coals contain 12,150 and 12,400 British thermal units as compared with the Eden Ridge coals, which contain on an average between 13,500 and 14,000 British thermal units. A study of the analyses of the Eden Ridge coals shows that the heat value of the samples in the air-dried condition is nearly in inverse proportion to the ash content. This relation is expressed graphically in the accompanying diagram (fig. 15).

The empirical formula of Parr and Wheeler for "unit coal"[1] was applied to ten analyses, Nos. 14045–14049 and 14827–14831, and the results averaged to determine the line A–B on this diagram. Analyses Nos. 17704–17708 have since become available and have been plotted on this diagram. By means of the diagram the heat value (within 200 British thermal units) of an unweathered sample of coal from this field can be ascertained directly from the percentage of ash, so that only the latter need be determined by analysis. For ex-

[1] Parr, S. W., and Wheeler, W. F., Unit coal and the composition of coal ash: University of Illinois Bull. No. 37, 1909.

Formula for heat value of unit coal:

$$\text{British thermal units of unit coal} = \frac{\text{Indicated British thermal units} - 5{,}000\,\dfrac{\text{Per cent sulphur}}{100}}{1-\left(\dfrac{\text{per cent moisture}}{100}+1.08\,\dfrac{\text{per cent ash}}{100}+\dfrac{22}{40}\,\dfrac{\text{per cent sulphur}}{100}\right)}$$

ample: To determine the approximate heat value of a sample containing 30 per cent ash, follow the horizontal line corresponding to 30 per cent on the left-hand vertical scale to its intersection with the line A–B. From this intersection follow the vertical line down to the horizontal scale at the bottom. The result is 9,000 British thermal units. That is, if a sample in the air-dried condition contains 30 per cent ash it may be confidently inferred that it yields approximately 9,000 British thermal units. In like manner a sample containing 10 per cent ash has approximately 12,000 British thermal units. Because of this practical value the diagram is given in the preliminary paper, but a description of the calculations involved in locating the line A–B and a discussion of the interpretation of the results obtained will be reserved for a final report, to be published later.

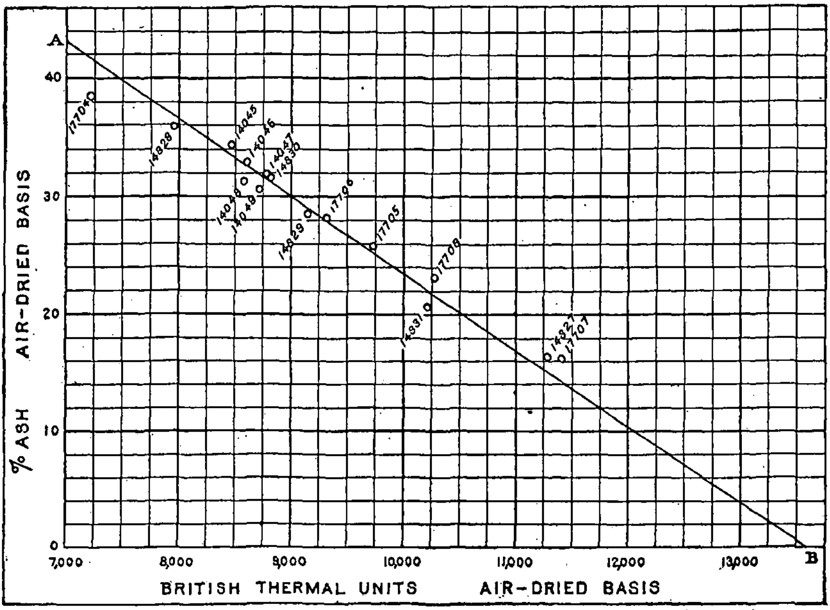


FIGURE 15.—Diagram showing relation between percentage of ash and heating value of coal from the Eden Ridge field, Oreg. Numbers along line A–B are laboratory numbers of analyses.

The high ash content in the Anderson and Carter beds, averaging about 30 per cent, is of course a decided detriment, and if not at least partly removable would probably prohibit their use for domestic fuel or for making steam. It is doubtful whether or not they could be profitably utilized as mined, even in the gas producer. An examination of the Eden Ridge coal beds shows that their high ash content is primarily due to the presence of bone and bony coal occurring in layers between the benches of coal. This bone contains 40 to 50 per cent of ash, and its removal would leave a coal material much lower in ash than the average of the bed as mined. A common method of separating bone from coal and thus improving its quality is washing. Bone and impure coal have a higher specific gravity than coal, and it is this physical fact on which the successful washing depends. As the Eden Ridge coals have not been commercially washed, the only means by which to judge of their adaptability to this method of cleaning is by float and sink tests. The results of investigations of the United States Geological Survey and Bureau of Mines [1] and the Canada Department of Mines [2] are considered to have demonstrated the adequacy of float and sink tests, properly interpreted, as an index of the adaptability of coal to commercial washing. The results of the float and sink tests and field analyses of coal in the Eden Ridge field made by the writer are given in the following table:

[1] Belden, A. W., Delamater, G. R., Groves, J. W., and Way, K. M., Washing and coking tests of coal at the fuel-testing plant, Denver, Colo., July 1, 1908, to June 30, 1909: Bureau of Mines Bull. 5, 1910.

[2] Porter, J. B., and Durley, R. J., An investigation of the coals of Canada with reference to their economic qualities: Canada Dept. Mines, Mines Branch, vol. 1, 1912.

Results of float and sink tests and field analyses of coal in the Eden Ridge coal field, Oreg.

[Tests and analyses by C. E. Lesher.]

No. on Pl. XXV.	Name of prospect.	Location.				Coal bed.	Thickness.		Float and sink test (per cent).			Ash (per cent).		
		Quarter.	Sec.	T. S.	R. W.		Coal bed.	Part sampled.	Float.	Sink.	Material through 60 mesh.	In float.	In sink.	In bed.[a]
							Ft. in.	*Ft. in.*						
1A	Ely Pierson	SE. ¼ SW. ¼	21	32	11	Lockhart	5 9	4 10	......	......	......	......	......	54
3A	Williams	SW. ¼ NW. ¼	29	32	11	Carter, upper bench	6 ½	1 6½	58	32	10	20	43	......
3B	....do	SW. ¼ NW. ¼	29	32	11	Carter, lower bench	6 ½	1 9	51	39	10	26	43	......
5A	Hammond	SW. ¼ NE. ¼	29	32	11	Carter	6 3½	2 7	71	16	13	15	38	......
6A	K. Pierson	SE. ¼ NE. ¼	29	32	11	....do	5 6¼	2 9¼	55	37	8	40	56	......
7A	Reeves	NW. ¼ NW. ¼	28	32	11	....do	8 1½	4 9½	48	42	10	36	48	......
9A	Cecil Carter	SE. ¼ SW. ¼	28	32	11	....do	4 9	2 11	55	35	10	25	42	......
10A	Johnson	SE. ¼ SE. ¼	29	32	11	....do	4 6½	4 5½	36	54	10	21½	42	......
11A	Hillis	NE. ¼ SE. ¼	32	32	11	....do	5 4	4 5	50	40	10	25	48	......
12A	Z. P. Pierson	SE. ¼ SE. ¼	31	32	11	....do	3 7	1 4½	37	53	10	40	56	......
14A	Everett Association	(b)	......	33	11	Anderson, upper bench	5 6	2 9	......	......	......	......	......	21
14B	....do	(b)	......	33	11	Anderson, lower bench	5 6	1 8	46	37	17	15	40	......
15A	W. B. Meyers	(b)	......	33	11	Anderson	6 2¾	5	51	39	10	24	32	......
16A	....do	(b)	......	33	11	Meyers	8 9	8 5	......	......	......	......	......	25
17A	H. E. Meyers	SE. ¼ SE. ¼	33	32	11	Anderson	5 7	3 10½	68	22	10	27	41	......
18A	O. L. Hillis	SE. ¼ NE. ¼	32	32	11	....do	5 5	5 2	43	47	10	22	36	......
19A	George Johnson	SE. ¼ SW. ¼	28	32	11	....do	5 10	5 3	56	34	10	23½	41	......
20A	Gant	NW. ¼ SE. ¼	28	32	11	....do	5 10½	5 8	58	32	10	29	47	......
21A	....do	SW. ¼ SE. ¼	28	32	11	....do	5 3½	5	40	50	10	20	42	......
22A	....do	NW. ¼ SE. ¼	28	32	11	Anderson, upper bench	5 1	2 9	42	48	10	26	45	......
22B	....do	NW. ¼ SE. ¼	28	32	11	Anderson, lower bench	5 1	2 1	67	23	10	27	44	......
23A	Flanagan	NW. ¼ NE. ¼	28	32	11	Anderson, upper bench	5 8½	2 7½	36	54	10	21	42	......
23B	....do	NW. ¼ NE. ¼	28	32	11	Anderson, lower bench	5 8½	2 4	47	43	10	26	......	......
23C	....do	NW. ¼ NE. ¼	28	32	11	Anderson	5 8½	5 4	42	48	10	25	45	......
25A	Pulford	NW. ¼ SW. ¼	22	32	11	....do	3 1	2 11	56	34	10	40	51	......
26A	Mrs. Pulford	SE. ¼ SW. ¼	20	32	11	....do	5 2½	4 3	52	22	26	32	49	......
27A	Vanderpool	NW. ¼ NE. ¼	30	32	11	....do	5 4	2 6½	55	35	10	25	34	......
28A	Peck	NE. ¼ NW. ¼	31	32	11	Anderson, upper bench	5 3½	2 2	54	36	10	25	35	......
28B	....do	NE. ¼ NW. ¼	31	32	11	Anderson, lower bench	5 3½	2 7	68	22	10	15	25	......
30A	Squaw Creek Association	(b)	......	33	11	Seven Foot	6	5 8	......	......	......	......	......	16

a No float and sink test.

b Unsurveyed.

In taking each sample for these tests the writer endeavored to obtain if possible a sample that would represent a minable portion of the bed. The tests were made on approximately 1 pound of coal broken into fragments one-fourth of an inch or less in size. All material finer than 60 mesh was screened and discarded, and the remainder was separated into float and sink in a calcium-chloride solution of 1.35 specific gravity. The column of liquid in which the separation was made was 8 inches high, and the division between float and sink was made 2½ inches from the bottom; that is, after the sample had come to rest in the apparatus all the material in the upper 5½ inches was taken out and treated as float, and all the material in the lower 2½ inches was treated as sink.

The average thickness sampled in each prospect on the Anderson bed on the south side of Eden Ridge (see secs. 14, 15, 17–23, and 28, Pl. XXV) is 59 inches, and the results of the tests as given above show in these samples an average of 54.2 per cent float with an approximate heating value of 10,000 British thermal units, and 45.8 per cent sink, which is probably worthless. The average thickness sampled on the Anderson bed on the north side of the ridge in prospects 25, 26, and 27 is 35 inches, and of the material in the samples 54 per cent was float with an approximate heating value of 8,500 British thermal units. The average thickness sampled in eight prospects on the Carter bed (see secs. 3, 5, 6, 7, and 9–12, Pl. XXV) is 36 inches, and the average of the results of the float and sink tests of these samples show that 50 per cent of the material is float with an approximate heating value of 9,500 British thermal units.

The tests thus indicate that in the greater part of the field the Anderson and Carter beds, though very bony, will yield to mechanical purification and will give a washed product, representing 50 to 60 per cent of the tonnage mined, which will contain from 15 to 25 per cent ash and have a heat value of 9,500 to over 10,000 British thermal units. Inasmuch, however, as the material must be broken into fragments less than 1 inch in diameter before being washed it is evident that the marketable coal will be in small fragments. Abundant water, a prime necessity in coal washing, is available in this field.

The best coal so far found in the field is at location 30 in Squaw Basin. Analysis No. 17707 shows it to contain 16 per cent ash and to have a heating value of more than 11,100 British thermal units. Although coking tests by the Bureau of Mines on samples from locations 29 and 30 gave negative results, selected portions of these beds were coked by the writer in a blacksmith forge. It is very probable that if the bone, though small in amount, were cleaned from the coal it could be commercially coked.

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

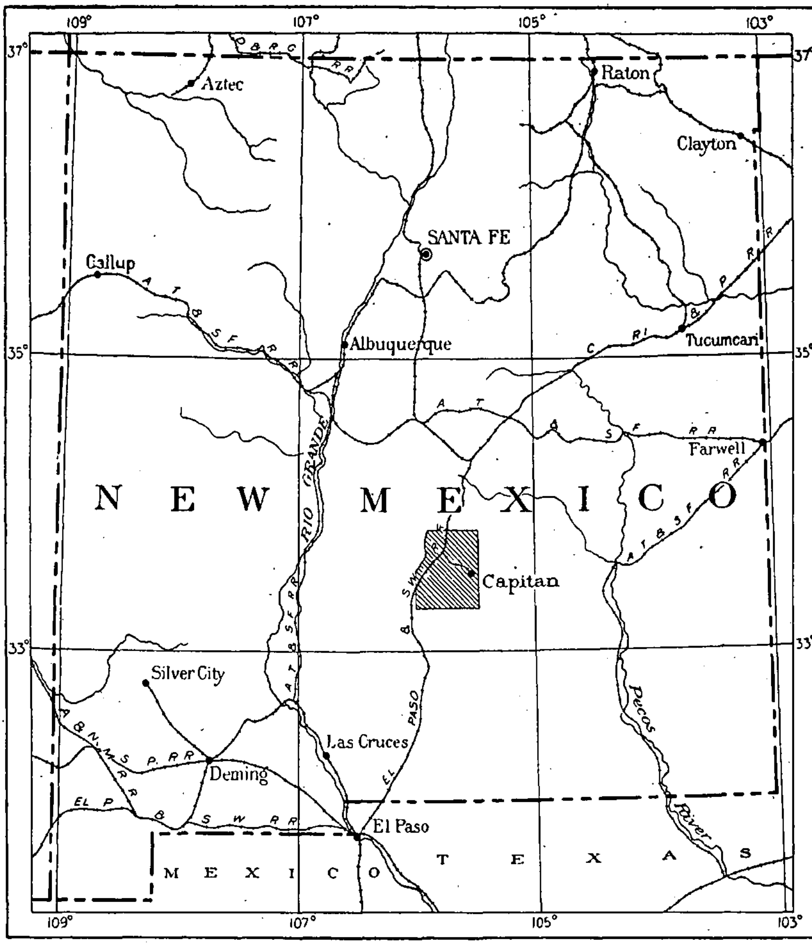


FIGURE 16.—Map of New Mexico, showing location of the Sierra Blanca coal field.

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.

[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 *Coïlopoceros 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. ¼ SW. ¼ sec. 32. (See Pl. XXVI.) The coal lies in two benches that are separated by 12 inches of shale, the upper bench measuring 9¾ inches and the lower 25 inches, including a 3-inch bone parting 2½ 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			3½
Coal	Mined		8¼
Bone	Mined		1¼
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:

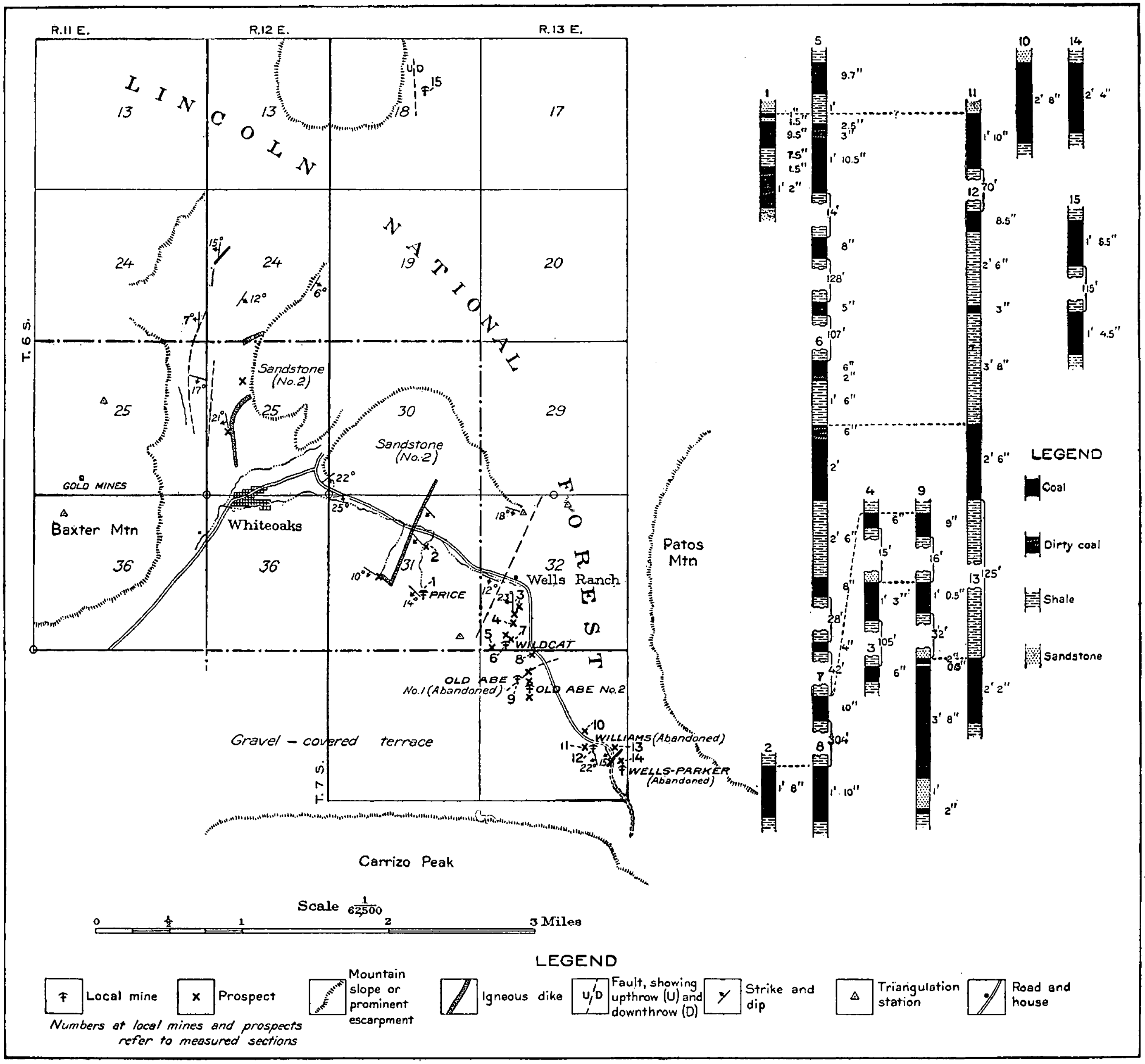
Section of coal beds in the SE. ¼ SW. ¼ sec. 26, T. 7 S., R. 13 E.

	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.

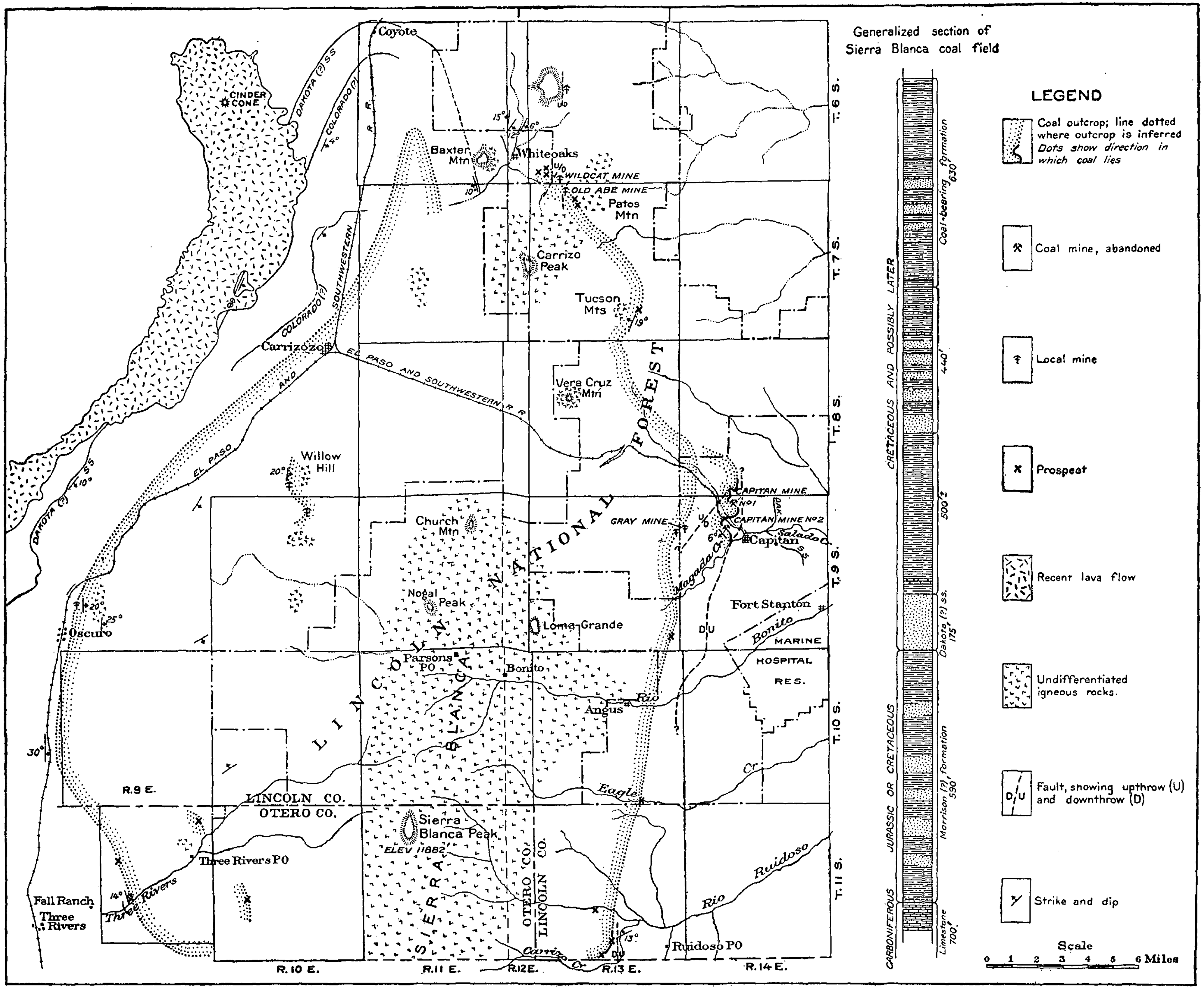
east of Carrizozo a narrow synclinal basin, which probably contains coal, lies between the outcrop of the Dakota (?) sandstone, which dips to the west on the west side of Baxter Mountain, and the outcrop of the formation underlying the coal, which dips to the east on the east side of the "malpais." The 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.

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[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

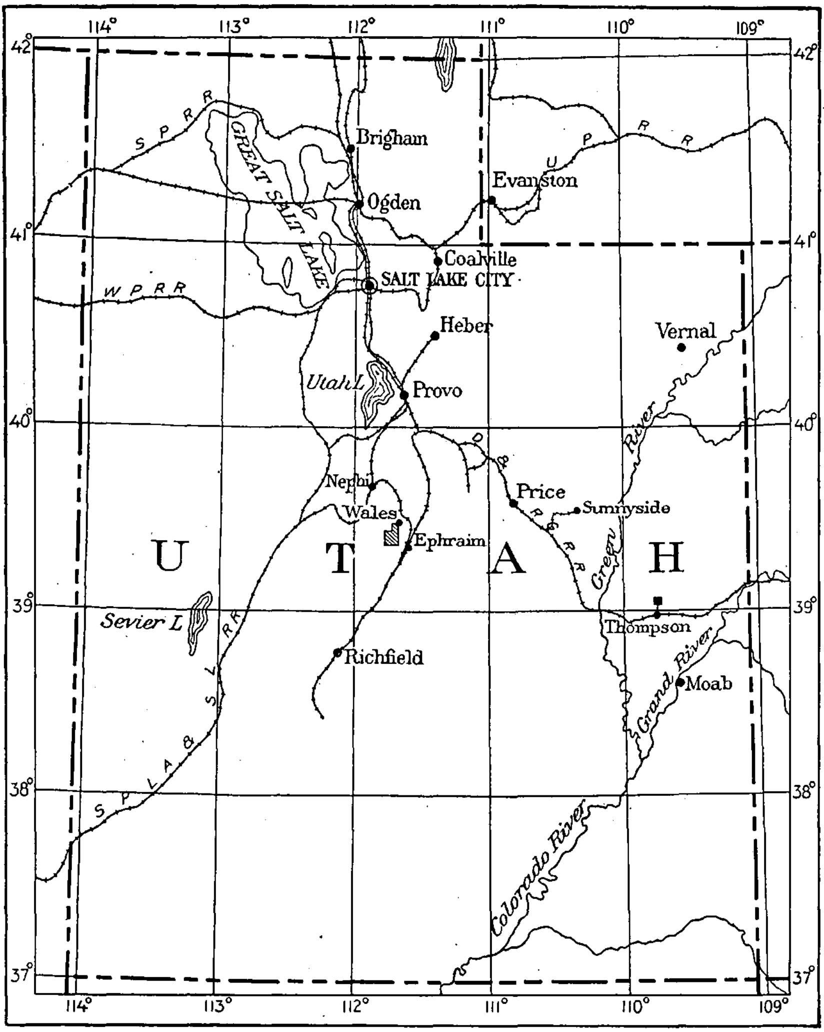


FIGURE 17.—Map of Utah, showing location of Thompson and Wales coal fields.

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

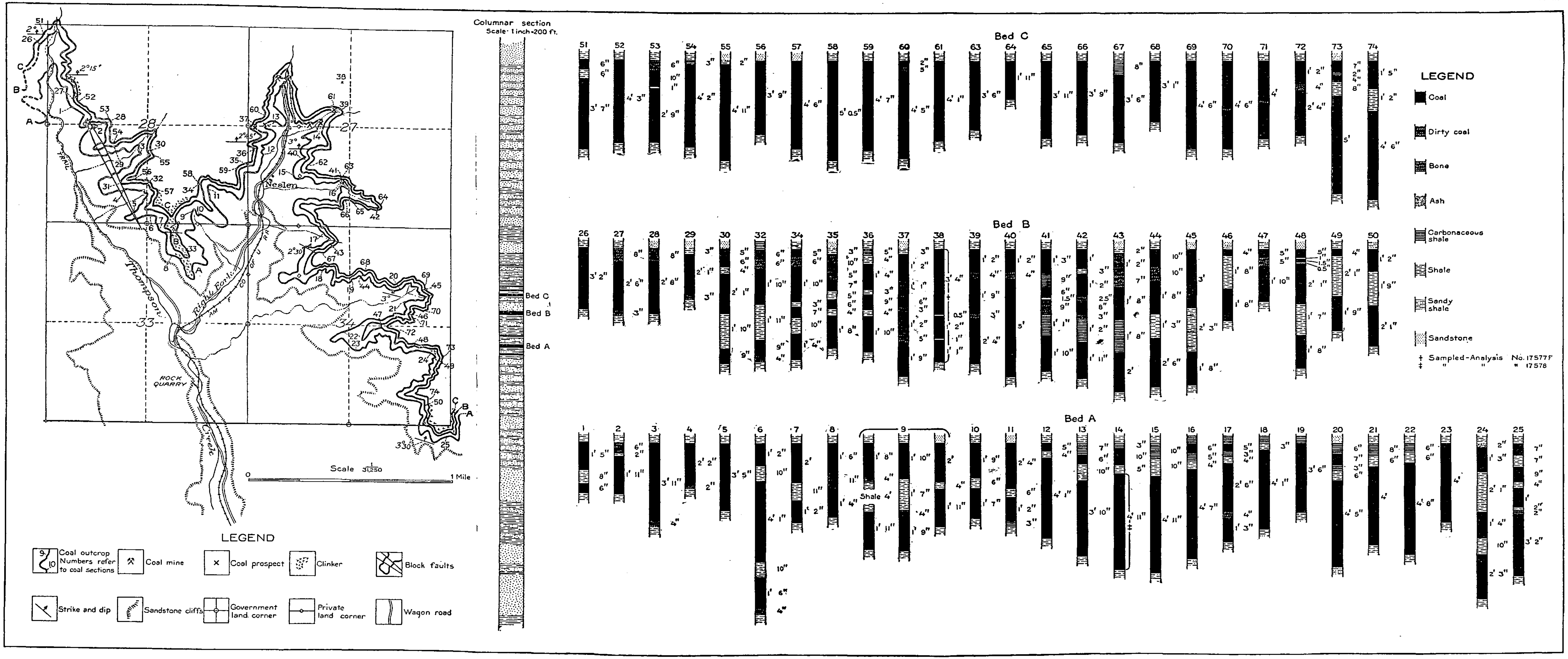
Location 14.

	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.

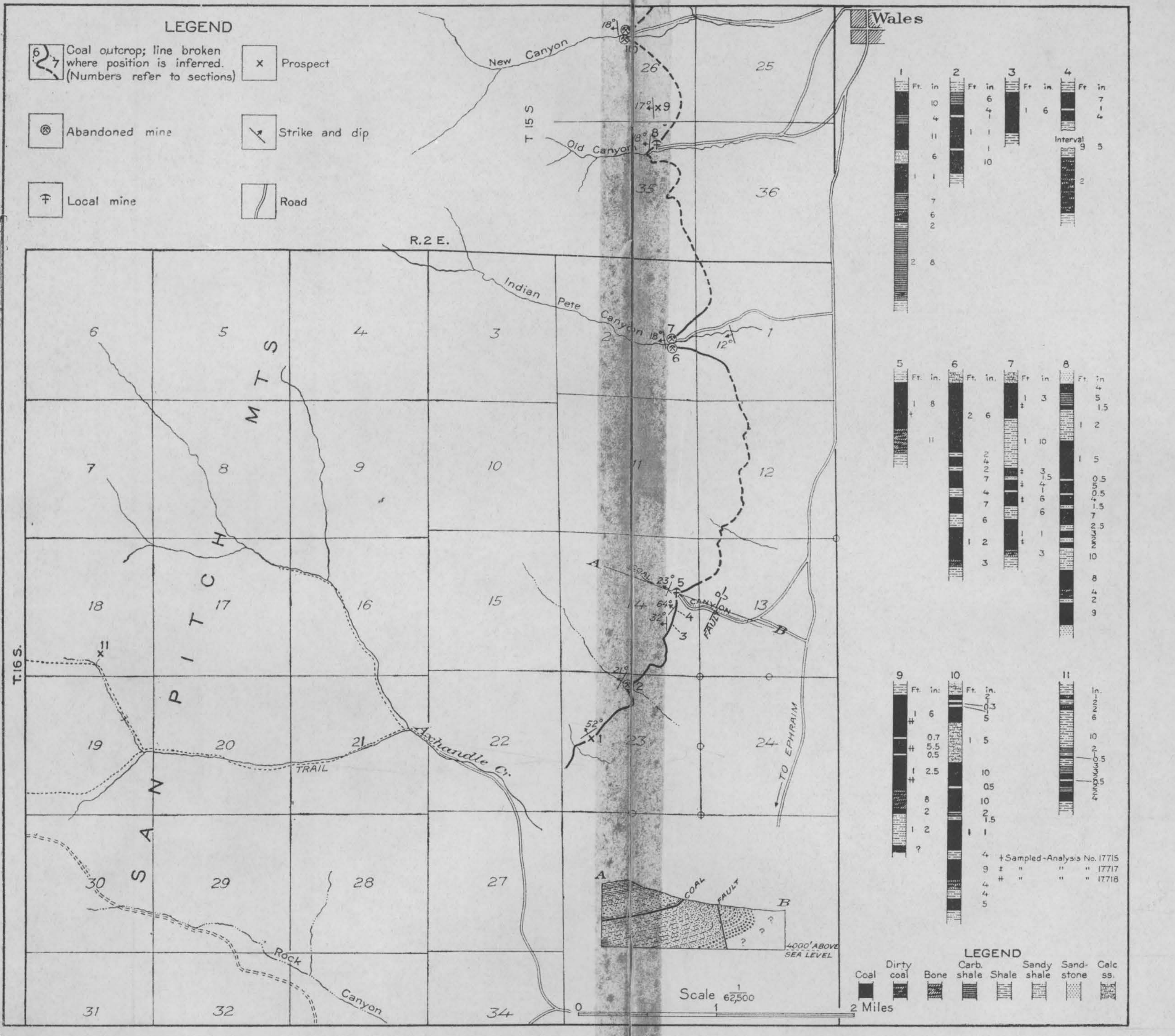
The coal which outcrops near the summit of Gunnison Plateau may belong to a coal-bearing zone composed of a series of lenses or it may represent a single stratigraphic horizon. It is here designated a zone. Only one measurement of the coal in this zone was obtained. This measurement was made at location 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.

ANALYSES OF COAL SAMPLES FROM VARIOUS FIELDS IN THE UNITED STATES.

By Marius R. Campbell.

INTRODUCTION.

The accompanying table gives the analysis of all coal samples collected by the United States Geological Survey during the year 1913. The analyses were made at the Pittsburgh laboratory of the Bureau of Mines by the same methods as those employed in all previous work by that bureau and by the Geological Survey, and consequently the results are comparable in every way with those already published by the two organizations.

In the course of a year many coal fields are examined in detail or reconnaissance by members of the United States Geological Survey. Those fields located in the eastern part of the United States are surveyed for the purpose of determining the amount and quality of the coal contained in them and of making public the facts concerning them in order to assist in their development. In the public-land States of the West the examinations are made in part for a similar purpose, but also (and in late years this has come to be the controlling motive) to gather data for the classification of the land as mineral or nonmineral according to its coal content. If the land is classed as coal land a valuation must be assigned it in accordance with certain rules and regulations adopted by the Interior Department, which take into account the amount of the coal and also its quality. The amount of the coal is determined from field data which are sufficiently complete for making a fairly reliable tonnage estimate; the quality of the coal is determined largely by chemical analysis. In determining the quality it is necessary to have not only the ordinary chemical analysis but also calorimeter determinations of the heating value. The analyses here given, as well as those previously published by the Bureau of Mines and the Geological Survey, generally give both of these factors for determining the value of a coal and afford a reliable basis for the valuation of the public land. In addition they present a vast amount of information by which almost any coal in the United States may be compared with others to determine its relative value for commercial uses.

Most of these analyses will be published in the descriptions of the fields to which they pertain, but as such reports will necessarily be delayed until all the data gathered in the field have been thoroughly classified and digested, they may not appear for several months or even a year. In order, however, to make the analyses immediately available to the public, they have been grouped according to States and counties and are herewith published in advance of the reports to which they relate. As a result of this mode of publication it is impossible to discuss and compare the analyses in order to show the relative grades of the coal samples, but it is believed that from the description of the samples that is given those wishing to make such comparisons can do so and can determine for themselves the relative efficiencies of the particular coals in which they are interested. This use is believed to be sufficiently great to justify the publication of the analyses in advance of the report on the field in which the samples were collected.

Many of the samples, especially those from public-land States, were collected in fields in which mining either has not been begun or has attained only negligible development. In these fields it is difficult, if not impossible, to secure fresh material, and hence the analyses show the coal to be of a lower grade than would appear were the sample made up of strictly unweathered coal. In the table all the weathered samples that have been recognized as such are marked. Their analyses should be taken with considerable allowance, and no important comparisons should be made with them or developments of the coal bed undertaken until they have been checked by the analysis of freshly mined coal. The analysis of weathered coal is valuable only until it can be supplanted by more reliable results.

In taking a sample of coal for analysis the geologist is instructed to make every endeavor to procure fresh unweathered material. He is supposed to face up the bed in the mine or prospect until fresh material is available, and then to obtain his sample by making a uniform cut across the bed from roof to floor, including all such benches and partings as an experienced and careful miner would include in commercial coal and throwing out such impurities as would certainly be excluded in practical operation. He is supposed to cut sufficient coal to give at least 6 pounds to the foot of coal bed sampled. The sample is hastily pulverized in the mine until it will pass through a ½-inch mesh and then is quartered down until about 4 pounds remain. This sample is placed in a galvanized-iron can, sealed with adhesive tape or paraffin, and mailed to the laboratory for analysis. The sampling is done on the principle that a coal mine should be sampled as carefully as a gold mine and that the sample should be even more carefully handled after it has been taken. The object of sealing is to prevent change in the moisture content, so that the coal may reach the laboratory in practically the same condition in which it exists in the mine. Coal is a very unstable substance, and great care must be exercised to prevent oxidation in the course of preparation and in transit. It is also important that the sample should consist of neither the best nor the poorest coal, but that it should be representative of the output of the mine, if one is in operation, or, if the field is undeveloped, it should represent as nearly as possible the merchantable coal that may be secured at some time in the future when mining is carried on.

Although the aim of the geologist in obtaining a sample by the method specified above is to obtain coal that is representative of the output of the mine, practical experience has shown that this is seldom or never accomplished. Almost invariably the sample obtained in the mine contains a lower percentage of impurities than does the coal which reaches the consumer. This is largely due to carelessness in mining and handling and probably could be largely eliminated were the conditions of mining more nearly ideal. By comparing a large number of samples taken in a mine with those taken at the point of consumption it has been found that there is a fairly constant though small difference in the percentage of moisture, ash, and sulphur, and that almost invariably the amount of these substances in the mine sample is less than it is in the coal as it reaches the market. For this reason a small amount should be added, especially to the ash given in the accompanying table, to correctly represent the ash in merchantable coal from the same mine.

During the early stages of land classification all the analytical work was done by the Geological Survey, but with the establishment of the Bureau of Mines "the analyzing and testing of coals, lignites, and other mineral-fuel substances" of the United States passed by law to that bureau. Accordingly all the analyses listed in this paper were made at the Bureau of Mines and to that bureau should be given the responsibility and credit. Although the analytical work has passed from one bureau to another, the laboratory and many of the chemists engaged in the work have remained the same and consequently the results are strictly comparable.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. This form is not well suited for comparing one coal with another in order to determine their relative merits as a fuel 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 as widely as the analyses of coal from different beds or from different fields. 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 probably represents the coal in its most stable condition and one approaching most closely its condition as it reaches the market. Therefore it is the form best adapted to the general purposes of 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 are obtained from the others merely by recalculation. They are useful in a study of the pure coal substance, free from impurity, but as this substance is not the same as the coal that reaches the bin of the consumer neither form C nor form D should be used in practical work.

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 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.

CLASSIFICATION OF COAL.

The classification of coal into various grades, such as bituminous, semibituminous, and lignite, is arbitrary and not at all satisfactory, but it is in common use in the United States and it seems desirable to give the class for each sample, because from the analysis one could not always determine this important point. The classes generally used in the United States are as follows: Anthracite, semianthracite, semibituminous, bituminous, subbituminous, and lignite.

Anthracite.—Anthracite coal is generally well known, but in a systematic classification it is generally defined as a hard coal having a fuel ratio (fixed carbon divided by volatile matter) of not less than 10. Most of this coal comes from the anthracite fields of eastern Pennsylvania, but small areas are known in some of the Western States where the coal has been changed to anthracite by the heat and pressure of masses of igneous rock.

Semianthracite.—Semianthracite coal has a fuel ratio ranging from 6 or 7 to 10. There is only a small amount of this coal in the United States, found in local basins or in close proximity to igneous rocks.

Semibituminous.—Semibituminous coal is of great commercial importance, but is not widely distributed. Its fuel ratio ranges from

3 to 6 or 7. It is the best steam coal in the country, and some of it can be utilized in the manufacture of coke. The centers of production are the Pocahontas and New River fields of Virginia and West Virginia, Georges Creek field of Maryland, Windber field of Pennsylvania, and the western end of the Arkansas field in the vicinity of Fort Smith. Though small areas containing this grade of coal have been found in Washington and Colorado, the amount of such coal in these fields is small.

Bituminous.—Bituminous coal is the most important grade in the country and includes most of the coals east of the Rocky Mountains. In the Western States there are large areas of bituminous coal, such as the Trinidad-Raton field of Colorado and New Mexico; the Grand Hogback field of Colorado; the Book Cliffs field of Utah; the Rock Springs, Kemmerer, and Black Hills fields of Wyoming; the Great Falls field of Montana; and many districts of Washington. This grade furnishes most of the coking coal of the country, and it is largely sold for steam raising and for domestic use.

Subbituminous.—The term "subbituminous" has been adopted by the Geological Survey for what has generally been called "black lignite." The latter term is objectionable, for the reason that the coal is not lignitic in the sense of being woody, and the use of the term seems to imply that the coal is little better than the brown, woody lignite of North Dakota, whereas many of the coals of this class closely approach the lowest grade of bituminous coal. In fact, it is extremely difficult to separate this class from the one below and the one above. It is generally distinguished from the lignite by its color and freedom from apparent woody texture and from bituminous coal by the slacking it undergoes when exposed to the weather. As the latter is an important difference in commercial use, it has been adopted by the Geological Survey as the criterion for the separation of subbituminous and bituminous coals.

Subbituminous coal is found in most of the western fields, being well known in the field about Boulder and Denver and in North Park, Colo.; Gallup, N. Mex.; Hanna, Douglas, Sheridan, and the Bighorn Basin, Wyo.; Red Lodge and Musselshell, Mont.; and in many of the districts of Washington and Oregon.

Lignite.—As used by the Geological Survey the term "lignite" is restricted to the coals that are distinctly brown and generally woody. They are intermediate in quality between peat and subbituminous coal. Lignite is abundant in the North in eastern Montana and North Dakota and in the northwest corner of South Dakota. In the South it is present in all of the Gulf States, but it has been developed commercially only in Texas.

ANALYSES.[a]

[Made by the Bureau of Mines. A. C. Fieldner, chemist in charge.]

ALABAMA.

DEKALB COUNTY.

Laboratory No.	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.
18230	2.6	A	3.6	19.0	65.9	11.5	1.44						
		B	1.1	19.5	67.6	11.8	1.48						
		C		19.7	68.4	11.9	1.49						
		D		22.4	77.6		1.69						
18233	2.8	A	3.4	18.7	63.4	14.54	1.22	4.29	72.86	1.27	5.82	7,055	12,700
		B	.6	19.2	65.2	14.95	1.25	4.09	74.92	1.31	3.48	7,255	13,060
		C		19.3	65.6	15.05	1.26	4.05	75.41	1.31	2.92	7,305	13,150
		D		22.7	77.3		1.48	4.77	88.77	1.54	3.44	8,595	15,480
18234	2.9	A	3.8	19.0	64.4	12.8	1.52					7,215	12,980
		B	1.0	19.6	66.3	13.1	1.56					7,425	13,370
		C		19.7	67.0	13.3	1.58					7,500	13,500
		D		22.8	77.2		1.82					8,645	15,560
18231	2.2	A	2.8	20.2	60.6	16.4	4.43						
		B	.6	20.7	62.0	16.7	4.53						
		C		20.8	62.4	16.8	4.56						
		D		25.0	75.0		5.48						
18232	3.0	A	3.5	20.6	64.8	11.1	2.64						
		B	.5	21.3	66.8	11.4	2.72						
		C		21.3	67.2	11.5	2.74						
		D		24.1	75.9		3.09						

COLORADO.

LA PLATA COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17745F	1.3	A	4.7	36.8	45.0	13.52	0.86	5.47	66.56	1.51	12.08	6,640	11,950
		B	3.4	37.3	45.6	13.70	.87	5.39	67.46	1.53	11.05	6,730	12,110
		C		38.6	47.2	14.18	.90	5.19	69.81	1.58	8.34	6,965	12,540
		D		45.0	55.0		1.05	6.05	81.34	1.84	9.72	8,115	14,610
17747	1.4	A	11.6	31.4	40.1	16.9	.61					4,615	8,300
		B	10.3	31.8	40.7	17.2	.62					4,680	8,420
		C		35.5	45.4	19.1	.69					5,220	9,400
		D		43.9	56.1		.85					6,455	11,620
17748	.7	A	4.2	36.1	44.6	15.1	.69					6,500	11,700
		B	3.6	36.4	44.8	15.2	.69					6,545	11,780
		C		37.7	46.5	15.8	.72					6,890	12,220
		D		44.8	55.2		.85					8,055	14,500
17855	2.5	A	5.8	37.2	50.3	6.71	.58	5.67	71.41	1.61	14.02	7,025	12,650
		B	3.3	38.2	51.6	6.88	.59	5.53	73.27	1.65	12.08	7,210	12,980
		C		39.5	53.4	7.12	.62	5.34	75.81	1.71	9.40	7,460	13,430
		D		42.5	57.5		.67	5.75	81.62	1.84	10.12	8,030	14,460

[a] Description of samples is given on pp. 508-526.

COLORADO—Continued.

MOFFAT COUNTY.

Laboratory No.	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.
17592	7.8	A....	23.3	[a] 29.6	40.0	7.13	0.65	5.79	54.00	0.68	31.75	4,925	8,870
		B....	16.8	32.1	43.4	7.73	.70	5.35	58.55	.74	26.93	5,340	9,610
		C....	....	38.6	52.1	9.29	.85	4.18	70.37	.89	14.42	6,420	11,550
		D....	....	42.5	57.5	......	.94	4.61	77.58	.98	15.89	7,075	12,740
17593	5.1	A....	22.1	[a] 31.6	42.0	4.34	.72	6.01	55.39	1.18	32.36	5,165	9,300
		B....	17.9	33.3	44.2	4.57	.76	5.73	58.37	1.24	29.33	5,445	9,800
		C....	....	40.6	53.8	5.57	.92	4.56	71.10	1.51	16.34	6,630	11,930
		D....	....	43.0	57.0	......	.97	4.83	75.29	1.60	17.31	7,020	12,640
17686	[b] 2.4	A....	11.7	38.0	44.3	5.96	.92	5.84	63.99	1.14	22.15	6,210	11,180
		B....	9.6	38.9	45.4	6.10	.94	5.71	65.54	1.17	20.54	6,360	11,450
		C....	....	43.0	50.2	6.75	1.04	5.14	72.48	1.29	13.30	7,035	12,670
		D....	....	46.2	53.8	......	1.12	5.51	77.73	1.38	14.26	7,545	13,580
17696	6.1	A....	18.9	[a] 30.4	44.4	6.29	.64	5.71	57.47	.82	29.07	5,400	9,720
		B....	13.6	32.4	47.3	6.70	.68	5.36	61.22	.87	25.17	5,755	10,360
		C....	....	37.5	54.7	7.76	.79	4.45	70.90	1.01	15.09	6,665	11,990
		D....	....	40.7	59.3	......	.86	4.82	76.86	1.09	16.37	7,225	13,000
17782	[b] 1.8	A....	11.9	36.8	45.6	5.72	.55	5.83	64.36	1.40	22.14	6,240	11,230
		B....	10.2	37.5	46.5	5.83	.56	5.73	65.56	1.43	20.89	6,355	11,440
		C....	....	41.7	51.8	6.49	.62	5.12	73.03	1.59	13.15	7,080	12,750
		D....	....	44.6	55.4	......	.66	5.48	78.10	1.70	14.06	7,575	13,630
17840	[b] 2.2	A....	14.2	36.3	45.3	4.18	.59	5.82	63.54	1.22	24.65	6,100	10,980
		B....	12.2	37.1	46.4	4.28	.60	5.70	64.98	1.25	23.19	6,235	11,230
		C....	....	42.2	52.9	4.87	.69	4.94	74.06	1.42	14.02	7,105	12,790
		D....	....	44.4	55.6	......	.73	5.19	77.85	1.49	14.74	7,470	13,450

ILLINOIS.

McDONOUGH COUNTY.

15119	10.1	A....	13.3	37.7	42.6	6.41	2.88	5.91	63.84	1.20	19.76	6,495	11,700
		B....	3.5	42.0	47.4	7.13	3.20	5.33	71.01	1.34	11.99	7,225	13,010
		C....	....	43.5	49.1	7.39	3.32	5.11	73.61	1.38	9.19	7,490	13,490
		D....	....	47.0	53.0	......	3.58	5.52	79.48	1.49	9.93	8,090	14,560

KENTUCKY.

PIKE COUNTY.

17459F	1.4	A....	3.2	33.0	58.7	5.08	0.62	5.33	78.45	1.40	9.12	7,710	13,880
		B....	1.9	33.5	59.5	5.15	.63	5.25	79.53	1.42	8.02	7,815	14,070
		C....	....	34.1	60.6	5.25	.64	5.14	81.05	1.45	6.47	7,965	14,340
		D....	....	36.0	64.0	......	.68	5.42	85.54	1.53	6.83	8,410	15,130
17460F	1.0	A....	2.5	34.8	58.4	4.26	.59	5.22	79.89	1.45	8.59	7,915	14,250
		B....	1.5	35.2	59.0	4.30	.60	5.16	80.69	1.46	7.79	7,995	14,390
		C....	....	35.7	59.9	4.37	.61	5.07	81.94	1.49	6.52	8,115	14,610
		D....	....	37.4	62.6	......	.64	5.30	85.68	1.56	6.82	8,490	15,280
17461F	1.3	A....	2.8	36.2	56.7	4.30	1.35	5.39	79.25	1.47	8.24	7,875	14,180
		B....	1.5	36.7	57.4	4.35	1.37	5.32	80.25	1.49	7.22	7,975	14,360
		C....	....	37.2	58.4	4.42	1.39	5.22	81.50	1.51	5.96	8,100	14,580
		D....	....	39.0	61.0	......	1.45	5.46	85.27	1.58	6.24	8,475	15,260

[a] Volatile matter determined by the modified official method. (See Bureau of Mines Bull. 22, p. 29.)
[b] The small air-drying loss indicates that the coal was weathered.

MONTANA.

BIGHORN COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heating value. Calories.	British thermal units.
17711	3.7	A	22.6	31.9	39.5	6.0	0.51					4,895	8,810
		B	19.6	33.1	41.1	6.2	.53					5,085	9,150
		C		41.2	51.1	7.7	.66					6,325	11,380
		D		44.6	55.4		.72					6,855	12,340

HILL COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17841F	10.1	A	24.1	[a] 29.2	37.4	9.28	1.15	5.98	50.03	1.02	32.54	4,705	8,470
		B	15.7	32.5	41.5	10.32	1.28	5.40	55.63	1.13	26.24	5,230	9,420
		C		38.5	49.3	12.23	1.52	4.35	65.95	1.34	14.61	6,205	11,170
		D		43.9	56.1		1.73	4.96	75.14	1.53	16.64	7,065	12,720
17842F	1.2	A	7.2	34.0	50.5	8.33	1.77	5.13	67.62	1.42	15.73	6,540	11,770
		B	6.0	34.4	51.2	8.43	1.79	5.06	68.45	1.44	14.83	6,620	11,920
		C		36.6	54.4	8.97	1.91	4.66	72.84	1.53	10.09	7,045	12,680
		D		40.2	59.8		2.10	5.12	80.01	1.68	11.09	7,740	13,930
17892	19.1	A	31.4	[a] 30.4	23.8	14.4	1.35						
		B	15.2	37.6	29.4	17.8	1.67						
		C		44.4	34.7	20.9	1.97						
		D		56.2	43.8		2.49						

MUSSELSHELL COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17586F	2.2	A	13.4	32.4	47.6	6.58	0.39	5.59	63.89	0.98	22.57	6,175	11,120
		B	11.5	33.1	48.7	6.73	.40	5.46	65.34	1.00	21.07	6,315	11,370
		C		37.4	55.0	7.60	.45	4.74	73.79	1.13	12.29	7,130	12,840
		D		40.4	59.6		.49	5.13	79.86	1.22	13.30	7,720	13,890
17587	3.4	A	14.5	31.5	47.5	6.5	.80					5,750	10,350
		B	11.6	32.6	49.1	6.7	.83					5,950	10,710
		C		36.9	55.5	7.6	.94					6,725	12,110
		D		39.9	60.1		1.02					7,280	13,100
17588	2.1	A	13.6	32.6	46.8	7.0	.58					6,105	10,990
		B	11.7	33.3	47.8	7.2	.59					6,235	11,220
		C		37.7	54.1	8.2	.67					7,065	12,710
		D		41.1	58.9		.73					7,690	13,840
17589	2.0	A	13.4	33.2	45.6	7.8	.51					6,050	10,890
		B	11.7	33.9	46.5	7.9	.52					6,175	11,120
		C		38.3	52.7	9.0	.59					6,990	12,590
		D		42.1	57.9		.65					7,685	13,830

NEW MEXICO.

COLFAX COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17703	0.9	A	2.6	36.0	45.3	16.08	0.56	5.35	67.63	1.56	8.82	6,750	12,150
		B	1.7	36.4	45.7	16.23	.57	5.30	68.25	1.57	8.08	6,810	12,260
		C		37.0	46.5	16.51	.57	5.19	69.43	1.60	6.70	6,930	12,470
		D		44.3	55.7		.68	6.22	83.16	1.92	8.02	8,300	14,940
17746F	1.6	A	5.7	37.4	44.6	12.28	1.09	5.47	66.31	1.40	13.45	6,655	11,980
		B	4.1	38.0	45.4	12.48	1.11	5.38	67.41	1.42	12.20	6,765	12,180
		C		39.6	47.4	13.02	1.16	5.13	70.33	1.48	8.88	7,055	12,700
		D		45.6	54.4		1.33	5.90	80.86	1.70	10.21	8,115	14,600
17781F	.4	A	2.0	35.7	49.2	13.10	.78	5.24	70.71	1.32	8.85	7,035	12,670
		B	1.6	35.9	49.4	13.15	.78	5.22	70.99	1.33	8.53	7,065	12,720
		C		36.4	50.2	13.36	.80	5.12	72.13	1.35	7.24	7,180	12,920
		D		42.1	57.9		.92	5.91	83.25	1.56	8.36	8,285	14,910

[a] Volatile matter determined by the modified official method.

NEW MEXICO—Continued.

SAN JUAN COUNTY.

Laboratory No.	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.
17749	1.6	A	6.6	35.4	44.9	13.1	0.66					6,380	11,490
		B	5.1	36.0	45.6	13.3	.67					6,485	11,680
		C		37.9	48.0	14.1	.71					6,835	12,300
		D		44.1	55.9		.83					7,950	14,310
17750	1.8	A	10.6	36.7	49.6	3.1	.64					6,115	11,010
		B	9.0	37.4	50.5	3.1	.65					6,225	11,210
		C		41.1	55.4	3.5	.72					6,840	12,310
		D		42.6	57.4		.75					7,085	12,750

SOCORRO COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17602	1.3	A	6.5	34.5	51.9	7.09	0.50	5.32	69.35	1.17	16.57	6,660	11,990
		B	5.3	34.9	52.6	7.18	.51	5.25	70.24	1.19	15.63	6,750	12,150
		C		36.9	55.5	7.58	.53	4.92	74.16	1.25	11.56	7,125	12,820
		D		39.9	60.1		.57	5.32	80.24	1.35	12.52	7,710	13,870
17728	6.7	A	18.5	a 31.7	39.0	10.8	.43					4,710	8,480
		B	12.6	34.0	41.8	11.6	.46					5,050	9,090
		C		38.9	47.9	13.2	.53					5,780	10,400
		D		44.8	55.2		.61					6,665	11,990

OREGON.

GRANT COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
18125	27.4	A	34.7	a 20.0	14.2	31.1	1.41						
		B	10.1	27.6	19.5	42.8	1.94						
		C		30.6	21.7	47.7	2.16						
		D		58.5	41.5		4.13						

WHEELER COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
18126	7.2	A	13.8	22.8	29.2	34.2	0.47						
		B	7.1	24.6	31.5	36.8	.51						
		C		26.5	33.9	39.6	.55						
		D		43.9	56.1		.91						
18127	6.6	A	13.4	23.7	32.1	30.8	.46					4,040	7,270
		B	7.3	25.4	34.3	33.0	.49					4,320	7,780
		C		27.4	37.0	35.6	.53					4,665	8,390
		D		42.5	57.5		.82					7,235	13,030

PENNSYLVANIA.

CENTER COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17444F	2.1	A	3.4	22.8	61.4	12.40	0.88	4.69	74.44	1.45	6.14	7,245	13,040
		B	1.3	23.3	62.7	12.67	.90	4.55	76.07	1.48	4.33	7,400	13,320
		C		23.6	63.6	12.83	.91	4.46	77.05	1.50	3.25	7,500	13,500
		D		27.1	72.9		1.04	5.12	88.39	1.72	3.73	8,600	15,480
17445	2.2	A	3.5	22.1	66.6	7.8	1.79					7,700	13,860
		B	1.4	22.5	68.1	8.0	1.83					7,875	14,170
		C		22.9	69.0	8.1	1.86					7,980	14,370
		D		24.9	75.1		2.02					8,685	15,630
17446F	2.1	A	3.5	23.7	61.6	11.24	2.66	4.78	73.51	1.34	6.47	7,255	13,060
		B	1.4	24.2	62.9	11.48	2.72	4.64	75.11	1.37	4.68	7,415	13,340
		C		24.6	63.8	11.64	2.75	4.56	76.13	1.39	3.53	7,515	13,530
		D		27.8	72.2		3.11	5.16	86.16	1.57	4.00	8,505	15,310
17447F	1.2	A	1.9	22.0	61.5	14.57	.99	4.43	73.26	1.26	5.49	7,095	12,780
		B	.6	22.3	62.3	14.75	1.00	4.34	74.18	1.28	4.45	7,185	12,940
		C		22.4	62.7	14.85	1.01	4.30	74.67	1.28	3.89	7,235	13,020
		D		26.3	73.7		1.19	5.05	87.69	1.50	4.57	8,495	15,290

a Volatile matter determined by the modified official method.

PENNSYLVANIA—Continued.

CLEARFIELD COUNTY.

Laboratory No.	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.
17441F	1.4	A....	2.4	22.4	66.4	8.75	3.15	4.71	78.05	1.36	3.98	7,660	13,790
		B....	1.1	22.7	67.3	8.87	3.19	4.62	79.14	1.38	2.80	7,770	13,980
		C....	....	23.0	68.0	8.97	3.23	4.55	80.01	1.39	1.85	7,855	14,140
		D....	....	25.2	74.8	......	3.55	5.00	87.89	1.53	2.03	8,625	15,530
17442F	1.9	A....	2.8	20.2	63.9	13.10	3.04	4.66	72.98	1.27	4.95	7,215	12,990
		B....	.9	20.6	65.1	13.35	3.10	4.54	74.40	1.29	3.32	7,355	13,240
		C....	....	20.8	65.7	13.48	3.13	4.48	75.10	1.31	2.50	7,425	13,370
		D....	....	24.0	76.0	......	3.62	5.18	86.80	1.51	2.89	8,580	15,450
17443F	1.0	A....	2.0	31.1	58.3	8.65	2.01	5.04	76.99	1.60	5.71	7,630	13,730
		B....	1.0	31.4	58.9	8.73	2.03	4.98	77.73	1.62	4.91	7,705	13,870
		C....	....	31.7	59.5	8.82	2.05	4.92	78.54	1.63	4.04	7,785	14,010
		D....	....	34.8	65.2	......	2.25	5.40	86.13	1.79	4.43	8,535	15,370

ELK COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17455	1.5	A....	2.9	34.7	52.7	9.66	3.92	5.19	72.67	1.41	7.15	7,380	13,280
		B....	1.5	35.2	53.5	9.80	3.98	5.10	73.75	1.43	5.94	7,490	13,480
		C....	....	35.7	54.3	9.95	4.04	5.02	74.86	1.45	4.68	7,600	13,680
		D....	....	39.6	60.4	......	4.49	5.57	83.13	1.61	5.20	8,440	15,200
17456F	1.3	A....	2.7	32.4	58.6	6.32	2.52	5.22	78.10	1.45	6.39	7,785	14,020
		B....	1.5	32.8	59.3	6.40	2.55	5.14	79.10	1.47	5.34	7,885	14,200
		C....	....	33.3	60.2	6.49	2.59	5.06	80.26	1.49	4.11	8,000	14,400
		D....	....	35.6	64.4	......	2.77	5.41	85.83	1.59	4.40	8,555	15,400
17457	1.8	A....	3.1	30.6	57.0	9.3	3.45	....	....	....	....	7,440	13,390
		B....	1.4	31.1	58.0	9.5	3.51	....	....	....	....	7,570	13,630
		C....	....	31.5	58.8	9.7	3.56	....	....	....	....	7,675	13,820
		D....	....	34.9	65.1	......	3.94	....	....	....	....	8,495	15,300
17458	1.0	A....	2.7	33.7	54.9	8.7	2.89	....	....	....	....	7,480	13,470
		B....	1.7	34.0	55.5	8.8	2.92	....	....	....	....	7,560	13,600
		C....	....	34.6	56.5	8.9	2.97	....	....	....	....	7,690	13,840
		D....	....	38.0	62.0	......	3.26	....	....	....	....	8,440	15,190

JEFFERSON COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17448F	1.2	A....	1.9	34.6	53.2	10.28	2.91	5.00	72.73	1.51	7.57	7,305	13,150
		B....	.7	35.0	53.9	10.40	2.95	4.93	73.61	1.53	6.58	7,395	13,310
		C....	....	35.3	54.2	10.48	2.97	4.88	74.11	1.54	6.02	7,445	13,400
		D....	....	39.4	60.6	......	3.32	5.45	82.79	1.72	6.72	8,315	14,970
17449F	1.2	A....	3.1	32.3	54.9	9.67	1.69	4.99	73.71	1.60	8.34	7,345	13,220
		B....	1.9	32.7	55.6	9.78	1.71	4.92	74.58	1.62	7.39	7,430	13,370
		C....	....	33.3	56.7	9.98	1.74	4.80	76.07	1.65	5.76	7,580	13,640
		D....	....	37.0	63.0	......	1.93	5.33	84.51	1.83	6.40	8,420	15,150
17450F	.5	A....	1.9	34.5	53.2	10.40	3.38	5.03	74.08	1.51	5.60	7,385	13,290
		B....	1.4	34.7	53.5	10.45	3.40	5.00	74.46	1.52	5.17	7,425	13,360
		C....	....	35.2	54.2	10.60	3.45	4.91	75.54	1.54	3.96	7,530	13,550
		D....	....	39.3	60.7	......	3.86	5.49	84.50	1.72	4.43	8,425	15,160

PENNSYLVANIA—Continued.

SOMERSET COUNTY.

Laboratory No.	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.
17689	2.9	A....	4.2	19.8	63.9	12.12	0.67	4.70	74.31	1.27	6.93	7,175	12,920
		B....	1.3	20.4	65.8	12.48	.69	4.51	76.51	1.31	4.50	7,385	13,300
		C....	....	20.7	66.7	12.65	.70	4.42	77.55	1.33	3.35	7,490	13,480
		D....	....	23.7	76.3	......	.80	5.06	88.78	1.52	3.84	8,570	15,430
17690	2.4	A....	3.2	17.1	64.6	15.11	1.47	4.38	72.65	1.31	5.08	7,165	12,890
		B....	.8	17.5	66.2	15.48	1.51	4.22	74.42	1.34	3.03	7,340	13,210
		C....	....	17.7	66.7	15.61	1.52	4.15	75.06	1.35	2.31	7,400	13,320
		D....	....	20.9	79.1	......	1.80	4.92	88.95	1.60	2.73	8,770	15,790
17691	2.0	A....	3.1	18.9	67.1	10.88	1.52	4.60	76.38	1.29	5.33	7,455	13,420
		B....	1.1	19.4	68.4	11.10	1.55	4.47	77.95	1.32	3.61	7,605	13,690
		C....	....	19.6	69.2	11.22	1.57	4.40	78.80	1.33	2.68	7,690	13,840
		D....	....	22.0	78.0	......	1.77	4.96	88.76	1.50	3.01	8,660	15,590
17692	2.1	A....	2.9	21.7	64.5	10.92	1.16	4.69	76.60	1.39	5.24	7,475	13,460
		B....	.8	22.1	65.9	11.15	1.18	4.56	78.24	1.42	3.45	7,635	13,750
		C....	....	22.3	66.4	11.25	1.19	4.50	78.91	1.43	2.72	7,700	13,860
		D....	....	25.2	74.8	......	1.34	5.07	88.92	1.61	3.06	8,680	15,620
17693	1.4	A....	2.1	21.1	65.0	11.82	2.44	4.57	76.40	1.30	3.47	7,465	13,430
		B....	.7	21.4	65.9	11.98	2.47	4.48	77.45	1.32	2.30	7,565	13,620
		C....	....	21.5	66.4	12.07	2.49	4.43	78.00	1.33	1.68	7,620	13,710
		D....	....	24.5	75.5	......	2.83	5.04	88.71	1.51	1.91	8,665	15,600
17694	2.7	A....	3.6	17.6	69.5	9.28	1.63	4.61	77.72	1.20	5.56	7,515	13,530
		B....	1.0	18.1	71.4	9.53	1.67	4.44	79.84	1.23	3.29	7,720	13,900
		C....	....	18.3	72.1	9.62	1.69	4.37	80.60	1.24	2.48	7,795	14,030
		D....	....	20.2	79.8	......	1.87	4.83	89.18	1.37	2.75	8,625	15,520
17695	1.7	A....	2.9	18.7	73.2	5.19	.63	4.82	82.90	1.42	5.04	7,975	14,350
		B....	1.2	19.0	74.5	5.28	.64	4.71	84.36	1.44	3.57	8,115	14,610
		C....	....	19.3	75.4	5.34	.65	4.63	85.37	1.46	2.55	8,210	14,780
		D....	....	20.4	79.6	......	.69	4.89	90.18	1.54	2.70	8,675	15,620
17831	6.0	A....	11.5	20.1	55.2	13.2	.78	......	......	......	......	5,680	10,230
		B....	5.9	21.3	58.7	14.1	.83	......	......	......	......	6,045	10,880
		C....	....	22.7	62.3	15.0	.88	......	......	......	......	6,420	11,560
		D....	....	26.7	73.3	......	1.03	......	......	......	......	7,555	13,600
17832	2.4	A....	3.5	20.4	67.9	8.2	.83	......	......	......	......	7,610	13,700
		B....	1.2	20.9	69.6	8.3	.85	......	......	......	......	7,795	14,040
		C....	....	21.1	70.4	8.5	.86	......	......	......	......	7,890	14,200
		D....	....	23.1	76.9	......	.94	......	......	......	......	8,620	15,510

TIOGA COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17451F	0.8	A....	1.7	21.5	67.6	9.23	1.73	4.54	78.50	1.38	4.62	7,670	13,810
		B....	.9	21.7	68.1	9.30	1.74	4.48	79.11	1.39	3.98	7,730	13,920
		C....	....	21.9	68.7	9.39	1.76	4.43	79.83	1.40	3.19	7,800	14,040
		D....	....	24.1	75.9	......	1.94	4.89	88.10	1.55	3.52	8,610	15,500
17452	1.5	A....	2.4	19.7	65.2	12.7	2.47	......	......	......	......	7,285	13,120
		B....	.8	20.1	66.2	12.9	2.51	......	......	......	......	7,400	13,320
		C....	....	20.2	66.8	13.0	2.53	......	......	......	......	7,465	13,430
		D....	....	23.2	76.8	......	2.91	......	......	......	......	8,575	15,440
17453	1.1	A....	1.9	20.6	65.0	12.5	2.87	......	......	......	......	7,305	13,150
		B....	.8	20.8	65.7	12.7	2.90	......	......	......	......	7,385	13,300
		C....	....	21.0	66.2	12.8	2.92	......	......	......	......	7,445	13,400
		D....	....	24.1	75.9	......	3.35	......	......	......	......	8,535	15,370
17454F	1.5	A....	2.3	20.9	66.9	9.88	1.28	4.52	78.15	1.43	4.74	7,565	13,620
		B....	.8	21.2	68.0	10.03	1.30	4.42	79.32	1.45	3.48	7,680	13,820
		C....	....	21.4	68.5	10.11	1.31	4.37	79.98	1.46	2.77	7,745	13,940
		D....	....	23.8	76.2	......	1.46	4.86	88.98	1.62	3.08	8,615	15,510

PENNSYLVANIA—Continued.

WESTMORELAND COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heating value. Calories.	Heating value. British thermal units.
17901 F	1.9	A	2.6	21.4	64.4	11.59	1.94	4.63	75.81	1.25	4.78	7,425	13,370
		B	.7	21.9	65.6	11.82	1.98	4.51	77.29	1.27	3.13	7,570	13,630
		C		22.0	66.1	11.90	1.99	4.46	77.84	1.28	2.53	7,625	13,720
		D		25.0	75.0		2.26	5.06	88.36	1.45	2.87	8,655	15,580

UTAH.

CARBON COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17604F	1.1	A	4.0	[a] 38.0	49.9	8.06	1.15	5.66	71.91	1.47	11.75	7,130	12,840
		B	2.9	38.4	50.5	8.15	1.16	5.59	72.74	1.49	10.87	7,215	12,980
		C		39.6	52.0	8.40	1.20	5.43	74.95	1.53	8.49	7,435	13,380
		D		43.2	56.8		1.31	5.93	81.82	1.67	9.27	8,115	14,610
17605	1.2	A	4.4	38.2	50.5	6.9	.82					7,090	12,760
		B	3.2	38.6	51.1	7.1	.83					7,180	12,920
		C		39.9	52.8	7.3	.86					7,420	13,350
		D		43.0	57.0		.93					8,000	14,400

GRAND COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17577F	2.0	A	7.1	37.1	45.4	10.44	0.66	5.59	65.98	1.45	15.88	6,510	11,720
		B	5.3	37.8	46.3	10.65	.67	5.48	67.29	1.48	14.43	6,640	11,950
		C		39.9	48.9	11.24	.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	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

SANPETE COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17715	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					5,725	10,300
		C		30.3	46.4	23.3	7.05					5,935	10,680
		D		39.5	60.5		9.20					7,745	13,940
17717	.2	A	2.4	32.4	46.0	19.2	3.71					6,225	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	.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	14,540

[a] Volatile matter determined by the modified official method.

VIRGINIA.

DICKENSON COUNTY.

Laboratory No.	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.
17559	1.8	A	2.6	25.5	61.0	10.9	0.70					7,470	13,440
		B	.9	25.9	62.1	11.1	.71					7,605	13,690
		C		26.1	62.7	11.2	.72					7,670	13,810
		D		29.5	70.5		.81					8,640	15,550
17560	1.7	A	2.6	26.0	63.2	8.2	.73					7,725	13,910
		B	.9	26.5	64.3	8.3	.74					7,860	14,150
		C		26.7	64.9	8.4	.75					7,935	14,290
		D		29.2	70.8		.82					8,660	15,590
17561F	1.8	A	2.6	26.2	61.7	9.48	.74	4.75	77.60	1.57	5.86	7,575	13,640
		B	.9	26.6	62.8	9.65	.75	4.64	78.98	1.60	4.38	7,710	13,880
		C		26.9	63.4	9.74	.76	4.58	79.70	1.61	3.61	7,780	14,010
		D		29.8	70.2		.84	5.07	88.30	1.78	4.01	8,620	15,520
17743	1.7	A	2.8	31.6	58.2	7.4	1.45					7,685	13,840
		B	1.1	32.2	59.1	7.6	1.47					7,815	14,070
		C		32.5	59.8	7.7	1.49					7,905	14,230
		D		35.2	64.8		1.61					8,565	15,410
17744	1.8	A	3.0	32.4	58.4	6.2	1.62					7,795	14,030
		B	1.2	33.0	59.5	6.3	1.65					7,935	14,290
		C		33.4	60.2	6.4	1.67					8,030	14,460
		D		35.7	64.3		1.78					8,575	15,440
17751	1.3	A	2.3	29.4	62.2	6.1	.76						
		B	1.0	29.8	63.0	6.2	.77						
		C		30.1	63.6	6.3	.78						
		D		32.1	67.9		.83						
17752	1.6	A	2.5	29.2	63.2	5.1	.80						
		B	.9	29.7	64.2	5.2	.81						
		C		29.9	64.8	5.3	.82						
		D		31.6	68.4		.87						

RUSSELL COUNTY.

18121F	1.9	A	2.9	31.9	57.8	7.4	1.78					7,655	13,780
		B	1.0	32.5	58.9	7.6	1.81					7,800	14,040
		C		32.8	59.6	7.6	1.83					7,880	14,190
		D		35.5	64.5		1.98					8,535	15,360
18122	1.6	A	2.5	35.6	56.2	5.7	.66					7,930	14,280
		B	.9	36.1	57.2	5.8	.67					8,060	14,510
		C		36.4	57.7	5.9	.68					8,135	14,640
		D		38.7	61.3		.72					8,640	15,550
18123	1.1	A	2.0	35.7	54.5	7.8	.66					7,685	13,830
		B	.9	36.1	55.1	7.9	.67					7,770	13,990
		C		36.4	55.6	8.0	.67					7,840	14,110
		D		39.5	60.5		.73					8,520	15,330
18124 F	1.4	A	2.3	35.5	55.5	6.71	.67	5.26	78.84	1.69	6.83	7,780	14,000
		B	.9	36.0	56.3	6.80	.68	5.18	79.94	1.71	5.69	7,890	14,200
		C		36.3	56.8	6.87	.69	5.13	80.66	1.73	4.92	7,960	14,330
		D		39.0	61.0		.74	5.51	86.61	1.86	5.28	8,545	15,390
18128	1.0	A	1.8	35.3	55.8	7.1	.58					7,800	14,040
		B	.8	35.7	56.3	7.2	.58					7,875	14,180
		C		35.9	56.8	7.3	.59					7,945	14,300
		D		38.8	61.2		.64					8,565	15,420
18129	1.4	A	2.4	36.3	55.1	6.2	.52					7,840	14,110
		B	1.0	36.8	55.9	6.3	.53					7,945	14,300
		C		37.2	56.4	6.4	.53					8,025	14,450
		D		39.7	60.3		.57					8,570	15,430

VIRGINIA—Continued.

RUSSELL COUNTY—Continued.

Laboratory No.	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.
18130	0.8	A	1.6	36.7	55.3	6.4	0.58					7,870	14,170
		B	.8	37.0	55.8	6.4	.58					7,935	14,290
		C		37.3	56.2	6.5	.59					8,000	14.400
		D		39.9	60.1		.63					8,550	15,390
18131F	1.1	A	1.8	36.2	55.5	6.53	.54	5.25	79.28	1.49	6.91	7,830	14,100
		B	.8	36.5	56.1	6.60	.55	5.18	80.12	1.51	6.04	7,915	14,250
		C		36.8	56.5	6.65	.55	5.14	80.76	1.52	5.38	7,980	14,360
		D		39.4	60.6		.59	5.51	86.51	1.63	5.76	8,545	15,380
18235	2.4	A	3.3	35.7	55.0	6.0	.55					7,760	13,970
		B	1.0	36.6	56.3	6.1	.56					7,945	14,310
		C		37.0	56.8	6.2	.57					8,030	14,450
		D		39.4	60.6		.61					8,555	15,400
18236	2.4	A	3.2	35.4	55.1	6.3	.59					7,760	13,970
		B	.9	36.3	56.4	6.4	.60					7,945	14,300
		C		36.6	56.9	6.5	.61					8,020	14,430
		D		39.1	60.9		.65					8,575	15,440
18237	2.4	A	3.3	35.1	56.9	4.7	.50					7,925	14,270
		B	.9	36.0	58.3	4.8	.51					8,115	14,610
		C		36.3	58.8	4.9	.52					8,195	14,750
		D		38.2	61.8		.55					8,615	15,510
18238	2.4	A	3.3	35.1	55.9	5.71	.55	5.37	78.72	1.37	8.28	7,820	14,080
		B	1.0	35.9	57.2	5.85	.56	5.23	80.62	1.40	6.34	8,010	14,420
		C		36.3	57.8	5.91	.57	5.17	81.44	1.42	5.49	8,095	14,570
		D		38.5	61.5		.61	5.49	86.55	1.51	5.84	8,600	15,490
18239	1.0	A	1.8	31.4	60.3	6.5	.52					7,880	14,180
		B	.8	31.8	60.9	6.5	.53					7,960	14,330
		C		32.0	61.4	6.6	.53					8,025	14,440
		D		34.3	65.7		.57					8,590	15,460
18240	1.8	A	2.5	31.9	59.5	6.1	.44					7,820	14,070
		B	.8	32.4	60.6	6.2	.45					7,960	14,330
		C		32.7	61.1	6.2	.45					8,020	14,430
		D		34.9	65.1		.48					8,555	15,400
18241	1.9	A	2.4	32.5	58.4	6.7	.49					7,790	14,020
		B	.6	33.1	59.5	6.8	.50					7,940	14,290
		C		33.3	59.8	6.9	.50					7,985	14,380
		D		35.7	64.3		.54					8,575	15,440
18242	1.6	A	2.2	31.9	59.4	6.50	.46	5.11	79.69	1.04	7.20	7,840	14,110
		B	.6	32.5	60.3	6.60	.47	5.02	80.94	1.06	5.91	7,960	14,330
		C		32.7	60.7	6.65	.47	4.98	81.48	1.06	5.36	8,015	14,430
		D		35.0	65.0		.50	5.33	87.28	1.14	5.75	8,585	15,460
18243	2.4	A	3.1	33.7	57.3	5.9	.79					7,860	14,150
		B	.8	34.5	58.7	6.0	.81					8,050	14,490
		C		34.8	59.1	6.1	.82					8,115	14,600
		D		37.0	63.0		.87					8,640	15,550
18244	1.6	A	2.4	34.6	57.3	5.7	.83					7,945	14,300
		B	.8	35.2	58.3	5.7	.84					8,075	14,540
		C		35.5	58.7	5.8	.85					8,140	14,660
		D		37.6	62.4		.90					8,645	15,560
18245	2.0	A	2.7	33.7	57.9	5.7	.78					7,920	14,260
		B	.8	34.4	59.0	5.8	.80					8,080	14,540
		C		34.7	59.5	5.8	.80					8,145	14,660
		D		36.8	63.2		.85					8,650	15,570
18246	2.0	A	2.7	33.8	57.7	5.78	.83	5.27	79.33	1.29	7.50	7,915	14,250
		B	.7	34.5	58.9	5.90	.85	5.15	80.93	1.32	5.85	8,075	14,530
		C		34.8	59.3	5.94	.85	5.11	81.55	1.33	5.22	8,135	14,650
		D		37.0	63.0		.90	5.43	86.70	1.41	5.56	8,650	15,570

VIRGINIA—Continued.

WISE COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heating value. Calories.	British thermal units.
18226	1.5	A	2.4	33.4	59.4	4.8	0.58					8,035	14,460
		B	.9	33.9	60.3	4.9	.59					8,160	14,680
		C		34.2	60.9	4.9	.59					8,235	14,830
		D		36.0	64.0		.62					8,660	15,590
18227	1.5	A	2.3	32.9	59.9	4.9	.53					8,035	14,460
		B	.9	33.4	60.7	5.0	.54					8,150	14,670
		C		33.7	61.3	5.0	.54					8,225	14,810
		D		35.5	64.5		.57					8,665	15,600
18228	1.4	A	2.3	32.7	59.2	5.8	.51					7,985	14,370
		B	.9	33.2	60.1	5.8	.52					8,100	14,580
		C		33.5	60.6	5.9	.52					8,170	14 710
		D		35.5	64.5		.55					8,685	15,630
18229F	1.5	A	2.3	32.9	59.6	5.22	.54	5.18	80.78	1.57	6.71	8,010	14,420
		B	.8	33.4	60.5	5.30	.55	5.09	81.97	1.59	5.50	8,130	14,630
		C		33.7	61.0	5.34	.55	5.05	82.67	1.61	4.78	8,200	14,760
		D		35.5	64.5		.58	5.33	87.33	1.70	5.06	8,660	15,590

WEST VIRGINIA.

McDOWELL COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17469	1.0	A	1.8	19.7	71.1	7.4	0.50					7,850	14,130
		B	.9	19.9	71.7	7.5	.50					7,925	14,270
		C		20.0	72.4	7.6	.51					7,995	14,390
		D		21.7	78.3		.55					8,650	15,570
17470	1.4	A	2.2	20.2	69.8	7.8	.77					7,820	14,070
		B	.8	20.5	70.8	7.9	.78					7,930	14,270
		C		20.7	71.3	8.0	.79					7,995	14,390
		D		22.4	77.6		.86					8,690	15,640
17471F	1.2	A	2.0	19.9	70.4	7.71	.69	4.47	80.95	1.53	4.65	7,835	14,110
		B	.8	20.2	71.2	7.80	.70	4.39	81.92	1.55	3.64	7,930	14,280
		C		20.3	71.8	7.87	.70	4.34	82.60	1.56	2.93	7,995	14,400
		D		22.1	77.9		.76	4.71	89.65	1.69	3.19	8,680	15,620

MINGO COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17462	1.8	A	4.0	37.3	53.8	4.9	0.68					7,610	13,700
		B	2.2	38.0	54.8	5.0	.69					7,750	13,950
		C		38.9	56.0	5.1	.71					7,925	14,270
		D		40.9	59.1		.75					8,350	15,030
17463	1.8	A	4.1	36.8	51.3	7.8	.80					7,310	13,150
		B	2.3	37.5	52.3	7.9	.81					7,440	13,400
		C		38.4	53.5	8.1	.83					7,615	13,710
		D		41.8	58.2		.90					8,290	14,930
17464	2.3	A	4.7	36.2	51.4	7.7	.65					7,260	13,070
		B	2.4	37.1	52.6	7.9	.67					7,430	13,380
		C		38.0	53.9	8.1	.68					6,715	13,710
		D		41.4	58.6		.74					8,290	14,920
17465F	2.0	A	4.2	37.3	51.7	6.81	.73	5.22	75.47	1.55	10.22	7,395	13,310
		B	2.3	38.0	52.7	6.95	.74	5.10	76.99	1.58	8.64	7,545	13,580
		C		38.9	54.0	7.11	.76	4.96	78.80	1.62	6.75	7,720	13,900
		D		41.9	58.1		.82	5.34	84.83	1.74	7.27	8,315	14,960
17466	2.1	A	4.5	35.5	51.3	8.7	.80					7,195	12,950
		B	2.4	36.3	52.4	8.9	.82					7,350	13,230
		C		37.1	53.8	9.1	.84					7,535	13,560
		D		40.9	59.1		.92					8,290	14,920

WEST VIRGINIA—Continued.

MINGO COUNTY—Continued.

Laboratory No.	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.
17467	2.4	A	5.5	32 8	50.0	11.7	1.02					6,795	12,230
		B	3.1	33.6	51.3	12.0	1.04					6,960	12,530
		C		34.7	52.9	12.4	1.08					7,185	12,940
		D		39.6	60.4		1.23					8,205	14,770
17468F	2.3	A	5.0	33.8	50.9	10.31	.85	5.15	71.13	1.51	11.05	6,975	12,550
		B	2.7	34.6	52.1	10.55	.87	5.01	72.77	1.55	9.25	7,135	12,840
		C		35.6	53.6	10.85	.89	4.84	74.84	1.59	6.99	7,335	13,210
		D		39.9	60.1		1.00	5.43	83.95	1.78	7.84	8,230	14,810
17472F	1.7	A	3.6	35.6	56.5	4.33	.66	5.41	79.67	1.51	8.42	7,775	13,990
		B	1.9	36.2	57.5	4.40	.67	5.31	81.04	1.54	7.04	7,910	14,230
		C		36.9	58.6	4.49	.68	5.19	82.61	1.57	5.46	8,060	14,510
		D		38.6	61.4		.71	5.43	86.49	1.64	5.73	8,440	15,190
17473F	1.5	A	3.7	33.6	59.1	3.64	.64	5.46	79.79	1.53	8.94	7,780	14,010
		B	2.2	34.1	60.0	3.70	.65	5.37	81.00	1.55	7.73	7,900	14,220
		C		34.8	61.4	3.78	.66	5.24	82.85	1.59	5.88	8,080	14,550
		D		36.2	63.8		.69	5.45	86.11	1.65	6.10	8,400	15,120
17474F	.8	A	2.2	36.0	54.3	7.54	1.65	5.00	76.45	1.58	7.78	7,650	13,770
		B	1.4	36.3	54.7	7.60	1.66	4.96	77.03	1.59	7.16	7,705	13,870
		C		36.8	55.5	7.71	1.69	4.86	78.12	1.61	6.01	7,815	14,070
		D		39.9	60.1		1.83	5.27	84.64	1.74	6.52	8,470	15,250
17475F	.8	A	2.4	32.8	60.5	4.30	.74	5.06	79.82	1.53	8.55	7,955	14,320
		B	1.6	33.1	61.0	4.33	.75	5.01	80.45	1.54	7.92	8,015	14,430
		C		33.6	62.0	4.41	.76	4.91	81.78	1.57	6.57	8,150	14,670
		D		35.2	64.8		.80	5.14	85.55	1.64	6.87	8,525	15,350
17476	1.4	A	2.8	31.5	61.1	4.6	1.39					7,905	14,230
		B	1.4	32.0	62.0	4.6	1.41					8,020	14,430
		C		32.4	62.9	4.7	1.43					8,140	14,650
		D		34.0	66.0		1.50					8,535	15,360
17477	1.9	A	3.3	31.0	60.4	5.3	1.14					7,765	13,980
		B	1.4	31.6	61.5	5.5	1.16					7,915	14,240
		C		32.1	62.4	5.5	1.18					8,030	14,450
		D		33.9	66.1		1.25					8,500	15,300
17478	1.9	A	3.3	30.9	58.9	6.9	1.11					7,680	13,830
		B	1.5	31.5	60.0	7.0	1.13					7,830	14,090
		C		32.0	60.9	7.1	1.15					7,950	14,310
		D		34.4	65.6		1.24					8,555	15,400
17479F	1.7	A	3.1	31.4	59.9	5.60	1.18	5.12	79.51	1.60	6.99	7,805	14,050
		B	1.4	32.0	60.9	5.70	1.20	5.02	80.90	1.63	5.55	7,945	14,300
		C		32.4	61.8	5.78	1.22	4.93	82.09	1.65	4.33	8,060	14,510
		D		34.4	65.6		1.29	5.23	87.12	1.75	4.61	8,555	15,400
17480	2.0	A	4.5	38.8	50.9	5.8	2.01					7,425	13,370
		B	2.5	39.6	52.0	5.9	2.05					7,580	13,650
		C		40.6	53.3	6.1	2.10					7,775	13,990
		D		43.2	56.8		2.24					8,275	14,900
17481	2.8	A	5.7	37.0	49.5	7.8	1.87					7,100	12,780
		B	3.0	38.1	50.9	8.0	1.92					7,300	13,140
		C		39.2	52.5	8.3	1.98					7,530	13,550
		D		42.8	57.2		2.16					8,210	14,780
17483	1.3	A	3.0	34.7	58.9	3.4	.66					7,920	14,250
		B	1.7	35.1	59.7	3.5	.67					8,025	14,440
		C		35.7	60.8	3.5	.68					8,165	14,700
		D		37.0	63.0		.70					8,460	15,230

WYOMING.

CONVERSE COUNTY.

Laboratory No.	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.
17657	7.0	A	22.8	34.7	37.0	5.52	0.71	6.07	54.68	1.02	32.00	5,150	9,270
		B	17.0	37.3	39.8	5.93	76	5.70	58.77	1.10	27.74	5,535	9,960
		C		44.9	48.0	7.15	.92	4.58	70.79	1.32	15.24	6,670	12,000
		D		48.4	51.6		.99	4.93	76.24	1.42	16.42	7,180	12,930
17658	5.5	A	21.1	[a]31.5	41.3	6.1	.73					5,105	9,190
		B	16.5	33.3	43.7	6.5	.77					5,400	9,720
		C		39.9	52.3	7.8	.92					6,470	11,640
		D		43.3	56.7		1.00					7,015	12,630
17722F	5.6	A	25.1	[a]32.0	38.1	4.77	.73	6.31	52.81	1.16	34.22	4,980	8,970
		B	20.6	33.9	40.4	5.05	.77	6.03	55.94	1.23	30.98	5,275	9,500
		C		42.7	50.9	6.37	.97	4.70	70.50	1.55	15.91	6,650	11,970
		D		45.6	54.4		1.04	5.02	75.29	1.66	16.99	7,100	12,780
17723F	5.5	A	23.5	[a]34.3	35.2	7.00	.59	5.85	51.19	.99	34.38	4,755	8,560
		B	19.1	36.3	37.2	7.40	.62	5.54	54.15	1.05	31.24	5,030	9,050
		C		44.9	46.0	9.15	.77	4.23	66.90	1.29	17.66	6,210	11,180
		D		49.4	50.6		.85	4.66	73.64	1.42	19.43	6,835	12,310
17902	14.1	A	27.2	[a]29.7	36.1	7.0	.40					4,275	7,700
		B	15.3	34.6	42.0	8.1	.47					4,975	8,950
		C		40.8	49.6	9.6	.55					5,870	10,570
		D		45.2	54.8		.61					6,495	11,690

FREMONT COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17584	[b]2.1	A	13.1	38.8	34.3	13.8	3.47					5,445	9,800
		B	11.3	39.7	35.0	14.0	3.54					5,560	10,010
		C		44.7	39.5	15.8	4.00					6,270	11,280
		D		53.1	46.9		4.75					7,450	13,410

HOT SPRINGS COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17709	2.0	A	13.7	35.8	41.7	8.8	0.60					5,800	10,440
		B	11.9	36.6	42.6	8.9	.61					5,915	10,650
		C		41.5	48.3	10.2	.69					6,720	12,090
		D		46.2	53.8		.77					7,480	13,460
17830	2.2	A	11.5	34.3	40.0	14.2	.45					5,545	9,990
		B	9.5	35.0	40.9	14.6	.46					5,675	10,210
		C		38.7	45.2	16.1	.51					6,270	11,280
		D		46.1	53.9		.61					7,475	13,450
17731	11.6	A	25.2	33.1	36.0	5.7	.98					4,180	7,520
		B	15.3	37.5	40.7	6.5	1.11					4,730	8,510
		C		44.2	48.1	7.7	1.31					5,580	10,050
		D		47.9	52.1		1.42					6,045	10,880

NATRONA COUNTY.

Laboratory No.	Air-drying loss.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
17778	6.1	A	24.1	[a]33.6	36.8	5.5	0.70					4,840	8,710
		B	19.2	35.8	39.2	5.8	.75					5,155	9,280
		C		44.3	48.5	7.2	.92					6,380	11,480
		D		47.8	52.2		.99					6,875	12,370
17895	10.0	A	24.9	[a]30.7	39.3	5.1	.40					4,830	8,700
		B	16.5	34.1	43.7	5.7	.45					5,370	9,670
		C		40.9	52.3	6.8	.53					6,435	11,580
		D		43.9	56.1		.57					6,900	12,420

[a] Volatile matter determined by the modified official method.
[b] This small air-drying loss indicates that the coal is weathered.

DESCRIPTIONS OF COAL SAMPLES.

ALABAMA.

DEKALB COUNTY.

18230. Semibituminous coal from Yellow Creek mine of W. C. Hill, sec. 24(?), T. 7 S., R. 9 E., 3 miles northwest of Blanche. Sample cut in mine 300 feet south of mouth, from surface of coal weathered for 10 months, on November 20, 1913, by Charles Butts. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Yellow Creek mine.

	Ft.	in.
Coal [1,2]	1	1
Clay [2]		½
Coal [1,2]		3
Clay [2]		½
Coal [1,2]		4
Clay [2]		1
Coal [1,2]		3½
	2	1½

18233. Semibituminous coal from same locality as No. 18230. Sample cut 20 inches below surface of coal weathered for 10 months. Sample dry.

18234. Semibituminous coal from same locality as No. 18230. Sample cut 1 foot below surface of coal weathered for 10 months. Sample dry.

18231. Semibituminous coal from Beeson Gap mine of McSpaden & Baker, T. 7 S., R. 9 E., 1 mile northeast of Fort Payne. Sample cut in mine 200 feet northeast of mouth on November 20, 1913, by Charles Butts. Coal bed at point sampled is 1 foot 1 inch thick. Sample represents entire thickness of bed. Sample dry.

18232. Semibituminous coal from prospect pit of W. T. Underwood, sec. 31 (?), T. 7 S., R. 10 E., 1 mile west of Blanche. Sample cut in pit 10 feet from mouth on November 20, 1913, by Charles Butts. Sample dry. Section at point of sampling is as follows:

Section of coal bed in prospect pit of W. T. Underwood.

	Ft.	in.
Coal	1	9
"Rash" [3]		2
	1	11

[1] Part sampled for Nos. 18230 and 18234.
[2] Part sampled for No. 18233.
[3] Not included in sample.

COLORADO.

LA PLATA COUNTY.

17745F. Bituminous coal from Mormon mine in sec. 17, T. 33 N., R. 11 W. Sample cut at end of main entry, 50 feet from mouth of mine, on August 6, 1913, by M. A. Pishel. Section at point of sampling is as follows:

Section of coal bed in Mormon mine.

	Ft.	in.
Coal		7
Shale [1]		½
Coal		7
Shale		¼
Coal, bony	1	9
Shale [1]		1
Coal		11
Shale [1]		½
Coal	1	5
	5	5¼

17747. Bituminous coal from Cinder Butte mine in sec. 14, T. 32 N., R. 12 W. Sample cut at end of entry on August 5, 1913, by M. A. Pishel. Coal weathered. Section at point of sampling is as follows:

Section of coal bed in Cinder Butte mine.

	Ft.	in.
Coal, bony		5
Coal		8
Shale [1]		1
Coal		3
Bone		5
Coal		5
Coal, bony		9
Bone		2
Coal	1	10
	5	

17748. Bituminous coal from Soda Spring mine in sec. 1, T. 32 N., R. 12 W. Sample cut in mine 100 feet west of mouth on August 5, 1913, by M. A. Pishel. Section at point of sampling is as follows:

Section of coal bed in Soda Spring mine.

	Ft.	in.
Coal, bony [1]	2	6
Coal	2	10
Shale [1]		11

[1] Not included in sample.

	Ft.	in.
Coal	1	10
Bone [1]		1
Coal		8
Bone [1]		1
Coal		8
Bone [1]	2	1
	11	8

17855. Bituminous coal from Wheeler mine in Hay Gulch in sec. 31, T. 35 N., R. 11 W., 7½ miles southwest of Hesperus, Upper No. 5 bed. Sample cut near end of entry, 75 feet from mouth of mine, on September 12, 1913, by M. A. Pishel. Section at point of sampling is as follows:

Section of coal bed in Wheeler mine.

	Ft.	in.
Coal	1	8
Bone [1]		1
Coal	3	
Coal, bony		10
	5	7

MOFFAT COUNTY.

17592. Subbituminous coal from Seick mine in sec. 2, T. 7 N., R. 92 W., 8 miles northwest of Craig. Sample cut in mine 120 feet N. 80° E. of mouth on July 24, 1913, by E. T. Hancock. Mine had not been worked for two years. Sample weathered (?). Section at point of sampling is as follows:

Section of coal bed in Seick mine.

	Ft.	in.
Coal (not mined)[1]	2	3
Coal	5	3
	7	6

17593. Subbituminous coal from Kimberly mine (not operated) in sec. 32, T. 7 N., R. 90 W. Kimberly bed. Sample cut in mine 120 feet N. 12° E. of mouth on July 25, 1913, by E. T. Hancock. Sample was wet (weathered ?). Section at point of sampling is as follows:

[1] Not included in sample.

Section of coal bed in Kimberly mine.

	Ft.	in.
Coal, impure	2	1
Coal	2	1
Coal, impure	1	5
Coal	2	1
	7	8

17686. Bituminous (?) coal from Lay mine of Wisconsin Coal Mining Co., 1 mile south of Lay, in sec. 31, T. 7 N., R. 93 W. Sample cut in mine 270 feet south of mouth on August 21, 1913, by E. T. Hancock. Sample weathered (?). Section at point of sampling is as follows:

Section of coal bed in Lay mine.

	Ft.	in.
Coal		11½
Coal, with streaks of shale		5
Sandstone		1½
Coal, with thin streaks of shale		4
Coal	1	
Shale, sandy		1½
Coal, with thin streaks of shale		6½
Coal [1]	4	7
Shale, sandy		7
Coal		10
Coal, with some streaks of shale	1	11
	11	5

17696. Subbituminous coal from Blevins mine in sec. 28, T. 8 N., R. 93 W. Sample cut in mine 140 feet N. 50° E. of mouth on August 19, 1913, by E. T. Hancock. Sample weathered (?). Section at point of sampling is as follows:

Section of coal bed in Blevins mine.

	Ft.	in.
Coal	1	5
Shale		1
Coal [1]	9	11½
	11	5½

17782. Subbituminous coal from Hart mine in T. 4 N., R. 91 W. (not subdivided). Sample cut in mine 100 feet N. 39° W. of mouth on September 22, 1913,

[1] Part sampled.

by E. T. Hancock. Coal bed at point sampled is 6 feet 9 inches thick, and sample represents entire bed. Sample wet.

17840. Bituminous (?) coal from Roby mine in T. 4 N., R. 91 W. (not subdivided). Sample cut in mine 75 feet N. 56° W. of mouth on September 24, 1913, by E. T. Hancock. Sample represents 7 feet 1½ inches of coal, entire thickness of bed. Sample wet and weathered.

ILLINOIS.

McDONOUGH COUNTY.

15119. Bituminous coal from mine of Frank Burdick in NE. ¼ sec. 16, T. 4 N., R. 2 W., 1 mile northwest of Industry. Murphysboro bed. Composite of samples 15117 and 15118.[1]

KENTUCKY.

PIKE COUNTY.

17459F. Bituminous coal from No. 2 mine of Burnwell Coal & Coke Co., 2 miles west of Matewan. No. 2 or Gas bed. Sample cut in room 9 off fourth left entry off main entry, 2,000 feet from mine mouth, on June 3, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in No. 2 mine.

	Ft.	in.
Coal		5
Bone[2]		7
Coal	1	2
Clay[2]		2
Coal	2	
Coal, splint		9
	5	1

17460F. Bituminous coal from Little Thacker mine of Thacker Coal Co., 1½ miles southwest of Thacker, Alum bed. Sample cut at face of first right entry off main air course, 700 feet from mine mouth, on June 5, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

[1] See U. S. Geol. Survey Bull. 531, pp. 338–339, 1913.
[2] Not included in sample.

Section of Alum coal bed in Little Thacker mine.

	Ft.	in.
Coal, bony		1½
Coal	2	5
Clay[1]		4
Coal, splint	1	8
	4	6½

17461F. Bituminous coal from Little Thacker mine of Thacker Coal Co., 1½ miles southwest of Thacker. Thacker bed. Sample cut at last right entry off No. 2 drift, 3,000 feet from mine mouth, on June 5, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of Thacker coal bed in Little Thacker mine.

	Ft.	in.
Coal, lustrous	1	4
Coal, splint	1	4
Coal, gray, splint		7
Coal, lustrous	1	10
	5	1

MONTANA.

BIG HORN COUNTY.

17711. Subbituminous coal from local strip pit in sec. 30, T. 1 N., R. 38 E., 36 miles south of Sanders. Sample cut 6 feet deep under heavy sandstone on August 27, 1913, by G. S. Rogers. Sample dry. Section at point of sampling is as follows:

Section of coal bed in local bank.

	Ft.	in.
Bone		2
Coal[2]	7	
Coal (weathered)	3	4
Coal, reported in drill record	21	
	31	6

HILL COUNTY.

17841F. Subbituminous coal from old mine of A. M. Banks and Charles Severn, in NW. ¼ sec. 28, T. 37 N., R. 9 E. No. 1 bed. Sample cut in first room on right,

[1] Not included in sample.
[2] Part sampled.

75 feet from mine mouth, on September 30, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in old mine of A. M. Banks and Charles Severn.

	Ft.	in.
Coal	3	2
Shale, coaly [1]		5
	3	7

17842F. Bituminous coal from West Butte mine of P. J. McDermott, NW. ¼ sec. 6, T. 36 N., R. 2 E. Sample cut in mine 100 feet west of shaft on September 11, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in West Butte mine.

	Ft.	in.
Coal	2	1
Shale [1]		4
	2	5

17892. Subbituminous coal from outcrop in SW. ¼ sec. 2, T. 37 N., R. 9 E., 35 miles north of Rudyard. No. 1 bed. Sample cut September 28, 1913, by Eugene Stebinger. Sample dry and weathered. Section at point of sampling is as follows:

Section of coal bed on outcrop.

	Ft.	in.
Coal	2	8
Shale, coaly [1]		4
	3	

MUSSELSHELL COUNTY.

17586F. Subbituminous coal from mine No. 2 of Republic Coal Co., in SE. ¼ sec. 36, T. 8 N., R. 25 E., 3½ miles southeast of Roundup. Roundup bed. Sample cut in mine 800 feet east of shaft on July 21, 1913, by C. T. Lupton. Sample dry. Section at point of sampling is as follows:

Section of coal bed in mine No. 2.

	Ft.	in.
Coal	4	3
Bone [1]		1
Coal	1	6
	5	10

[1] Not included in sample.

17587. Subbituminous coal from mine No. 4 of Davis Coal Co., in SE. ¼ sec. 17, T. 8 N., R. 25 E., 3 miles southeast of Roundup. Roundup bed. Sample cut in mine 3,000 feet S. 5° W. of mouth on July 21, 1913, by C. T. Lupton. Sample damp. Section at point of sampling is as follows:

Section of coal bed in mine No. 4.

	Ft.	in.
Coal		2
Bone [1]		2
Coal	3	2
	3	6

17588. Subbituminous coal from mine No. 3 of Roundup Coal Mining Co., NE. ¼ sec. 22, T. 8 N., R. 25 E., one-half mile west of Roundup. Roundup bed. Sample cut in room 2, off seventh entry west, 3,000 feet west from mouth of entry, on July 21, 1913, by C. T. Lupton. Sample represents 5 feet 8 inches of coal, entire thickness of bed. Sample dry.

17589. Subbituminous coal from Keene mine of Pine Creek Coal Mining Co., in NE. ¼ sec. 28, T. 8 N., R. 25 E., 3½ miles southwest of Roundup. Roundup bed. Sample cut in mine 500 feet northeast of mouth on July 19, 1913, by C. T. Lupton. Sample represents 3 feet of coal, entire thickness of bed. Sample dry.

NEW MEXICO.

COLFAX COUNTY.

17703. Bituminous coal from Brilliant mine of St. Louis, Rocky Mountain & Pacific Co., T. 31 N., R. 23 E. Tin Pan bed. Sample cut in first east entry off No. 5 main south entry of Tin Pan Canyon on August 30, 1913, by W. T. Lee. Section at point of sampling is as follows:

Section of coal bed in Brilliant mine.

	Ft.	in.
Coal		6
Shale [1]		2
Coal		9
Shale [1]		8
Coal	1	9
Bone [1]		½

[1] Not included in sample.

	Ft.	in.
Coal	1	2
Shale [1]		2
Coal		8
	5	10½

17746F. Bituminous coal from mine of Yankee Fuel Co., in sec. 35, T. 32 N., R. 62 W. Highest bed. Sample cut in mine 570 feet N. 20° E. from mouth on September 18, 1913, by W. T. Lee. Sample dry. Section at point of sampling is as follows:

Section of coal bed in mine of Yankee Fuel Co.

	Ft.	in.
Coal		7
Shale [1]		11
Coal	1	7
Shale [1]	1	1
Coal	1	9
	5	11

17781F. Bituminous coal from Koehler No. 3 mine of St. Louis, Rocky Mountain & Pacific Co., at Koehler. Raton bed. Sample cut in room 71, off second east entry, on September 23, 1913, by W. T. Lee. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Koehler No. 3 mine.

	Ft.	in.
Coal		10
Coal, bony		4
Coal		6
Bone [1]		1
Coal	1	5
Bone [1]		½
Coal	1	1
Bone [1]	1	4
Coal		9
Bone [1]		1
Coal	3	2
	9	7½

SAN JUAN COUNTY.

17749. Bituminous coal from the New Mexico mine in sec. 22, T. 32 N., R. 12 W., 28½ miles southwest of Durango. Bed A. Sample cut in mine 75 feet east of mouth on August 5, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

Section of coal bed in New Mexico mine.

	Ft.	in.
Coal, bony	4	9
Shale [1]		2
Coal	2	1
	7	

17750. Bituminous coal from Government mine in sec. 21, T. 30 N., R. 16 W., 20 miles northwest of Farmington. Hogback bed. Sample cut in mine 100 feet southwest of mouth on August 22, 1913, by M. A. Pishel. Sample represents 6 feet 3 inches of coal, entire thickness of bed.

SOCORRO COUNTY.

17602. Bituminous (?) coal from prospect in sec. 18, T. 1 N., R. 6 W., 20 miles northwest of Magdalena. Sample cut in face of entry, 30 feet from mouth, on July 28, 1913, by D. E. Winchester, Sample dry. Section at point of sampling is as follows:

Section of coal bed in prospect.

	Ft.	in.
Bone [1]		2
Coal		4½
Shale, carbonaceous [1]		2
Coal		4
Shale [1]		¼
Coal	1	7
	2	7¾

17728. Bituminous coal from prospect in SW. ¼ sec. 20, T. 3 N., R. 9 W., 65 miles northwest of Magdalena. Sample cut in face of entry, 8 feet from mouth, on September 5, 1913, by D. E. Winchester. Sample dry and slightly weathered. Section at point of sampling is as follows:

Section of coal bed in prospect.

	Ft.	in.
Coal		6
Bone [1]		2
Coal		6
Bone [1]		1½
Coal	2	3
	3	6½

[1] Not included in sample.

[1] Not included in sample.

OREGON.

GRANT COUNTY.

18125. Lignite from prospect on the Stewart ranch in NW. ¼ NW. ¼ sec. 11, T. 13 S., R. 27 E., 5½ miles east of Dayville. Sample cut from face of old prospect. Lignite probably weathered. Section at point of sampling is as follows:

Section of lignite bed in old prospect.

	Ft.	in.
Lignite [1]	1	
Sandstone [1]		6
Lignite	2	2
Sandstone [1]		4
Lignite [1]	1	8
	5	8

WHEELER COUNTY.

18126. Subbituminous (?) coal from prospect in Dry Hollow in SW. ¼ SE. ¼ sec. 28, T. 8 S., R. 21 E. Sample cut 20 feet from mouth of drift 130 feet long. Section at point of sampling is as follows:

Section of coal bed in prospect in Dry Hollow.

	Ft.	in.
Coal and bone [2]	1	
Coal and bone [2 3]	1	6
Sandstone		6
Coal [3]	1	6
Coal [2 3]	5	6
	10	

18127. Subbituminous (?) coal from same locality as No. 18126.

PENNSYLVANIA.

CENTER COUNTY.

17444F. Bituminous coal from Macon drift, Poormansite mine of Lehigh Valley Coal Co., 1½ miles northeast of Clarence. Lower Kittanning bed. Sample cut in side entry, 1,000 feet from mine mouth, on May 31, 1913, by M. A. Pishel. Section at point of sampling is as follows:

Section of coal bed in Macon drift, Poormansite mine.

	Ft.	in.
Coal		8
Bone [1]		3
Coal	2	10
	3	9

[1] Not included in sample.
[2] Parts sampled for No. 18127.
[3] Parts sampled for No. 18126.

17445. Semibituminous coal from Poormansite "High Coal" of Lehigh Valley Coal Co., 1½ miles northeast of Clarence. Lower Freeport bed. Sample cut in side entry, 600 feet from mine mouth, on May 31, 1913, by M. A. Pishel. Sample moist. Section at point of sampling is as follows:

Section of coal bed in Poormansite "High Coal" mine.

	Ft.	in.
Coal	2	7
Bone [1]		10
Coal	2	6
	5	11

17446F. Bituminous coal from mine No. 15 of Lehigh Valley Coal Co., one-half mile northeast of Gillintown. Lower Freeport bed. Sample cut in main entry, 500 feet from mine mouth, on May 31, 1913, by M. A. Pishel. Sample damp. Section at point of sampling is as follows:

Section of coal bed in mine No. 15.

	Ft.	in.
Bone [1]		10
Coal	1	6
Bone [1]		2
Coal	1	
	3	6

17447F. Bituminous coal from mine No. 22 of Lehigh Valley Coal Co., 1½ miles northwest of Clarence. Lower A bed. Sample cut in main entry, three-fourths of a mile from mine mouth, on May 31, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

Section of coal bed in mine No. 22.

	Ft.	in.
Coal, bony [1]		8
Fire clay [1]		5
Coal	3	2½
Clay [1]		1½
Coal		8
	5	1

CLEARFIELD COUNTY.

17441F. Bituminous (?) coal from Horseshoe mine of Potter, Bigler & Potter, one-half mile south of Karthaus. Lower Kittanning bed. Sample cut from room 3, second entry, 1,000 feet from mine

[1] Not included in sample.

mouth, on June 2, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Horseshoe mine.

	Ft.	in.
Coal, bony[1]		9
Coal	2	8
Pyrite[1]		½
Coal		5
	3	10½

17442F. Semibituminous coal from the Shinola mine of Shadock & Kelly at Karthaus. Bed A. Sample cut in main entry, 600 feet from mine mouth, on June 2, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Shinola mine.

	Ft.	in.
Coal	1	6
Bone[1]		4
Coal	1	8
Bone[1]		5
	3	11

17443F. Bituminous coal from Eriton mine of Northwestern Mining & Exchange Co., 3½ miles south of Dubois. Lower Freeport bed. Sample cut in mine 200 feet southwest of shaft on June 5, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Eriton mine.

	Ft.	in.
Coal, bony[1]	1	6
Coal	5	5
Shale[1]		1½
Coal		8
	7	8½

ELK COUNTY.

17455. Bituminous coal from Dagus mine of Northwestern Mining & Exchange Co., at Dagus. Lower Kittanning bed. Sample cut in room off face heading, first right entry (Fleming section), 1 mile from mine mouth, on June 4, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

[1] Not included in sample.

Section of coal bed in Dagus mine.

	Ft.	in.
Coal, bony[1]		1½
Coal, good	2	
Pyrite[1]		½
Coal	1	6
	3	7½

17456F. Bituminous coal from Byrnedale No. 31 mine of Shawmut Mining Co., at Byrnedale. Lower Kittanning bed. Sample cut in first left entry off main entry, 600 feet from mine mouth, on June 3, 1913, by M. A. Pishel. Section at point of sampling is as follows:

Section of coal bed in Byrnedale No. 31 mine.

	Ft.	in.
Coal, bony[1]		4
Coal	2	10
Pyrite[1]		½
Coal		4
	3	6½

17457. Bituminous coal from mine No. 1 of Dents Run Mining Co., at Wilmere. Lower Kittanning bed. Sample cut in fourth left entry, 600 feet from mine mouth, on June 3, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

Section of coal bed in mine No. 1.

	Ft.	in.
Coal, bony		10
Clay		1½
Coal		2
Clay		7
Coal[2]	2	7
	4	3½

17458. Bituminous coal from Elbon No. 5 mine of Shawmut Mining Co., at Brandy Camp. Lower Kittanning bed. Sample cut in first left entry, No. 4 drift, 1,000 feet from mine mouth, on June 4, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

[1] Not included in sample.
[2] Part sampled.

Section of coal bed in Elbon No. 5 mine.

	Ft.	in.
Coal	1	9
Mineral charcoal		½
Coal	1	2
	2	11½

JEFFERSON COUNTY.

17448F. Bituminous coal from West Clarion mine of Northwestern Mining & Exchange Co., 1 mile west of Brockwayville. Lower Freeport bed. Sample cut in second right entry, drift No. 8, 800 feet from mine mouth, on June 5, 1913, by M. A. Pishel. Sample represents 3 feet 4 inches of coal, entire thickness of bed. Sample dry.

17449F. Bituminous coal from West Clarion drift No. 14 of Northwestern Mining & Exchange Co., 1 mile west of Brockwayville, Upper Freeport bed. Sample cut in second room off main entry on June 5, 1913, by M. A. Pishel. Sample represents 2 feet 6 inches of coal, entire thickness of bed. Sample dry.

17450F. Bituminous coal from West Clarion No. 1 mine of Northwestern Mining & Exchange Co., 1 mile west of Brockwayville, Lower Kittanning bed. Sample cut in third right entry off first entry, face drift No. 1, 4,000 feet from mine mouth, on June 5, 1913, by M. A. Pishel. Sample represents 4 feet of coal, entire thickness of bed. Sample dry.

SOMERSET COUNTY.

17689. Semibituminous coal from mine of Perry Wyand, one-half mile south of Bakersville. Sample cut in mine 300 feet southwest of mouth on August 30, 1913, by J. H. Hance. Section at point of sampling is as follows:

Section of coal bed in mine of Perry Wyand.

	Ft.	in.
Shale [1]		2
Coal	1	8
Binder [1]		3
Coal		6
	2	7

[1] Not included in sample.

17690. Semibituminous coal from Ralphton No. 6 mine of Quemahoning Coal Co., at Zimmermantown. Upper Freeport (E) bed. Sample cut in mine 1,200 feet east of shaft on August 30, 1913, by J. H. Hance. Section at point of sampling is as follows:

Section of coal bed in Ralphton No. 6 mine.

	Ft.	in.
Coal	2	7
Binder [1]		1¾
Coal		4
Binder		1
Coal		4¼
	3	6

17691. Semibituminous coal from mine of Levi Berkey, 1¾ miles northwest of Edie. Upper Freeport (E) bed. Sample cut in mine 400 feet N. 60° W. of mouth on August 30, 1913, by J. H. Hance. Section at point of sampling is as follows:

Section of coal bed in Levi Berkey mine.

	Ft.	in.
Coal	2	11½
Binder [1]		1¼
Coal		4½
Binder [1]		½
Coal		7¼
	4	1

17692. Bituminous (?) coal from mine of Jake Miller, 1¾ miles southwest of Gillette. Sample cut in mine 500 feet northeast of mouth on August 30, 1913, by J. H. Hance. Section at point of sampling is as follows:

Section of coal bed in mine of Jake Miller.

	Ft.	in.
Coal	2	
Binder [1]		2
Coal		4½
Coal, dirty		5½
	3	

17693. Semibituminous coal from Neva mine of James McKelvey, three-fourths of a mile northeast of Somerset. Sample cut in mine 400 feet from mouth on

[1] Not included in sample.

August 29, 1913, by J. H. Hance. Section at point of sampling is as follows:

Section of coal bed in the Neva mine.

	Ft.	in.
Shale [1]		3
Coal	2	4
Binder [1]		1
Coal		3½
Binder [1]		¾
	3	¼

17694. Semibituminous coal from mine of Sanner & Sheffar, one-half mile southeast of Somerset. Unidentified bed. Sample cut in mine 300 feet from mouth on August 29, 1913, by J. H. Hance. Section at point of sampling is as follows:

Section of coal bed in Sanner & Sheffar mine.

	Ft.	in.
Bone [1]		3
Coal	2	8½
Binder [1]		5
Coal, dirty [1]		9
	4	1½

17695. Semibituminous coal from the Stauffer No. 2 mine of Myersdale Coal Co., 4½ miles northeast of Somerset. Lower Freeport (D) bed (?). Sample cut in mine 500 feet from mouth on August 29, 1913, by J. H. Hance. Section at point of sampling is as follows:

Section of coal bed in Stauffer No. 2 mine.

	Ft.	in.
Shale [1]		2
Coal	4	1½
	4	3½

17831. Bituminous coal from mine of Reuben Horner, 2 miles northwest of Boswell. Pittsburgh bed. Sample cut in mine 50 feet from mouth on September 29, 1913, by G. B. Richardson. Coal bed at the point sampled is 10 feet 6 inches thick. Sample represents lower 10 feet. Sample weathered.

17832. Semibituminous coal from mine of J. G. Berkey, 2 miles northwest of Boswell. Pittsburgh bed. Sample cut in mine 200 feet from mouth, on September 29, 1913, by G. B. Richardson. Coal bed at the point sampled is 4 feet 10 inches thick. Sample represents lower 3 feet 6 inches. Sample weathered.

[1] Not included in sample.

TIOGA COUNTY.

17451F. Semibituminous coal from New mine of Morris Run Coal Mining Co., at Morris Run. Morgan bed. Sample cut in fourth room, first entry, 1 mile from mine mouth, on May 27, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

Section of coal bed in New mine.

	Ft.	in.
Coal, bony [1]		6
Coal	2	8
	3	2

17452. Semibituminous coal from Bear Run mine of Blossburg Coal Co., one-half mile north of Landrus. Bloss bed. Sample cut in pillar in main entry 700 feet from mine mouth, on May 28, 1913, by M. A. Pishel. Section at point of sampling is as follows:

Section of coal bed in Bear Run mine.

	Ft.	in.
Coal	1	1½
Shale [1]		3
Coal, dirty [1]		10
Coal	1	2
Pyrite (lens)[1]		3
Coal		6
	4	1½

17453. Semibituminous coal from Anna S. mine of Fall Brook Coal Co., one-half mile west of Antrim. Bloss bed. Sample cut in room off side entry 1 mile from mine mouth, on May 29, 1913, by M. A. Pishel. Section at point of sampling is as follows:

Section of coal bed in Anna S mine.

	Ft.	in.
Coal	1	11
Bone [1]		3
Coal	1	0
Bone [1]		5
Coal		10
	4	5

[1] Not included in sample.

17454F. Semibituminous coal from New mine of Morris Run Coal Mining Co., at Morris Run. Bloss bed. Sample cut in Sterling heading, 3 miles from mine mouth, on May 27, 1913, by M. A. Pishel. Sample dry. Section at point of sampling is as follows:

Section of coal bed in New mine.

	Ft.	in.
Coal, bony [1]		7
Coal, good	2	5
	3	

WESTMORELAND COUNTY.

17901F. Bituminous coal from mine of John Dyer, 3 miles southeast of Ligonier. Upper Freeport bed. Sample cut in end of entry, 200 feet from mine mouth, on October 15, 1913, by G. B. Richardson. Section at point of sampling is as follows:

Section of coal bed in mine of John Dyer.

	Ft.	in.
Coal	2	1
Shale [1]		1
Coal		4
Shale [1]		1
Coal		4
	2	11

UTAH.

CARBON COUNTY.

17604F. Bituminous coal from No. 3 mine of Utah Fuel Co., in the SW. ¼ SW. ¼ sec. 4, T 15 S., R. 14 E., 1 mile southeast of Sunnyside. Lower bed. Sample cut in face of second left entry in dips, about 150 feet within room 1, 1 mile northeast of mine mouth, on August 5, 1913, by F. R. Clark. Sample dry. Section at point of sampling is as follows:

Section of coal bed in No. 3 mine.

	Ft.	in.
Coal [1]	1	
Coal	6	10
Coal [1]	2	
	9	10

17605. Bituminous coal, same as No. 17604F. Sample cut in face of room 5 off second right entry, about 1 mile south of mine mouth. Sample represents 5 feet 4 inches of coal, entire thickness of bed. Sample dry.

[1] Not included in sample.

GRAND COUNTY.

17577F. Bituminous coal from mine No. 1-A of American Fuel Co., of Utah, in the NW. ¼ sec. 27, T. 20 S., R. 20 E., 5 miles north of Thompson; middle bed of Bear coal. Sample cut in face of main entry, 1,200 feet east slightly southeast of mine mouth, on July 17, 1913, by F. R. Clark. Sample dry. Section at point of sampling is as follows:

Section of coal bed in No. 1-A mine.

	Ft.	in.
Coal	1	3
Coal, bony	1	1
Coal	1	
Shale		½
Coal	1	2
Bone		1
Coal	1	1
	5	8½

17578. Bituminous coal from prospect of American Fuel Co. of Utah, in SE. ¼ NW. ¼ sec. 27, T. 20 S., R. 20 E., 5 miles north of Thompson. Lower bed of Bear coal. Sample cut in face of prospect, 85 feet east from mouth, on July 17, 1913, by F. R. Clark. Sample dry and probably slightly weathered. Section at point of sampling is as follows:

Section of coal bed in prospect.

	Ft.	in.
Coal [1]		10
Clay [1]		5
Coal	4	3½
	5	6½

SANPETE COUNTY.

17715. Bituminous coal from Coal Creek mine of Johnny Reese in SE. ¼ NE. ¼ sec. 14, T. 16 S., R. 2 E., 6 miles northwest of Ephraim. Sample cut in mine 300 feet N. 24° E. of mouth on September 4, 1913, by F. R. Clark. Sample dry. Section at point of sampling is as follows:

[1] Not included in sample.

Section of coal bed in Coal Creek mine.

	Ft.	in.
Coal, bright		5
Coal, dull		5
Coal, bright		2
Coal, dull		8
Bone[1]		11
	2	7

17717. Bituminous coal from abandoned mine ("north tunnel") in NE. ¼ SE. ¼ sec. 2, T. 16 S., R. 2 E., 3½ miles southwest of Wales. North tunnel bed. Sample cut beyond zone of weathering, 300 feet N. 5° E. of mine mouth, on September 9, 1913, by F. R. Clark. Sample wet. Section at point of sampling is as follows:

Section of coal bed in North Tunnel mine.

	Ft.	in.
Coal	1	3
Shale[1]	1	10
Coal		3
Shale[1]		1½
Coal		4
Shale[1]		1
Coal		6
Shale[1]		6
Coal	1	1
Bone[1]		3
	6	2½

17718. Bituminous coal from mine of Henry Thomas (Old Canyon) in N. ½ NE. ¼ sec. 35, T. 15 S., R. 2 E., 2 miles west of Wales. Sample cut from face of room 6, 1,400 feet north of mine mouth, on September 9, 1913, by F. R. Clark. Sample fresh and dry. Section at point of sampling is as follows:

Section of coal bed in mine of Henry Thomas.

	Ft.	in.
Coal	1	6
Bone		¾
Coal		5½
Bone		½
Coal	1	2½
Bone[1]		8
Coal[1]		2
Shale[1]	1	2
Coal (not mined).[1]		
	5	3¼+

[1] Not included in sample.

VIRGINIA.

DICKENSON COUNTY.

17559. Bituminous coal from Nora Mills mine of Clinchfield Coal Corporation at Nora. Widow Kennedy coal bed. Sample cut 300 feet east of drift mouth on July 12, 1913, by Henry Hinds. Sample includes entire bed. Sample wet. Section at point of sampling is as follows:

Section of coal bed in Nora Mills mine.

	Ft.	in.
Coal		6⅜
Bone		¼
Coal	1	3
"Rash"		⅛
Coal		3¾
"Rash"		¼
Coal		2⅝
"Rash"		⅛
Coal		4
	2	8½

17560. Bituminous coal from same mine as No. 17559. Sample wet. The section of the coal bed at point sampled, 300 feet northeast of drift mouth, is as follows:

Section of coal bed in Nora Mills mine.

	Ft.	in.
Coal		5½
Bone		⅛
Coal		6¼
Shale[1]		1¾
Coal		5¾
Bone		¼
Coal		8
	2	3⅝

17561F. Bituminous coal. Composite of Nos. 17559 and 17560.

17743. Bituminous coal from mine of Yellow Poplar Lumber Co., 4 miles northwest of Prater, Buchanan County. Upper Banner (?) coal bed. Sample cut in mine 200 feet from mouth on September 17, 1913, by T. K. Harnsberger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Yellow Poplar Lumber Co. mine.

	Ft.	in.
Coal, pyritiferous[1]		8
Shale[1]		7
Coal		3

[1] Not included in sample.

	Ft.	in.
"Rash"		⅛
Coal		9½
Bone [1]		1
Coal	1	1½
Sandstone [1]		1½
Coal	1	3
	4	10⅝

17744. Bituminous coal from same mine as No. 17743. Sample dry. Section at point of sampling, 220 feet N. 85° E. of mine mouth, is as follows:

Section of coal bed in Yellow Poplar Lumber Co. mine.

	Ft.	in.
Coal, pyritiferous [1]		9½
Shale [1]		6½
Coal		3
"Rash"		¼
Coal		8⅛
Bone [1]		1
Coal	1	2⅞
Sandstone [1]		1
Coal	1	3½
	4	11¾

17751. Bituminous coal from mine of C. C. Owens, 1 mile northeast of Mart. Splash Dam coal bed. Sample cut 10 feet north of main drift, 75 feet east of mine mouth, on September 19, 1913, by T. K. Harnsberger. Sample dry, coal slightly weathered. Section at point of sampling is as follows:

Section of coal bed in C. C. Owens's mine.

	Ft.	in.
Coal		8½
"Rash"		¼
Coal		11
Shale		¼
Coal		2
Shale [1]		1¼
Coal		7½
	2	6¾

17752. Bituminous coal from same mine as No. 17751. Sample dry, coal slightly weathered. Section at point of sampling, 15 feet south of main entry and 75 feet east of mine mouth, is as follows:

[1] Not included in sample.

Section of coal bed in C. C. Owens' mine.

	Ft.	in.
Coal	1	8
Shale [1]		½
Coal		2
Shale [1]		1
Coal		3½
Shale and pyrite		¼
Coal		4
	2	7¼

RUSSELL COUNTY.

18121F. Bituminous coal from mine No. 103 of Clinchfield Coal Corporation. Widow Kennedy bed. Sample cut in mine 260 feet N. 55° W. of mouth on November 17, 1913, by T. K. Harnsberger. Sample represents 5 feet 2 inches of coal, entire thickness of bed.

18122. Bituminous coal from mine No. 52 of Clinchfield Coal Corporation. Lower Banner bed. Sample cut 325 feet northeast of mouth of No. 0 drift on November 17, 1913, by T. K. Harnsberger. Sample represents 3 feet of coal, entire thickness of bed.

18123. Bituminous coal from same mine as No. 18122. Sample cut 1,700 feet southwest of mouth of No. 1 drift. Section at point of sampling is as follows:

Section of coal bed in mine No. 52.

	Ft.	in.
Coal	2	6½
Coal and shale [1]		2
	2	8½

18124F. Bituminous coal. Composite of samples Nos. 18122 and 18123.

18128. Bituminous coal from No. 2 mine of Clinchfield Coal Corporation. Upper Banner bed. Sample cut 2,400 feet S. 18° E. of mouth of drift No. 3 on November 18, 1913, by T. K. Harnsberger. Section at point of sampling is as follows:

Section of coal bed in No. 2 mine.

	Ft.	in.
Coal	1	10
Sandstone [1]		1½
Coal	1	2½
Sandstone [1]		½
Coal	2	5
	5	7½

[1] Not included in sample.

18129. Bituminous coal from same mine as No. 18128. Sample cut 2,750 feet S. 78° E. of mouth of drift No. 5, tunnel line. Section at point of sampling is as follows:

Section of coal bed in No. 2 mine.

	Ft.	in.
Coal	1	4
Sandstone [1]		1
Coal	1	2
Shale [1]		1
Coal	1	6
	4	2

18130. Bituminous coal from same mine as No. 18128. Sample cut 3,400 feet S. 85° W. of mouth of drift No. 1, middle incline. Section at point of sampling is as follows:

Section of coal bed in No. 2 mine.

	Ft.	in.
Coal	1	6
Sandstone [1]		1
Coal	1	5
Sandstone [1]		1
Coal	1	10
	4	11

18131F. Bituminous coal. Composite of samples 18128, 18129, and 18130.

18235. Bituminous coal from mine No. 6 of Clinchfield Coal Corporation, at Wilder. Upper Banner coal bed. Sample cut 3,000 feet S. 71° W. of mouth of No. 1 opening on November 25, 1913, by T. K. Harnsberger. Section at point of sampling is as follows:

Section of coal bed in mine No. 6.

	Ft.	in.
Coal	1	6
Sandstone [1]		1
Coal	1	6¾
Shale [1]		1
Coal	2	2
Shale [1]		3¼
Coal	1	1½
	6	9½

18236. Bituminous coal from same mine as No. 18235. Sample cut in room 5, 1,250 feet S. 35° E. of No. 3 opening, on November 26, 1913. Section at point of sampling is as follows:

Section of coal bed in mine No. 6.

	Ft.	in.
Coal	1	2
Sandstone [1]		1
Coal	1	6½
Coal and shale [1]		4½
Coal		4¼
Shale [1]		½
Coal	1	5
Coal and shale [1]		6
Coal		8½
	6	1¾

18237. Bituminous coal from same mine as No. 18235. Sample cut 4,000 feet S. 10° W. of No. 3 opening. Section at point of sampling is as follows:

Section of coal bed in mine No. 6.

	Ft.	in.
Coal	1	7
Sandstone [1]		1
Coal	1	8½
Shale [1]		1
"Rash" [1]		4½
Coal	1	11
"Rash" and clay [1]		6
Coal	1	5
	7	8

18238. Bituminous coal. Composite of samples Nos. 18235, 18236, and 18237.

18239. Bituminous coal from mine No. 201 of Clinchfield Coal Corporation, 1 mile northeast of Slemp. Bed No. 4. Sample cut 5,200 feet N. 33° W. of shaft on November 26, 1913, by T. K. Harnsberger. Section at point of sampling is as follows:

Section of coal bed in mine No. 201.

	Ft.	in.
"Rash" [1]		9
Coal	2	
Sandstone [1]		3
Coal	3	1
	6	1

[1] Not included in sample.

18240. Bituminous coal from same mine as No. 18239. Sample cut 1,600 feet N. 68° W. of shaft. Section at point of sampling is as follows:

Section of coal bed in mine No. 201.

	Ft.	in.
Coal	1	9½
Shale [1]		5
Coal	2	3
	4	5½

18241. Bituminous coal from same mine as No. 18239. Sample cut 2,900 feet N. 27° W. of shaft. Section at point of sampling is as follows:

Section of coal bed in mine No. 201.

	Ft.	in.
Coal	1	4½
Shale [1]		3½
Coal	2	3
	3	11

18242. Bituminous coal. Composite of samples Nos. 18239, 18240, and 18241.

18243. Bituminous coal from mine No. 55 of Clinchfield Coal Corporation, at Wilder. Lower Banner coal bed. Sample cut 900 feet S. 60° W. of No. 3 opening on November 25, 1913, by T. K. Harnsberger. Section at point of sampling is as follows:

Section of coal bed in mine No. 55.

	Ft.	in.
Coal	3	4
"Rash" [1]		3½
	3	7½

18244. Bituminous coal from same mine as No. 18243. Sample cut 2,500 feet S. 35° E. of No. 5 opening. Section at point of sampling is as follows:

Section of coal bed in mine No. 55.

	Ft.	in.
Coal		7
"Rash" [1]		2
Sandstone [1]	1	9
Coal	3	5
"Rash" [1]		7
	6	6

[1] Not included in sample.

18245. Bituminous coal from same mine as No. 18243. Sample cut 1,300 feet N. 35° W. of No. 2 opening. Section at point of sampling is as follows:

Section of coal bed in mine No. 55.

	Ft.	in.
"Rash" [1]		½
Coal	3	6
"Rash" [1]		4
	3	10½

18246. Bituminous coal. Composite of samples Nos. 18243, 18244, and 18245.

WISE COUNTY.

18226. Bituminous coal from Cranesnest No. 1 mine of Clinchfield Coal Corporation, near Caney (Dickenson County). Upper Banner coal bed. Sample cut 1,500 feet southwest of entrance to main entry on November 22, 1913, by T. K. Harnsberger. Section at point of sampling is as follows:

Section of coal bed in Cranesnest No. 1 mine.

	Ft.	in.
Coal		1½
Sandstone [1]		½
Coal	2	
Sandstone [1]		1
Coal	1	7½
Coal and shale [1]		2½
Coal		3½
Shale [1]		4
Coal		2
Shale [1]		1¾
Coal		10
	5	10¼

18227. Bituminous coal from same mine as No. 18226. Sample cut 500 feet

[1] Not included in sample.

northeast of mine mouth. Section at point of sampling is as follows:

Section of coal bed in Cranesnest No. 1 mine.

	Ft.	in.
Coal	1	10
Sandstone [1]		1
Coal	2	2
	4	1

18228. Bituminous coal from same mine as No. 18226. Sample cut 4,100 feet southeast of entrance to main entry. Section at point of sampling is as follows:

Section of coal bed in Cranesnest No. 1 mine.

	Ft.	in.
Coal	2	10
Sandstone [1]		1
Coal	1	5¾
Shale		¼
Coal		3
Shale [1]		5
Coal		6
Shale		⅛
Coal		9½
	6	4⅝

18229F. Bituminous coal. Composite of samples Nos. 18226, 18227, and 18228.

WEST VIRGINIA.

McDOWELL COUNTY.

17469. Semibituminous coal from mine of Central West Coal Co., 8 miles south of Iaeger. Pocahontas No. 5 bed. Sample cut in mouth of dip entry off main entry, 500 feet from mine mouth, on June 7, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed of Central West mine.

	Ft.	in.
Coal, lustrous		4
Coal, laminated		7
Coal, splint		11
Coal, lustrous	1	6
	3	4

17470. Semibituminous coal from same mine as No. 17469. Sample cut in second left entry off main entry, 1,500 feet from mine mouth. Sample dry. Section at point of sampling is as follows:

Section of coal bed of Central West mine.

	Ft.	in.
Coal, lustrous		3
Coal, fine-grained		4
Coal, splint	1	5
Coal, lustrous	1	1
	3	1

17471F. Semibituminous coal. Composite of samples Nos. 17469 and 17470.

MINGO COUNTY.

17462. Bituminous coal from Winifrede mine of Williamson Coal & Coke Co., 1 mile east of Williamson. Winifrede bed. Sample cut 700 feet northeast of mine mouth on May 31, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Winifrede mine.

	Ft.	in.
Coal, splint	2	4
Coal, bony		4
Coal, splint	1	1
Clay [1]		2
Coal, splint	1	9
	5	8

17463. Bituminous coal from Buffalo mine of Buffalo Collieries Co., 1 mile northeast of Chataroy. Winifrede bed. Sample cut in room 1 on right, off drift No. 12, 500 feet from mine mouth, on May 30, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Buffalo mine.

	Ft.	in.
Coal, splint	3	1
Coal, bony [1]		4
Coal, splint	2	
	5	5

17464. Bituminous coal from the mine of E. L. Sternberger Coal Co., 1½ miles northeast of Williamson. Winifrede bed. Sample cut in room 2 on left, off shop entry, 900 feet from mine mouth, on May 29, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

[1] Not included in sample.

[1] Not included in sample.

Section of coal bed in Winifrede mine.

	Ft.	in.
Coal, splint	2	7
Coal, bony		3½
Coal, splint		5
Coal, lustrous		7
Clay [1]		10
Coal, splint	1	6
Coal, lustrous		5
	6	7½

17465F. Bituminous coal. Composite of samples Nos. 17462, 17463, and 17464.

17466. Bituminous coal from mine of Howard, Jr., Coal Co., 2 miles northeast of Chataroy. Coalburg bed. Sample cut in first air course on main entry, 700 feet from mine mouth, on May 30, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Howard mine.

	Ft.	in.
Coal, splint	3	3
Bone [1]		3
Coal, lustrous, hard		11
Bone [1]		1
Coal, lustrous		6
Bone [1]		1
Coal, lustrous		7
	5	8

17467. Bituminous coal from Buffalo mine of Buffalo Collieries Co., 1 mile northeast of Chataroy. Coalburg bed. Sample cut in room 3 on left off main entry, 700 feet from mine mouth, on May 30, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Buffalo mine.

	Ft.	in.
Coal, dull, hard	1	4
Clay [1]		1
Coal, lustrous, soft		6
Clay [1]		1
Coal, dull, hard		9
Bone [1]		4
Coal, splint		9
Bone [1]		2
Coal, lustrous, soft	1	
	5	

[1] Not included in sample.

17468F. Bituminous coal. Composite of samples 17466 and 17467.

17472F. Bituminous coal from mine of White Star Mining Co., 3 miles northwest of Matewan. Alum bed. Sample cut in third left entry off main entry, 1,000 feet from mine mouth, on June 3, 1913, by Eugene Stebinger. Sample represents 3 feet 4 inches of coal, entire thickness of bed. Sample dry.

17473F. Bituminous coal from mine of White Star Mining Co., 3 miles northwest of Matewan. No. 2 or Gas bed. Sample cut at heading of main entry, 700 feet from mine mouth, on June 3, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in White Star mine.

	Ft.	in.
Coal, splint		4
Bone [1]		9
Coal, lustrous	2	6
Coal, splint		8
	4	3

17474F. Bituminous coal from mine of Red Jacket, Jr., Coal Co., 4 miles northeast of Matewan. Red Jacket bed. Sample cut in room 15 on left off main entry, 1,200 feet from mine mouth, on June 2, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Red Jacket, Jr., mine.

	Ft.	in.
Coal, lustrous		8
Coal, splint	1	8
Coal, banded		3
Coal, bony		2
Coal, lustrous	1	3
	4	

17475F. Bituminous coal from War Eagle mine of War Eagle Coal Co., 3 miles northeast of War Eagle. War Eagle No. 2 bed. Sample cut in first room on right off main entry, 200 feet from mine mouth,

[1] Not included in sample.

on June 6, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in War Eagle mine.

	Ft.	in.
Coal, laminated		7
Coal, lustrous	2	9
Coal, bony		2
Coal, lustrous	2	8
	6	2

17476. Bituminous coal from Papoose mine of War Eagle Coal Co., 2 miles east of War Eagle. War Eagle No. 1 bed. Sample cut in fifth left entry off main straight entry, 600 feet from mine mouth, on June 6, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Papoose mine.

	Ft.	in.
Coal, lustrous, with sulphur streaks		5
Clay [1]		½
Coal, lustrous		9
Coal, splint		8
Coal, lustrous		9
Clay [1]		2
Coal, lustrous	2	10
	5	7½

17477. Bituminous coal from same mine as No. 17476. Sample cut at heading No. 5 drift, 1,200 feet from mine mouth. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Papoose mine.

	Ft.	in.
Coal, lustrous	1	1
Coal, splint		11
Clay [1]		5
Coal, lustrous		4
Coal, splint		9
Coal, lustrous	2	7
	6	1

17478. Bituminous coal from Mephisto mine of War Eagle Coal Co., 3 miles northeast of War Eagle, War Eagle No. 1 bed. Sample cut at heading of second left air course, 500 feet from mine mouth, on June 6, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Mephisto mine.

	Ft.	in.
Coal, soft	2	7
Clay [1]		6
Coal, hard	1	
Coal, soft	2	
	6	1

17479F. Bituminous coal. Composite of samples 17476, 17477, and 17478.

17480. Bituminous coal from Buffalo mine of Buffalo Collieries Co., 1 mile east of Chataroy. Thacker bed. Sample cut in prospect entry 60 feet in on May 30, 1913, by Eugene Stebinger. Sample wet. Section at point of sampling is as follows:

Section of coal bed in Buffalo mine.

	Ft.	in.
Coal, lustrous	2	7
Clay [1]		4
Coal, under water [1]		6
	3	5

17481. Bituminous coal from Winifrede mine of Williamson Coal & Coke Co., 1 mile east of Williamson. Thacker bed. Sample cut in new prospect drift 60 feet in on May 31, 1913, by Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of Thacker coal bed in Winifrede mine.

	Ft.	in.
Coal, dull		7
Clay [1]		½
Coal, lustrous	2	4
Clay [1]		1
Coal, lustrous		8
	3	8½

17483. Bituminous coal from mine of Red Jacket, Jr., Coal Co., 4 miles northeast of Matewan. Thacker bed. Sample cut in room 15 on left off main entry, 1,200 feet from mine mouth, on June 2, 1913, by

[1] Not included in sample.

[1] Not included in sample.

Eugene Stebinger. Sample dry. Section at point of sampling is as follows:

Section of coal bed in Red Jacket, Jr., mine.

	Ft.	in.
Coal, lustrous	1	4
Coal, splint		8
Coal, lustrous	2	3
	4	3

WYOMING.

CONVERSE COUNTY.

17657. Subbituminous coal from mine of Fairview Coal Co., in NE. ¼ sec. 5, T. 33 N., R. 75 W., at Glenrock. Sample cut in mine 200 feet northeast of shaft on August 15, 1913, by J. B. Reeside, jr. Sample wet. Section at point of sampling is as follows:

Section of coal bed in Fairview Coal Co. mine.

	Ft.	in.
Coal	1	4
Shale [1]		2
Coal	5	
	6	6

17658. Subbituminous coal from mine of Glenrock Coal Co., in NE. ¼ SW. ¼ sec. 4, T. 33 N., R. 75 W., one-fourth mile east of Glenrock. Sample cut in mine 75 feet N. 34° E. of main entry on August 15, 1913, by J. B. Reeside, jr. Sample dry. Section at point of sampling is as follows:

Section of coal bed in mine of Glenrock Coal Co.

	Ft.	in.
Coal		11
Bone		4
Shale		2
Coal [2]	5	4
	6	9

17722F. Subbituminous coal from mine of Big Muddy Consolidated Coal Co., in SE. ¼ sec. 26, T. 34 N., R. 77 W., at Big Muddy. Upper Big Muddy bed. Sample cut 300 feet down slope on September 12, 1913, by J. B. Reeside, jr. Sample fresh and dry. Section at point of sampling is as follows:

[1] Not included in sample.
[2] Part sampled.

Section of coal bed in mine of Big Muddy Consolidated Coal Co.

	Ft.	in.
Coal	4	
Bone [1]		1
	4	1

17723F. Subbituminous coal from mine of Big Muddy Consolidated Coal Co., in NW. ¼ sec. 36, T. 34 N., R. 77 W., at Big Muddy. Lower Big Muddy bed. Sample cut in mine 40 feet from mouth of unused slope on September 12, 1913, by J. B. Reeside, jr. Sample represents 4 feet 3 inches of coal, entire thickness of bed. Sample dry, hard, and unweathered.

17902. Subbituminous coal from a prospect in SE. ¼ sec. 9, T. 33 N., R. 75 W., 2 miles south of Glenrock. Sample cut in prospect 40 feet from mouth, on October 15, 1913, by J. B. Reeside, jr. Sample dry Section at point of sampling is as follows:

Section of coal bed in prospect.

	Ft.	in.
Bone [1]		4
Coal	3	
	3	4

FREMONT COUNTY.

17584. Subbituminous coal from prospect in sec. 25, T. 42 N., R. 108 W., 8 miles northwest of Dubois. Sample cut 10 feet from mouth of prospect by D. Dale Condit. Sample wet and weathered. Section point of sampling is as follows:

Section of coal bed in prospect.

	Ft.	in.
Clay with lenses of coal	2	6
Coal		3
Clay	1	5
Coal [2]		10
Shale, gypsiferous		½
Coal [2]	1	1
Coal, bony		2
Coal [2]		7½
Clay	1	7
Coal		6½
Clay		4
Coal		2½

[1] Not included in sample.
[2] Part sampled.

	Ft.	in.
Clay		4
Coal		5½
	10	4¼

HOT SPRINGS COUNTY.

17709. Subbituminous coal from mine of Vede Putney, in sec. 24, T. 44 N., R. 99 W. Putney bed. Sample cut at face of room, 70 feet S. 65° W. from a point in the main entry 80 feet from the mouth, on August 27, 1913, by D. F. Hewett. Sample weathered (?). Section at point of sampling is as follows:

Section of coal bed in mine of Vede Putney.

	Ft.	in.
Coal	1	1
Coal, bony		3
Coal	2	1
Shale [1]		1
Coal [1]		4
Shale [1]		3
Coal [1]		6
	4	7

17830. Subbituminous coal from prospect of E. L. Gwynn in sec. 1, T. 45 N., R. 99 W. Bed B. Sample cut in prospect 40 feet from mouth and 30 feet west on September 15, 1913, by D. F. Hewett. Section at point of sampling is as follows:

Section of coal bed in prospect of E. L. Gwynn.

	Ft.	in.
Coal	1	2
Shale		6
Coal		2
Shale		1
Coal		1
Shale		5
Coal [2]	4	
Shale	1	6
Coal		4
	8	3

[1] Not included in sample.
[2] Part sampled.

17731. Subbituminous coal from Owl Creek mine of Berry Bros. in sec. 28, T. 44 N., R. 98 W. Sample cut in south wall of entry, 40 feet from mine mouth, on August 27, 1913, by D. F. Hewett. Section at point of sampling is as follows:

Section of coal bed in Owl Creek mine.

	Ft.	in.
Coal		3
Shale		2
Coal		4
Shale		2
Coal [1]	2	11
	3	10

NATRONA COUNTY.

17778. Subbituminous coal from prospect in SE. ¼ sec. 22, T. 33 N., R. 78 W., 7 miles southeast of Casper. Sample cut in prospect 40 feet from mouth on September 22, 1913, by J. B. Reeside, jr. Sample dry; weathered (?). Section at point of sampling is as follows:

Section of coal bed in prospect.

	Ft.	in.
Coal	2	
Bone [2]		3
	2	3

17895. Subbituminous coal from prospect in the SW. ¼ sec. 13, T. 36 N., R. 79 W., 5 miles north of Casper. Sample cut 20 feet in prospect on October 12, 1913, by J. B. Reeside, jr. Sample weathered (?). Section at point of sampling is as follows:

Section of coal bed in prospect.

	Ft.	in.
Bone		½
Coal	2	3
Bone [2]		5
	2	8½

[1] Part sampled.
[2] Not included in sample.

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