

# COAL INVESTIGATION IN THE SALINE-GALLATIN FIELD, ILLINOIS, AND THE ADJOINING AREA.

By FRANK W. DEWOLF.

## INTRODUCTION.

The area here described is near the southwest edge of the Eastern Interior coal field, lying mostly in Illinois, but extending also into Indiana and Kentucky. Its boundaries are slightly beyond those of the Eldorado and New Haven quadrangles, and it measures  $30\frac{1}{2}$  miles from east to west and  $18\frac{1}{2}$  miles from north to south, thus including approximately 550 square miles. Parts of four counties in Illinois—Saline, Gallatin, White, and Hamilton—are comprised within the area.

Coal production in this region is increasing so rapidly that geologic work carried on here assumes an important economic aspect. The rapid development of this part of the coal basin is due to the excellent quality of the fuel, its extensive distribution, and favorable mining conditions. The production to date has been entirely in the Illinois portion of the area and until the last year only in Gallatin and Saline counties. White County also is now producing. In 1906 the area included in this report produced 314,927 tons, a gain of 115 per cent over 1905.<sup>a</sup> Coal mining in the Eldorado quadrangle is facilitated by the presence of several railroads; the New Haven quadrangle has none. The whole area, however, has so little relief that it can be easily reached by railroads where desired.

This preliminary statement of geologic field work performed during three autumn months of 1906 is the first published report for this area since 1875,<sup>b</sup> though adjoining areas in Indiana<sup>c</sup> and Kentucky<sup>d</sup> have received later attention. The two quadrangles here described are the first of a series extending across the southern Illinois coal field, the mapping of which will be completed in the near future. The topographic and geologic work is being executed in cooperation by the Illinois Geological Survey and the United States Geological Survey. Information in regard to additional quadrangles on the west will also be included in the final report.

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<sup>a</sup> Mineral Resources U. S. for 1906, U. S. Geol. Survey.

<sup>b</sup> Geol. Survey Illinois, vol. 6, 1875.

<sup>c</sup> Rept. Indiana Dept. Geol. and Natural Resources, 1899, pp. 1399, et seq.

<sup>d</sup> Repts. Inspector of Mines of Kentucky. 1893, etc.

The writer is indebted to Stuart Weller and David White for their assistance in correlating the rocks of the region and to George H. Ashley for suggestions in the office. Such value as this report possesses is due largely to the kind cooperation of those coal companies which have placed drill records and other data in the hands of the Survey. To many well drillers and other persons thanks are cordially given for numerous services.

#### SURFACE RELIEF AND DRAINAGE.

Mining conditions in this field are rendered favorable on the whole by the moderate surface relief. Though the altitudes vary from 340 to 600 feet above sea level, most of the area lies between 365 and 420 feet. The drainage is tributary to Ohio River directly or through the Wabash, Little Wabash, and Saline rivers and their branches. It is deficient in a large area, especially along the Wabash, but considerable reclamation is promised by systematic ditching now in progress.

The topography is of two types—uplands and bottoms. Prominent hills of the New Haven quadrangle are indicated on Pl. VII. Bottom lands constitute about two-thirds of the area of the New Haven quadrangle and about one-third of the Eldorado.

The detailed topographic character of the area and the distribution of timber, houses, roads, and land lines are indicated on the colored contour maps of the Eldorado and New Haven quadrangles.<sup>a</sup> Pl. VIII (p. 120) shows relief and altitude above sea level by contour lines, each of which passes through points of equal altitude on the land, one being drawn for every 20 feet of increase in elevation.

#### GEOLOGY.

##### INTRODUCTION.

The economic value of the geologic examination of the various coals of this region lies in determining for each its vertical position, horizontal extent, thickness, quality, structure, and correlation with beds in other areas. Since the study of the region has not yet been fully completed, some of the field observations may be subject to a different interpretation in the final report.

Field work is difficult here because of the presence of glacial and fluviatile deposits which very largely conceal the underlying rocks. The most valuable data were obtained from numerous records of coal borings and a few deeper holes bored for oil. A little information was also derived from water wells. The best exposures of value are those occurring beyond the drift border in the region immediately to the south of this area along Saline River and in the neighboring part of Kentucky.

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<sup>a</sup> These maps may be obtained for 5 cents each by addressing The Director, U. S. Geological Survey, Washington, D. C.

## STRATIGRAPHY.

## GENERAL STATEMENT.

The rocks of this area consist of a varying thickness of fluvial and glacial deposits, overlying alternating shales and sandstones with relatively thin, more or less lenticular beds of limestone, coal, and fire clay. They have been explored to a depth of about 1,500 feet. The hard rocks belong to the Pennsylvanian series of the Carboniferous system.

## CORRELATION.

Division of the Pennsylvanian beds of the Kentucky-Illinois area in earlier reports into the "Upper" or "Barren Measures" and the "Lower" or "Productive Measures" was made partly for convenience and partly to conform with earlier subdivisions of the Carboniferous rocks in Pennsylvania. D. D. Owen<sup>a</sup> used as a horizon for this division the Anvil Rock sandstone. In later reports for Illinois A. H. Worthen<sup>b</sup> used, instead, the Carlinville limestone, a bed higher stratigraphically, thought to be identical with the Carthage limestone of Kentucky. It may be questioned whether either of these two horizons or any other has sufficient persistence and prominence to be employed for the division throughout any large part of the Eastern Interior coal basin.

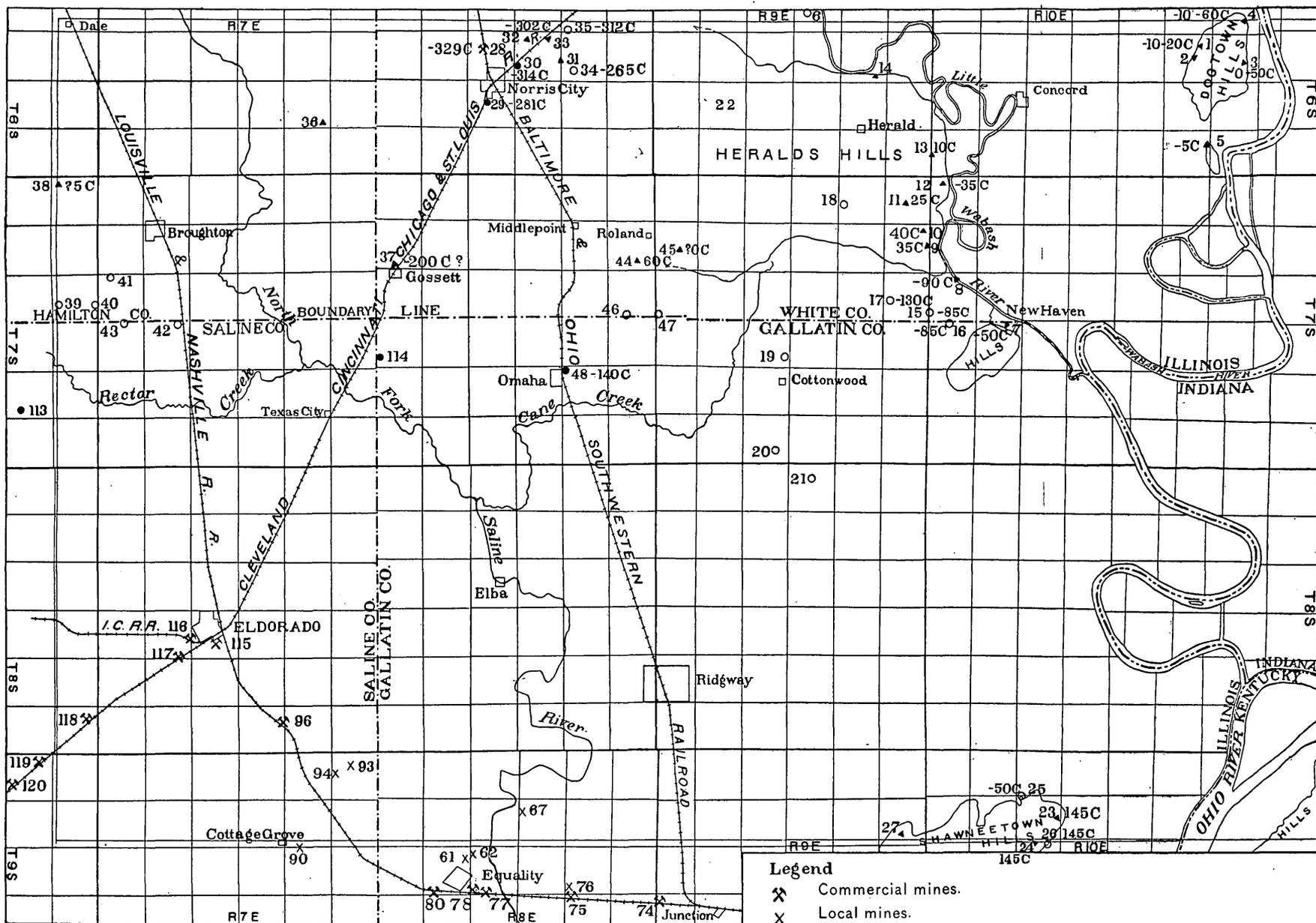
For further convenience in description and correlation the old surveys of Kentucky and Illinois numbered the coal beds upward from the bottom. In the "Lower Measures" the old Kentucky section, however, shows twelve numbered coals, with a few additional beds either designated by letters or not named; while the old Illinois section distinguishes nine numbered coals, and recognizes one of minor thickness to which no number has been applied. The total number of Pennsylvanian coals in the old Illinois section is sixteen. The two stratigraphic columns compiled by the old surveys disagree in the lower portions, and likewise in the upper portions, since Illinois reports place the Carthage limestone not more than 184 feet above coal No. 7,<sup>b</sup> whereas Kentucky reports describe it as occurring 450 feet above the corresponding bed.<sup>c</sup> In the middle portion of the column, however, the coals numbered by Worthen from 8 to 2 seem to be identical with the similar series numbered from 12 to 5 by Owen.<sup>d</sup> No single columnar section can safely be considered representative of conditions over a wide area, since the character of the rocks varies greatly within short distances. As the sections in fig. 2 indicate persistence of certain beds, however, there is reason to hope that study

<sup>a</sup> Kentucky Geol. Survey, vol. 1, 1856, pp. 30-45.

<sup>b</sup> Geol. Survey Illinois, vol. 6, 1875, p. 3.

<sup>c</sup> Geol. Survey Kentucky, vol. 3, 1857, p. 20.

<sup>d</sup> See correlation sheet by C. J. Norwood, in Rept. Inspector of Mines in Kentucky, 1893, p. 96.



**Legend**

- ✕ Commercial mines.
- X Local mines.
- ▲ Rock outcrop.
- Coal test boring.
- Well.
- 52C Calculated altitude of coal No. 5 above sea level.
- 67 Datum locality referred to in text or mine table.

MAP OF SALINE-GALLATIN COAL FIELD.

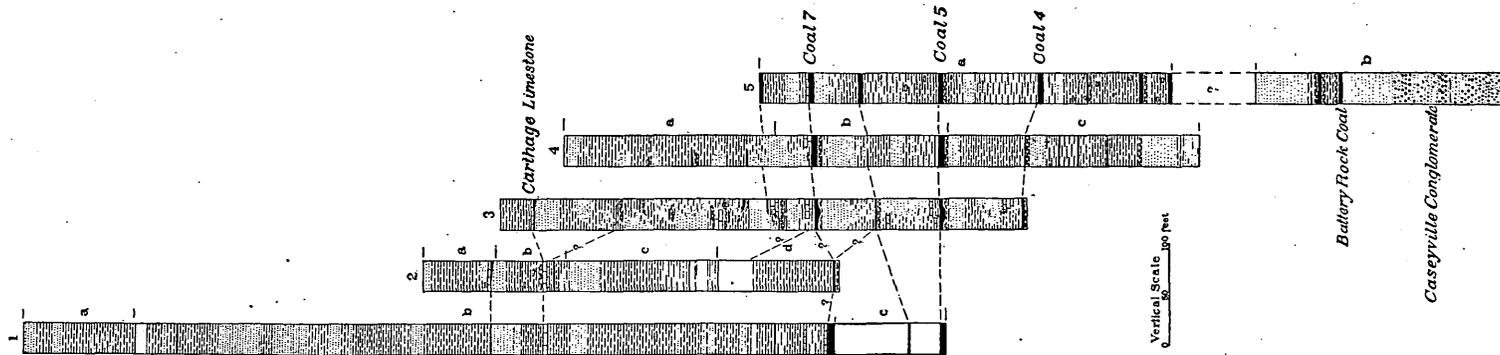


FIG. 2.—Representative columnar sections of Saline-Gallatin coal field, Illinois. These sections are compiled from the following sources (numbers refer to localities indicated by corresponding numbers on Pls. VII and VIII):

- |                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>1. a. From observations at locs. 31, 32, 33.<br/>           b. From core drillings at locs. 30 and 28.</p> <p>2. a. From ravines at locs. 8 to 13.<br/>           b. From locs. 49 and 7.<br/>           c. From Shawneetown Hills at locs. 23 and 24.<br/>           d. From well at loc. 26.</p> <p>3. From numerous tube borings in the southwestern part of the area.</p> | <p>4. a. From tube borings near Junction.<br/>           b. From record and exposures at loc. 79.<br/>           c. From drilling by Broughton Temple at Equality.</p> <p>5. a. From Gallatin County section by Cox (Geol. Survey Illinois, vol. 6, 1875, p. 202).<br/>           b. From Battery Rock, Ill., and Caseyville, Ky.</p> |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

of drill records and field evidence will result in a correct correlation of the various horizons. The present use of numbers in the Illinois fields probably does not indicate the true correlation of the coals, though locally over considerable areas the designations are doubtless consistent. It seems advisable in this report to use the numbers so widely accepted in this region, but with the understanding that they are of local significance only and do not imply correlation with beds bearing the same numbers in other areas.

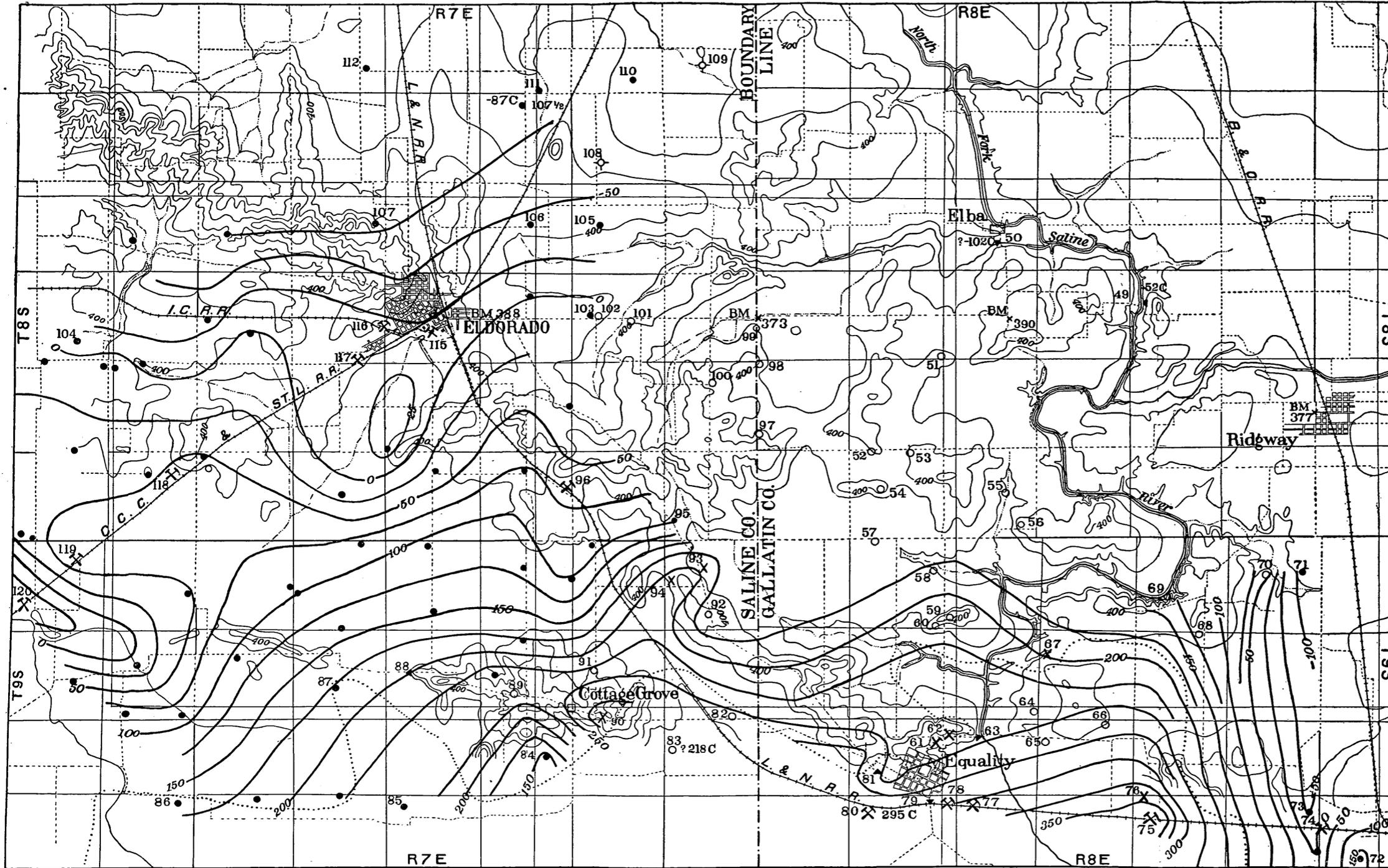
#### GENERAL DESCRIPTION OF STRATIGRAPHIC COLUMN.

The approximate columnar sections given in fig. 2, compiled from outcrops and borings, indicate the character of the rocks in several parts of the area and show the apparent persistence of certain beds and the local, lenslike character of others. The variations exhibited, however, are due in part to scant and imperfect data. Of the localities referred to in this paper, Nos. 49-112 are shown on Pl. VIII and the others on Pl. VII.

The persistence of the coals from No. 8 to No. 5, inclusive, is notable in the columnar sections. Other beds of special importance stratigraphically are certain limestones. One occurs in section 1, 265 feet above coal No. 7, and is also shown in section 2. Another is indicated in section 3, 190 feet above No. 7, and a third occurs in the same section 45 feet above No. 7. The first of these is tentatively regarded as the Carthage limestone, which is especially important here. It takes its name from a former settlement three-fourths of a mile west of Uniontown, Ky., where the rock is exposed along Ohio River. When fresh, it is hard and blue gray in color, outcrops in vertically-jointed cliffs, and shows a tendency to split into slabs. When weathered, the rock is usually buff or reddish brown. On its surface and through its interior occur abundant brachiopods, crinoid stems, and other fossils. Because of the persistence of these lithologic characters and the similarity of fossil content, limestones at several localities within the area have with some hesitancy been identified with the Carthage.

The distance from this bed to the identifiable coals of the section has considerable economic interest and is a matter of disagreement in the old State reports, as already indicated. It is probable that neither of the old estimates is clearly applicable to this region, although the evidence here presented is not altogether conclusive.

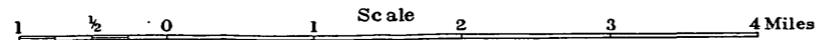
At New Haven a churn-drill well, which commenced on a level with a limestone, probably Carthage, outcropping at loc. 7, reached a thin coal at 260 feet and stopped in a limestone 10 feet lower. No coal referable to No. 7 was passed, though the bottom limestone may



**LEGEND.**

- + Section lines.
- - - - - Public roads.
- 400 Contours showing elevation of land above sea level.
- 200 Contours showing elevation of base of Coal No. 5 above sea level.
- · - · - · - Approximate outcrop of Coal No. 7.
- X Commercial mines.
- X Local mines.
- ▲ Rock outcrop.
- Coal test boring.
- Well.
- ⊕ Oil or gas prospect boring.
- 52C Calculated altitude of Coal No. 5 above sea level.
- 67 Datum locality referred to in text or mine table.

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MAP OF PART OF THE ELDORADO QUADRANGLE, ILLINOIS.  
Showing topography and structural geology.

be the roof of that bed. At Round Pond (loc. 26) a well commencing 160 feet below the outcrop of a limestone, presumably Carthage, reached a 2-foot coal at a distance of 268 feet below that bed, but passed none with the usual characteristics of coal No. 7. In borings near Junction, which strike the first hard rocks 230 feet above coal No. 7, no limestone comparable to the Carthage is reported. These records show either that the interval between the Carthage and the No. 7 coal at these localities exceeds 270 feet, or that there is a lack of development or absence at the first two places of the No. 7 coal and at the last of the Carthage limestone.

A core drill at Norris City (loc. 30) reached a 5-foot limestone 265 feet above coal No. 7. As this limestone is almost identical in character with the Carthage, and carries the same fossils, it may be regarded as that bed, especially because the associated strata are similar to those observed with the so-called Carthage, as indicated in section 2 (fig. 2). The interval between the Carthage and No. 7 coal at Norris City seems therefore to be 265 feet.

Different conditions are recorded around Eldorado. At loc. 102 a thin dark-blue limestone occurs about 225 feet above the horizon of the No. 7 coal, as determined at loc. 103, but at locs. 10, 13, 14, 15, and 16 no limestone is reported at this horizon. One occurs, however, 190 to 210 feet above No. 7 in all the borings in that vicinity which reach its horizon. Its persistence and uniform thickness of about 5 feet suggest that this bed may possibly be the Carthage, though it is separated from the No. 7 coal by an interval 55 to 75 feet less than at Norris City, Equality, New Haven, and Round Pond. Such a change in interval, although improbable, is perhaps further indicated by the imperfect record at Omaha (loc. 48), which reports a hard limestone at 180 feet and coal, comparable to No. 7, 225 feet lower. It seems more likely that the Carthage limestone is lenticular and that it dies out between Norris City and Eldorado or is represented by the thin limestone reported at loc. 102 and others near by. If the identification as Carthage of various limestone beds in this region is correct, its outcrop, representing the boundary between the upper and lower "Coal Measures," would be indicated roughly, beginning near Dogtown, by a line connecting locs. 4, 5, 7, 44, 49, 97, 101, and 103 with an outlyer in the Shawneetown Hills and the area westward to Junction. Future work must demonstrate whether the Carthage limestone can be identified and used as a key rock over this coal field.

Another limestone, as already noted, occurs rather persistently 45 feet above the No. 7 coal. It is generally encountered in borings in the southwest corner of the area and outcrops  $1\frac{1}{2}$  miles west of Cottage Grove at loc. 88.

## STRUCTURE.

## GENERAL STATEMENT.

Although the coals and associated strata of this region are nearly parallel and horizontal, the distances between the strata change from place to place and the beds slope or dip in varying directions and amounts. The determination of the altitude of the coals is important for the reason that economical mining must take advantage of natural slopes for haulage, drainage, and ventilation.

The structure bears an intimate relation to an east-west displacement, just south of the area mapped, which marks the north edge of Gold Hill Range. The amount of this disturbance, which has caused a relative sinking of the strata to the north, is roughly indicated by data obtained at Equality, Cottage Grove, and in the hills to the south.

The lower slope of the range reveals limestones of Mississippian age; the capping is the Caseyville conglomerate. In Prospect Hill this conglomerate has an altitude of about 900 feet, and the altitude of coal No. 5 at this point, if uneroded, would be over 1,425 feet. The same coal  $3\frac{1}{2}$  miles farther north, at loc. 84, is nearly 1,300 feet lower, or at an altitude of 145 feet. There is no evidence that this change in level is due to dip, for at both localities the rocks appear to dip southward.

The dips of the coals are predominantly northward, toward the center of the Eastern Interior basin. There are, however, numerous local exceptions. The amount of dip also varies greatly; it exceeds 100 feet to the mile in some localities, but probably averages only half that amount and locally is negligible. There is some evidence of conditions similar to those in the faulted area on the south. Thus at Eldorado, in O'Gara mine No. 8, a 6-foot dike of igneous rock cuts vertically through coal No. 5 and produces a narrow zone of "natural coke." The rock resembles and probably is related to dikes of the Illinois-Kentucky fluorspar district. Elsewhere there are certain abrupt changes in level of the beds, possibly due to faulting, as between Equality and Junction. These conditions are described on page 123. The possible occurrence of such structural changes within the untested areas treated in this report is a source of uncertainty in the determination of the horizontal distribution of the coals.

## METHOD OF SHOWING STRUCTURE.

The dips are indicated by a comparison of the figures placed on Pl. VII (p. 118), which show, at various datum points, the measured or calculated altitude of coal No. 5. Additional evidence in the southern portion of the Eldorado quadrangle is shown on Pl. VIII. The structure contours of this map were drawn in the following

manner: The depth to coal No. 5 was either determined from records of test holes and shafts or calculated from the presence in shallow wells or at surface outcrops of other higher strata which could be identified. This figure at each datum point was subtracted from the altitude of the ground in order to obtain the altitude of the coal. Where the coal lies at different altitudes at adjoining points the dip between these was regarded as uniform and points of equal altitude were connected by a contour line. Thus between every two contours there is indicated a dip of 25 feet, except in the southeast corner, where every other line is omitted and the dip is 50 feet between contours. The resultant map may be slightly inaccurate. As the surface elevations were determined by hand level or barometer from bench marks, there are probably small errors. Furthermore, it is possible that in a few places where the depth of the coal was calculated from overlying beds the interval assumed was slightly incorrect. The most important source of error is the assumption that between datum points dips are uniform. It is still reasonably certain that in Saline County the error along any contour line is less than 25 feet, but in Gallatin County, because of lack of data, it may be more.

The dips of the area are readily determined by reference to this map, but attention should be called to the possibility of faulting as an explanation of abrupt changes in altitude in certain localities. Such an explanation is suggested for changes in elevation of the Carthage limestone in the Shawneetown Hills, at locs. 23 and 25.

At Cottage Grove either an anticlinal fold trending east and west or a fault with the downthrow on the south is indicated, for between locs. 84 and 89 there is a change in level of 85 feet in three-fourths of a mile. An abrupt descent of 100 feet also occurs from locs. 93 and 94 to loc. 95, though the distance but slightly exceeds half a mile. Similarly, a descent of about 115 feet occurs from loc. 119 to loc. 120, three-fourths of a mile apart. Underground workings have not yet shown whether this is due to dip or to a fault.

The most interesting locality from this standpoint lies in the southeast corner of the area, between Junction and locs. 75 and 76, where the contours show an apparent dip of 400 feet in  $1\frac{3}{4}$  miles. There is an additional source of possible error here, since the correlations may be incorrect. Probably the test holes in this vicinity, except at locs. 73 and 72, stopped in coal No. 7. The hole at loc. 73 stopped just before reaching it, and that at loc. 72 went through to No. 5. If, however, this interpretation of the records is incorrect and all these test borings reached No. 5, then there is an additional descent of 120 feet between the points mentioned and loc. 73. A considerable proportion of this descent may be due to a fault along a north-south line:

Some such condition is indicated also between locs. 70 and 71, where the levels change 180 feet in half a mile. The information at loc. 70, however, was obtained from a churn-drill boring and may be incorrect.

#### DESCRIPTIONS OF DATUM LOCALITIES.

The following notes record observations at the localities shown by numbers on the accompanying maps, except those made at coal mines, which are grouped in a later table. Locs. 1 to 48, 113, and 114 are shown on Pl. VII, the others on Pl. VIII, and where possible the calculated altitude of coal No. 5 is shown.

*Locs. 1-18.*—At these points occurs either the Carthage limestone, an upper bed lying stratigraphically about 50 feet higher, or other closely associated strata. Thin coals usually underlie the limestones. In this region coal No. 7 may be looked for about 275 feet below the Carthage limestone, and coal No. 5 about 120 feet lower. They should occur 50 feet farther below the upper limestone.

*Locs. 1-4:* The public roads near Dogtown show outcrops of an 18-inch limestone which is underlain by a thin coal at locs. 1 and 2 and which resembles the Carthage bed in fossil content, but corresponds to the higher limestone in thickness. It is from 385 to 395 feet in altitude.

*Loc. 5:* At the base of the hill occurs a thin coal overlain by a limestone 6 feet thick, which is probably Carthage.

*Loc. 6:* A 3-foot limestone struck in the well of David Hayes probably occurs stratigraphically considerably above the Carthage.

*Loc. 7:* At New Haven an exposure occurs in the river bank as follows:

##### *Section at New Haven.*

	Ft.	in.
Limestone (Carthage), blue-gray, hard, brittle, fossiliferous.....	5	
Shale, black.....	3	
Coal.....		2
Fire clay.....	3	
Sandstone and shaly sandstone, soft, fine grained.....	6	
Shale, sandy.....	5½	
Sandstone, fine, soft, thin bedded, gray-brown.....	3	
Low water, Little Wabash River.		

*Loc. 8:* Near the mouth of Rocky Branch a limestone bed 18 inches thick forms a riffle across the Little Wabash. It carries a somewhat different fauna from the Carthage, which it probably overlies by 50 feet. Above it occurs 6 feet of blue-gray shale bearing iron nodules and below it streaks of coal, embedded in 1 foot of bituminous shale and underlain by blue clay shale.

Locs. 9-18: The same coal and limestone or beds near this horizon are exposed in ravines to the north, accompanied by the beds shown in the columnar sections. A summary follows.

*Summary of observations at locs. 9-18.*

Loc. No.	Name.	Kind of rock.	Coal.			Remarks.
			Thick-ness.	Depth.	Altitude.	
			<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>	
9	.....	Limestone, coal.....	+	0	410	
10	Owen Wilborn.....	Limestone, coal.....	+	0	415	
11	J. F. Medlin.....	Sandstone, coal.....	18	0	430	Old mine.
12	.....	Limestone, coal.....	+	0	370	
13	.....	Coal.....	+	0	415	Old mine.
14	"Devil's Biscuit".....	Sandstone <sup>a</sup> .....				
15	Mrs. Rhoda Grant.....	Limestone, coal.....	+	60	360	
16	John Sturm.....	Limestone, coal.....	+	60	360	
17	Alex. Questell.....	Coal.....	+	125	315	
18	Isaac Bayley.....	Coal.....	+	200+	330-	

<sup>a</sup> Thickness of sandstone 20 feet; altitude 380 feet.

Locs. 19-22.—There is some doubt in regard to the stratigraphy of the thin coals and hard rock, presumably limestone, which occur in wells near Cottonwood, and of the sandstones and underlying shale exposed along the hill roads to the north, as at Iron.

Locs. 23-27.—In the region of Round Pond three occurrences of the Carthage limestone furnish a basis for calculating the altitudes of workable coals.

*Section at Round Pond.*

	Feet.
Limestone, Carthage, altitude 540 feet.....	5
Concealed.....	2
Coal, bloom.....	+
Concealed.....	24
Sandstone, hard, massive, gray.....	30
Concealed.....	35
Shale, argillaceous and sandy, blue-gray.....	33
Concealed.....	5
Shale, brown.....	5
Shale, black, and coal bloom.....	2
Shale, brown, sandy.....	20
Concealed to Round Pond.....	40

Loc. 24: The limestone occurs also at the same altitude near the top of the hill at the road forks.

Loc. 25: A limestone 35 feet below the surface in the well of William Satterly overlies a 2-foot coal and appears on the evidence of lithologic character and fossils to be the Carthage. Its altitude, 195 feet lower than at loc. 23, is probably due to a fault.

Loc. 26: A churn-drill well on the R. L. Millsbaugh farm, starting 160 feet below the Carthage limestone, passes through 37 feet of clay and gravel, 71 feet of shale, and 2 feet of coal. While this may be the No. 7 coal without its usual thickness and limestone roof, this test is not conclusive. It is noted under "Stratigraphy" (p. 121)

that near Eldorado, coal No. 7 occurs 200 feet below a limestone which may possibly, but not probably, prove to be the Carthage. If the same interval holds at Round Pond, coal No. 7 should occur where the section is now filled with clay and gravel. Its presence in workable thickness can be determined by a test hole at a point on the hill slope located above this well, so as to avoid the surface clays.

Loc. 27: Though the 25-foot sandstone cliff here has the same elevation as a similar bed in the section at loc. 23, and may indicate absence of dip, the evidence is not strong enough to be trustworthy.

*Locs. 28-35.*—Near Norris City stratigraphic notes are obtainable from three diamond-drill logs and from hill outcrops, as shown in fig. 2. The altitudes of coal No. 7 in the test borings indicate a dip N. 5° W. of 48 feet to the mile, but the outcrops indicate in the area to the northeast a dip of the same amount N. 26° W. The calculations are based on a cinnamon-brown sandstone and certain thin coals.

Loc. 31: The rocks exposed at the hilltop consist of 10 feet of gray sandstone over 15 feet of brown shale. A few rods to the north, at the crossroads, occur the underlying beds, consisting of cinnamon-brown sandstone 10 feet thick which overlies 20 feet of ferruginous clay shale.

Loc. 32: In a gully west of the road this same sandstone is exposed with its accompanying shale.

Loc. 33: The railroad cut reveals 25 feet of shale and sandy shale, probably occurring 40 feet below the brown sandstone mentioned.

*Locs. 34-35:* The thin coal 8 feet below the surface at loc. 34 is probably identical with the lower one of two which occur 35 feet apart on the Henson farm at loc. 35 and with the first coal in the boring at loc. 30.

*Locs. 36-37.*—Beds which are probably well above the Carthage limestone, but of which the horizons are uncertain, occur in the hill west of Norris City and at Gossett. At loc. 36 sandstone and shale partially exposed for 80 feet resemble those beds east of Norris City. At loc. 37 a 10-foot sandstone overlies fire clay which half a mile farther north occurs over a thin coal. A uniform dip from borings south of Texas City to Norris City would bring coal No. 5 about 675 feet below the railroad at Gossett.

*Loc. 38.*—West of Broughton, on the land of J. T. Barker, a thin coal which outcrops at an altitude of 430 feet is overlain by fire clay and a band of limestone. A 3-foot limestone which lies 32 feet below the coal in a shaft at this point contains typical Carthage fossils and suggests that coal No. 7 should occur 275 feet below it and No. 5 120 feet lower. Since the evidence is not conclusive, coal No. 5 may lie much lower yet.

*Locs. 39-43.*—Thin coals are struck in a number of wells near Broughton at an altitude about the same as the coal at loc. 38, but it is impossible to identify them or to calculate the depths to workable coals at these points. The occurrences are on the farms of Messrs. Roberts, William Stevens, Golson, C. H. Francis, and Griffin.

*Loc. 44.*—Southwest of Roland occurs a 3-foot limestone which on lithologic and fossil evidence is probably the Carthage. Coal No. 7 should be reached about 275 feet below it and No. 5 120 feet lower. As this is much less than the depth at Norris City and Omaha, this vicinity would seem to be a favorable place to prospect.

*Loc. 45.*—Exposures 50 feet higher than at loc. 44 show a sandstone which overlies sandy shale and which probably is identical with that occurring along the Little Wabash, 110 feet above the Carthage limestone. This would indicate a dip of 60 feet from loc. 44 to loc. 45.

*Locs. 46-47.*—Limestone is reported in wells to the south at an altitude about 35 feet lower than the Carthage at loc. 44.

*Loc. 48.*—The Omaha well struck at 403 feet a thick coal, which is overlain by 4 feet of limestone and probably is coal No. 7. Another limestone, doubtfully reported 223 feet above it, is possibly the Carthage limestone.

*Locs. 49-50.*—The Carthage limestone and the upper limestone are probably exposed south and east of Elba, and offer a basis for calculating the altitude of workable coals. At loc. 49 a section of 45 feet is exposed with a 4-foot limestone, probably Carthage, at the base, altitude 343 feet; a 3-foot sandstone at the top; and brown shale between. The beds dip upstream about 1 foot in 40. At loc. 50 a 17-foot section of shale and sandstone shows, 4 feet above the base, a thin bed of limestone and iron ore, at an altitude of 348 feet, but probably lying 50 feet above the Carthage. The dip is to the east, 1 foot in 50.

*Locs. 51-69.*—The following observations were made between Elba and Equality:

*Summary of observations at locs. 51-69.*

Loc. No.	Name.	Kind of rock.	Thick-	Depth.	Altitude.		Geologic horizon.
			ness.				
			<i>Ft. in.</i>	<i>Feet.</i>	<i>Feet.</i>		
51	— McCormick.....	Limestone.....		52	340	Carthage (?)	
52	H. G. Morton.....	Shale, coal.....	+	23	375		
53	John Burton.....	Coal.....	4	60	340		
54	— Johnson.....	Coal.....	+	31	380		
55	.....	Coal.....	+	21	330		
56	W. A. Wathen.....	Limestone.....	+	25	365		125 or 50 feet over No. 7.
57	F. M. McLean.....	Limestone.....		36	350		
58	Broughton Temple.....	Coal.....	+	80	280	No. 7.	
59	John Nave.....	Coal.....	+	90	315	No. 7.	
60	— Percil.....	Coal.....	+	90	315	No. 7.	
63	.....	Shale.....	15	0	355	Over No. 6.	
64	Frank Hamel.....	Black shale.....	+	130	250	Over No. 5.	
65	John Davenport.....	Black shale.....	+	130	250	Over No. 5.	
66	— Beatty.....	Coal.....	+	47	335	No. 6.	
68	— Siebman.....	Coal.....	18	65	335	(?)	
69	John Hish.....	Coal.....	2	0	350		
		Limestone, coal.....	4	93	257	No. 7.	

*Loc. 70.*—In the 250-foot well of Louis Drone five coals, 18 inches to 10 feet thick, are reported. The thickest bed, probably No. 7, was reached 188 feet down, or at an altitude of 115 feet.

*Loc. 71.*—Joseph Devous's test hole strikes a coal with limestone roof, probably No. 7, at 380 feet and another, probably No. 5, at 484 feet.

*Locs. 72-73.*—Test borings of Vandell Mining Company.

*Loc. 79.*—The following outcrop occurs above the railroad at Equality:

*Section at Equality.*

	Feet.
Sandstone, coarse, gray, micaceous.....	10
Shale, light gray.....	18
Coal, No. 6.....	2
Fire clay.....	1
Sandstone and shaly sandstone.....	4½
Railroad level.	

*Loc. 81.*—The altitude of an outcrop of the roof limestone of No. 7 coal at Equality, compared with data given on the mine map of the Gallatin Coal Company, shows an interval of 117 feet between coals Nos. 7 and 5.

*Loc. 82.*—A 156-foot well on the Charles Manel farm probably passes the horizon of coal No. 7, filled with surface clay, and stops just short of coal No. 5.

*Loc. 83.*—The Pearce well reaches an 18-inch coal, possibly No. 6, at a depth of 77 feet, or an altitude of 283 feet.

*Loc. 84.*—Coal test boring of Davenport Coal Company.

*Locs. 85-87.*—Test borings of O'Gara Coal Company.

*Locs. 88-89.*—West of Cottage Grove a 2-foot limestone, probably 50 feet over coal No. 7, is reached in a well and also outcrops under a 5-foot sandstone and over fire clay.

*Loc. 91.*—A well reaches coal No. 7 at 365 feet altitude.

*Loc. 92.*—A. D. Robinson's well reaches a 6-foot coal bed at 124 feet, or at 270 feet altitude. It underlies a limestone and is probably coal No. 7.

*Loc. 95.*—Test boring of National Mining Company.

*Locs. 97-102.*—Wells east and south of Eldorado strike limestones at about the Carthage horizon, and these, together with certain coals, seem to indicate a northeasterly dip. A summary follows:

*Summary of observations at locs. 97-101.*

Loc. No.	Name.	Kind of rock.	Depth. Altitude.	
			Feet.	Feet.
97	Tim Sisk.....	Coal.....	100	325
98		Limestone.....	52	348
99	C. A. Jones.....	Limestone.....	40	350
		Coal, thin.....	100	290
100	Philip Collins.....	Limestone.....	55	360
101	J. E. Westbrook.....	Limestone (?).....	27	380

*Locs. 103-107½.*—Test borings of O'Gara Coal Company.

*Loc. 108.*—Test boring of Wabash Petroleum Company, depth 1,093 feet, dry.

*Loc. 109.*—Gas well of W. T. Overton.

*Locs. 110-114.*—Coal test borings of Eldorado Mining Company, Terre Haute, Ind. Records not furnished for use of the Survey.

## COAL RESOURCES.

### INTRODUCTION.

This region produced 314,927 tons of coal in 1906, a gain of 115 per cent over 1905. Saline and Gallatin counties combined produced 1,069,425 tons in 1906, gaining 58 per cent over the preceding year.

As already described, and as indicated by the columnar sections in fig. 2 (p. 119), coals occur at twenty horizons, at least, but many of these are local in extent and worthless. Only two beds are now mined, Nos. 7 and 5, but inasmuch as three or more lower coals are workable in adjoining areas to the south and east and in other parts of Illinois, it seems likely that drilling may show similar conditions in parts of this region.

### EXTENT OF COAL DEPOSITS.

The areal extent of workable coals has been only partly determined, for the persistence of thick beds in the area untested by borings is uncertain; the presence and depth of preglacial valleys is concealed by overlying deposits of glacial drift and of alluvium; and, in addition, it is possible that structural movements may have exposed the coals to preglacial erosion to a degree not now suspected.

In the New Haven quadrangle coals Nos. 7 and 5 will very probably prove to be workable. Their horizons undoubtedly occur under the various hill tracts indicated on Pl. VIII (p. 120), and, in the absence of evidence to the contrary, presumably also under the intervening areas, which are covered by glacial and fluvial deposits. The only information serving to indicate their probable depth below the surface is offered by the outcrops of the supposed Carthage limestone and other related beds at the locations indicated on the map. Though the thickness of the beds here is doubtful, they are generally workable in western Kentucky. They are mined near the southeast corner of the quadrangle at Morganfield, and they are presumably minable also at Mount Vernon, Ind., near the northeast corner, at depths of 625 and 710 feet respectively.<sup>a</sup> In view of these facts and the general thick development of these coals under the Eldorado quadrangle, it seems likely that they are workable under most of this area also unless preglacial erosion lines are deep and extensive.

<sup>a</sup> Core record of Mount Vernon Coal and Mining Company.

Under the Eldorado quadrangle coal No. 7 is probably everywhere present except in a small area along the south margin, as indicated by its outcrop shown on Pl. VIII. It is absent in the southwest corner in borings at locs. 85-87, and has been eroded from the middle of the valley, separating the hills at Cottage Grove and Equality. From the latter place it is absent to a point a little east of locs. 75 and 76, where it reappears. The presence of the coal southward from Equality to the Gold Hill Range is doubtful, because of the probability of structural irregularities and preglacial erosion. Coal No. 5 has similar but somewhat greater extent than No. 7. It is known to extend beyond the margin of the Eldorado quadrangle in the southwest corner. East of Equality it is absent for a short distance between North Fork of Saline River and locs. 75 and 76, also for a short distance farther east. This statement presupposes that the changes in altitude of the rock between Equality and Junction are due, not to a fault, but to uniform dips.

#### DESCRIPTION OF COALS NOW MINED.

Of the coals now worked, to judge from chemical analyses and from the physical conditions of the beds and their overlying and underlying rocks, No. 5 is more valuable than No. 7, though the latter is nevertheless an excellent bed.

#### COAL NO. 5 (HARRISBURG COAL).

Coal No. 5, which is identical with No. 9 in Kentucky, is extensively mined at Harrisburg, Eldorado, Equality, and near-by points, as shown by the accompanying table of mines (p. 136). It lies about 100 feet below coal No. 7, and probably about 390 feet below the Carthage limestone. It is about 90 feet above coal No. 4, and 430 feet or more above the Caseyville conglomerate.

The uniform thickness and purity of the bed is characteristic. As observed or reported at 56 places in the area, it averages 4 feet 11 inches in thickness; at only two of these is it less than 4 feet, and at two it exceeds 6 feet. Based on the average thickness of this coal and a specific gravity of 1.3, as determined for one sample, each acre underlain by it contains about 8,700 tons. The coal is either lustrous or dull black, and here and there streaked with "mother coal" or "mineral charcoal." Only a few bands or patches of sulphur are present, and while these are most likely to occur near the top of the bed, they are merely local features. The coal ranges from rather hard and tough to soft and brittle, and has a hackly fracture.

The mining conditions of coal No. 5 are excellent. The roof is a hard shale which usually stays up well without excessive timbering. It is characterized by the presence of pyrite balls, or "niggerheads," and more rarely is associated with thin bands of limestone within 2 or 3

feet of the coal. In several mines the shale adheres closely to the coal, and some falls with it. Beneath the bed occurs a thin layer of fire clay. The coal is easily cut in all directions, there being no strong development of face or butt cleats. In a few mines this bed generates inflammable gas, but it is not dangerous under normal mining conditions.

Analyses of coal No. 5 and of one coke sample from this bed are given in the table on page 135. At Dekoven, Ky., this coal is coked extensively after washing. At Equality the Gallatin Coal and Coke Company converts its slack into coke, which is marketable, although somewhat higher in ash and sulphur than is desired. Experiments are now in progress looking to improvement of the quality. As Illinois produces no coke except from this bed, so far as shown by published reports, thorough experiments with it are very desirable.

#### COAL NO. 7 (EQUALITY COAL).

Coal No. 7 is mined for shipment at Norris City, and for home use at two small mines near Equality, where the bed outcrops. It is identical with coal No. 11 of Kentucky. The position of the bed is approximately 50 feet below coal No. 8, 55 feet above coal No. 6, and 90 to 128 feet above coal No. 5. It is thought to lie about 275 feet below the Carthage limestone and 550 feet or more above the Caseyville conglomerate.

The average thickness of the bed, as reliably indicated at 61 places in the area, is 4 feet 4 inches. In seven of these localities it is less than 4 feet thick, and in four others is practically absent. Present data indicate that the areas of thin coal are only local, and that there is no definite tendency to thin out in any particular direction. Thus the coal may be well developed within three-fourths of a mile from points where borings show it to be less than 4 feet thick. At Norris City, where the greatest measurements were obtained, the bed ranges from 5 feet 9 inches to 6 feet 6 inches. The coal is lustrous black, and where seen is tender and brittle. The high quality of the coal itself is impaired by a persistent band of clay shale, which ranges from half an inch to 3 inches, and averages about 2 inches in thickness. This occurs from 12 to 24 inches above the fire clay, but usually about 18 inches. From 6 to 10 inches below the top of the coal there is also a rather persistent sulphur streak, which is usually less than one-half inch thick, but may measure 1 inch. A few other patches or streaks of sulphur occur locally through the bed. Analyses of coal No. 7 appear in the accompanying table (p. 135).

The mining conditions of this bed, though not known from extensive operations, are apparently good. A layer of black shale, varying in thickness up to 17 inches, and locally banded, separates the top of the coal from a limestone that is from 4 to 7 feet thick. However, sandstone is said to overlie and partly cut out the coal at places in the

mine at loc. 67. Care is necessary to prevent the shale from falling with the coal. The bed is underlain by 1 to 5 feet of fire clay. Here and there small rolls or horsebacks are present, and the character of the roof and floor is such that squeeze or creep is liable to occur unless care is exercised in mining.

#### CHEMICAL ANALYSES OF THE COALS.

The accompanying analyses indicate that the coals of this area rank with the very best of the State. The several results, however, are not equally suited for close comparison with other analyses, since some represent samples which were taken and analyzed under unknown conditions, and even though they may have been, when fresh, truly representative of the several mines, they are not known to have been similarly handled, either to preserve the normal moisture content or to expel part or all of it. Higher efficiency, of course, is shown by dried samples, other things being equal, than by those which contain moisture. Varying amounts of time elapsed between taking and analyzing the several samples, and it has been shown by chemists at the State Geological Survey that those which stand long before analysis lose volatile matter when opened, and that the resulting efficiency determinations are really lower than they should be. The analyses here presented were obtained under the conditions described below.

Analyses 1, 14, 17, and 18 were made by W. F. Wheeler, of the Illinois Geological Survey, from samples collected by the writer in the following manner: A clean exposure, representative of the average condition of the bed, was grooved from top to bottom and the sample collected on clean oilcloth. No impurities were thrown out except those usually excluded from commercial shipments. The sample was further prepared in the mine or at the surface by crushing, mixing, quartering, and sealing in an air-tight can as quickly as possible in order to preserve the normal moisture of the coal. Analyses were made after four to five months without air drying the samples.

Analysis 1 represents a sample from the end of the first west entry off the main south entry, about 1,000 feet from the shaft, where the coal measures 4 feet 6 inches. The sample was prepared in the mine without excluding impurities and was immediately sealed on reaching the surface. It is probable that some extraneous water reached the sample while ascending the shaft.

Analysis 14 represents the bed at the end of the first main north entry, 400 feet from the shaft, where it has a thickness of 5 feet 4 inches. A little of the sulphur showing at this place was excluded from the sample. The coal was prepared and sealed promptly above ground.

Analysis 17 represents the coal at the end of the first entry off the main entry, where it measures 4 feet 7 inches, and shows no impurities which are excluded from shipment. This sample was prepared and sealed within five minutes after leaving the mine.

Analysis 18 represents coal taken at the country mine of Mr. Dobbin, where the following section was measured:

*Section in Dobbin's mine.*

	Ft.	in.
Limestone.....	4	
Shale.....	1	
1. Coal.....		6
2. Sulphur and shale.....		$\frac{1}{2}$
3. Coal.....	2	7
4. Shale.....		$2\frac{1}{2}$
5. Coal.....		10
Fire clay.....	4+	
Total coal bed.....	4	2

Impurities from layers 2 and 4 are picked from the coal before marketing and are excluded from the sample.

Analyses 8, 13, and 16 were made without air drying by W. F. Wheeler, of the State Geological Survey, from samples collected by F. F. Grout in the manner already described. When analyzed, these samples had stood sealed for eleven months.

Analysis 8 represents a sample taken in the second room off the second west entry, where the coal measures 56 inches thick and shows no persistent bands.

Analysis 13 represents the coal in the first room off the second east entry on the north, where the following section was measured:

*Section in O'Gara mine No. 12.*

	Inches.
Shale, pebbly (many feet).....	
Draw slate, second.....	5
Draw slate, first.....	7
1. Coal.....	27
2. Sulphur.....	$\frac{1}{8}$ - 1
3. Coal.....	32
Fire clay.....	
Total coal bed.....	60

The sample includes layers 1 and 3. No. 1 has two partings of sulphur 3 inches and 8 inches from the top which are not persistent, but are common in the mine.

Analysis 16 was made from a sample obtained near the shaft, which includes Nos. 1, 3, and 5 of the following measured section:

*Section in mine of Norris City Coal Company.*

	Ft.	in.
Limestone.....	4	6
Shale.....		2-16
1. Coal.....		7
2. Sulphur.....		$\frac{1}{2}$
3. Coal.....		31
4. Blue band.....		up to 3
5. Coal.....		18
Fire clay.		

Analyses 2 to 7, inclusive, by Prof. S. W. Parr, of the State University of Illinois, were recently published in Bulletin No. 3 of the State Geological Survey. The samples were collected in canvas bags at the mines from the surface of car lots prepared for shipment, and were sealed in air-tight jars in the laboratory. Since the moisture of the samples after shipment differed presumably by varying amounts from that shown under normal conditions in the mines, analyses were preceded by air drying.

Of analyses 9, 10, 11, and 12, kindly furnished by Superintendent Thomas, of the O'Gara Coal Company, No. 9 was made by Professor Parr and the others by various private chemists. The exact method of sampling and treatment before analysis is not stated.

Analysis 15, made by the General Chemical Company, of Chicago, was obtained through the courtesy of Supt. J. B. Kitch, of the National Mining Company. The percentage noted in the sulphur column includes "sulphur and waste."

Analyses 19 and 20, made by Regis Chauvenet & Bro., of St. Louis, for the Gallatin Coal and Coke Company, were kindly furnished by President Hugh Murray.

Analyses of coal and coke from Saline-Gallatin field, Illinois.

	No. on Pl. VII or VIII.	Mine.	No. of bed.	Size.	How obtained.	Condition.	Moisture.	Ash.	Volatile matter.	Fixed carbon.	Sulphur.	British thermal units.
1	116	O'Gara Coal Co. No. 10 (Eldorado Coal and Coke Co.).	5		Face cut	As mined	8.43	8.85			1.98	12,026
2	116	do.	5	Lump	Car.	Air dry	5.68	8.90	33.32	52.10	1.18	12,668
3	116	do.	5	Slack	do.	do.	4.36	23.58	29.36	42.70	2.00	10,400
4	116	do.	5	do.	do.	do.	5.04	10.88	34.36	49.72	2.00	12,179
5	116	do.	5	do.	do.	do.	4.00	20.88	30.78	44.34	3.70	10,924
6	119	O'Gara Coal Co. No. 1 (Diamond Coal Co.).	5	Lump	do.	do.	4.10	6.76	37.17	51.97	1.55	12,940
7	119	do.	5	Slack	do.	do.	4.72	14.28	32.72	48.28	2.70	11,351
8	115	O'Gara Coal Co. No. 8	5		Face cut	As mined	6.93	8.12			1.69	12,298
9	115	do.	5		Not known	Not known	2.31	7.67	34.75	55.27	.53	12,678
10	115	do.	5		do.	do.	4.84	6.26	29.59	57.80	1.51	
11	115	do.	5		do.	do.	4.64	6.32	31.24	57.80	1.50	
12	115	do.	5		Face cut	do.	2.37	11.28	30.07	56.28	2.16	12,840
13	120	O'Gara Coal Co. No. 12 (Harrisburg and Big Muddy Coal Co.).	5		do.	As mined	5.38	8.47			2.40	12,475
14	96	National Mining Co.	5		do.	do.	4.69	11.74			4.03	12,211
15	96	do.	5		Not known	Not known		7.18	38.16	54.66	3.03	13,000
16	28	Norris City Coal Co.	7		Face cut	As mined	7.97	10.73			2.68	11,512
17	77	East Side Coal Co.	5		do.	do.	4.30	10.74			4.36	12,452
18	93	Dobbins bank.	7		do.	do.	5.73	11.19			3.13	12,177
19	80	Gallatin Coal and Coke Co.	5		Not known	Not known	1.91	9.75	34.99	53.35	2.14	
20	80	do.	5	Coke	do.	do.	0.00	15.61	1.43	82.96	2.28	

## DESCRIPTION OF COAL MINES.

The appended table presents a list of the coal mines of this area. Inasmuch as the district includes old and new mines, both primitive and modern methods of mining are employed. This paper does not review in detail the technology of these mining methods, but merely outlines prevalent or important conditions.

In the mines visited,<sup>a</sup> which are laid out according to various adaptations of the room-and-pillar plan, pick mining prevails, and the coal is shot down, then hauled in wooden cars of 1 to 2 tons capacity, by mules. Usually the shafts are divided into two parts, 9 by 14 feet each, and are provided with single-decked cages of metal construction, with safety clutches. The most popular hoisting engine is one that acts directly on a 6-foot drum. The coal dumps automatically into scales and into shaker or revolving screens. Box-car loaders are employed to a small extent. The mines require little pumping, and some need sprinkling in certain seasons. Ventilation is usually effected by Capell propelling fans about 12 feet in diameter. Speaking tubes between engine room and shaft bottom are installed in a few mines, and electric lights are also used underground by the National Mining Company.

Screened coal chiefly is shipped, and although no figures were collected to show the sizes made it is estimated that in some cases as much as 30 per cent is slack. This condition is almost certain to be remedied by the introduction of machine mining. As already stated, at Equality the slack of coal No. 5, after washing, makes a marketable coke, and the further development and perfection of this process is thought to promise much for this field.

*Partial list of coal mines in Saline-Gallatin field, Illinois.*

Name of mine or owner.	No. on Pl. VII or VIII.	Location.	Character of opening.	No. of bed.	Average thickness.	Depth to base of coal.	Remarks.
					<i>ft. in.</i>	<i>feet.</i>	
Slaten.....	90	Cottage Grove.....	Slope...	7	4 0	.....	Abandoned.
Dobbin.....	93	Northwest of Equality.	Shaft.....	7	4 2	57	Local.
East Side Coal Co.	77	Equality.....	do.....	5	4 7	40	
Gallatin Coal and Coke Co.	80	do.....	do.....	5	4 10	80	
Gold Nugget.....	78	do.....	do.....	5	4 7	40	
Gordon.....	67	Northeast of Equality.	Slope.....	7	4 2	41	Local, suspended.
Hargrave.....	75	East of Equality.....	Drift.....	5	4 3	.....	
McLain.....	61	North of Equality.....	do.....	7	4 2	.....	Local.
National Mining Co.	96	Southeast of Eldorado.	Shaft.....	5	5 4	336	
Norris City Coal Co.	28	Norris City.....	do.....	7	5 4	640	
O'Gara Coal Co., No. 1....	119	4 miles southwest of Eldorado.	do.....	5	.....	302	
O'Gara Coal Co., No. 8....	115	Eldorado.....	do.....	5	4 6	407	
O'Gara Coal Co., No. 10....	116	do.....	do.....	5	4 6	411	
O'Gara Coal Co., No. 11....	117	do.....	do.....	5	4 6	404	
O'Gara Coal Co., No. 12....	120	5 miles southwest of Eldorado.	do.....	5	.....	421	
Percil.....	62	North of Equality.....	Drift.....	7	4 2	.....	Abandoned.
Sanks.....	76	East of Equality.....	Slope.....	5	4 4	27	Local.
Swinney.....	94	Northwest of Equality.	Shaft.....	7	4 2	30	Suspended.
Vandell Mining Co.....	74	Junction.....	do.....	7?	.....	.....	Sinking shaft.
Wasson Coal Co.....	118	2½ miles southwest of Eldorado.	do.....	5	.....	328	Do.

<sup>a</sup> The mines at locs. 80, 119, and 120, which lie beyond the borders of the quadrangles proper, were not examined personally in this preliminary work.

# THE ARKANSAS COAL FIELD.

By ARTHUR J. COLLIER.

## INTRODUCTION.

Both the Carboniferous and Tertiary rocks of Arkansas contain extensive deposits of coal, but only those of the older system have been exploited and are known to the trade. They grade from bituminous to semianthracite, and recent experiments at the United States Geological Survey fuel-testing plant have demonstrated that they are of a quality not to be found elsewhere in the United States west of West Virginia.<sup>a</sup> Mining operations within the field have demonstrated that its structure is more complex and the areas of workable coal more limited than the results of previous surveys would indicate.<sup>b</sup> For these reasons a detailed reconnaissance of the field was made from March 1 to August 1, 1906, the results of which are embodied in Bulletin No. 326 of the United States Geological Survey, soon to be issued, from which the following paper is abstracted.

## GEOGRAPHY.

The coal field herein described is situated in the western part of Arkansas, adjoining the Indian Territory line, from which it extends eastward along the Arkansas River valley for 75 miles. (See Pl. IX.) It is about 50 miles wide at its west end, but the belt containing workable coal contracts abruptly 12 miles from the boundary, and beyond this point the average width is not more than 20 miles. The workable coal areas are more or less irregularly distributed over this district, and many of them are in detached basins not known to be connected with one another. The productive areas of the east end of the field are north of Arkansas River; those of the west end are south of it.

<sup>a</sup> Campbell, M. R., Classification of coals, in Report on the operations of the coal-testing plant: Prof. Paper U. S. Geol. Survey No. 48, 1906, pp. 156-173.

<sup>b</sup> The Geological Survey of Arkansas, under the direction of Dr. J. C. Branner, made a comprehensive investigation of this coal field and in 1888 published a preliminary report entitled "Geology of the coal regions," by Arthur Winslow. (See Ann. Rept. Geol. Survey Arkansas, 1888, vol. 3.) Mr. Winslow's final report has, unfortunately, never been published. The topographic maps made to accompany this report were prepared jointly by the State and Federal surveys, and they have been used in the present investigation.

Fort Smith, the center of the coal-mining industry, is the principal town in western Arkansas and has a population of about 20,000.<sup>a</sup> It is approximately 250 miles from Kansas City, 350 miles from St. Louis, and 400 miles from the Gulf of Mexico, with which points it is connected by railroads. Branch lines and independent railroads of less importance radiate from Fort Smith and afford transportation to the various local mining centers.

### GENERAL GEOLOGY.

The Arkansas field comprises the east end of a large area of coal land which has its greatest extent in Indian Territory, where the stratigraphic relations have already been studied in detail and mapped by the geologists of this Survey. A part of the northern edge of the coal field in Arkansas has also been mapped and the results of these investigations published or submitted for publication.<sup>b</sup> The formations comprising the stratigraphic column in Arkansas are directly comparable to those of Indian Territory and there is also a marked similarity in the general type of geologic structure in the two districts. The various rock formations as defined and named in Indian Territory are therefore practically identical with those which are present in the Arkansas coal field.

### STRUCTURE.

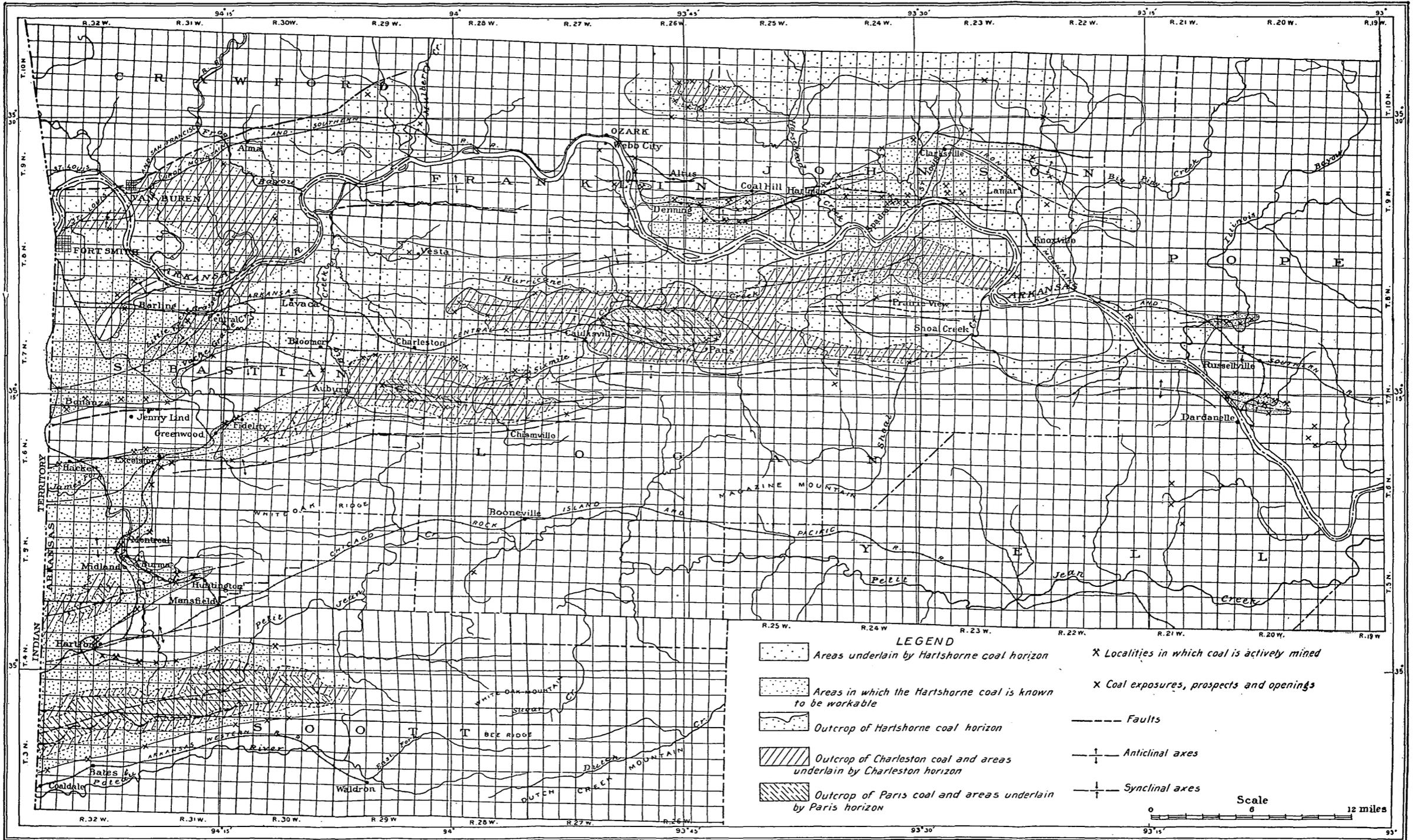
#### GENERAL CONDITIONS.

The coal field lies in a long, comparatively narrow synclinal trough extending eastward along the Arkansas River valley from the Indian Territory line. North and south of the field the coal-bearing strata have been eroded, leaving only barren rocks exposed. This trough lies between the Boston Mountains on the north and the Ouachita Mountains on the south. These ranges, as will be shown, are very diverse in their geologic structure.

The various strata comprising the Ouachita Mountain mass have been compressed in a north-south direction, being thrown into folds whose axes extend approximately east and west. Subsequent to this crumpling the upper parts of the folds have been eroded, leaving the edges of the harder beds projecting in ridges as we now find them. In the process of folding the strata were often broken and in many localities the beds slipped out of place, so that their outcrops are not

<sup>a</sup> The population of Fort Smith in 1900, as determined by the Eleventh Census, was 11,587.

<sup>b</sup> Taff, J. A., and Adams, G. I., *Geology of the eastern Choctaw coal field*: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 259-311. Taff, J. A., *Geologic Atlas U. S., Coalgate folio* (No. 74), 1901; *Atoka folio* (No. 79), 1902; *Tahlequah folio* (No. 122), 1905; *Sallisaw and Windingstair folios*, in preparation; *The southwestern coal field*: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, pp. 361-413; *Maps of segregated coal lands in Indiana Territory*: U. S. Dept. Interior Circulars Nos. 1, 2, 3, 4, 5, 6, 1904. Purdue, A. H., *Geologic Atlas U. S., Winslow folio*, in preparation.



MAP OF ARKANSAS COAL FIELD.

now continuous for very great distances. In general these fractures are of the type called thrust faults, and the rocks on the south side have ridden over those on the north. The faults extend approximately east and west, parallel with the trend of the ridges.

The rocks of the Boston Mountain province are not folded like those of the Ouachita province, but, on the other hand, are in most places only slightly distorted from their original positions, and are characterized by low dips. This part of the earth's crust appears to have been raised up into a broad, flat dome. Where such a movement has occurred the beds at the two levels must either bend or break, and both kinds of adjustment are to be seen along the southern margin of this mountain province. The flexures are of the type described as monoclines or monoclinial folds, and the fractures or faults are of the normal type, differing from those in the Ouachita Mountains in that they occur in beds not crumpled by lateral pressure and otherwise little disturbed from their original positions. Normal faults of this type are characteristic of the geologic structure of the Boston Mountains, and a series of them extends approximately east and west along the north side of the Arkansas Valley, separating the Boston Mountain province from the coal field. It will be seen from this description that the Arkansas Valley syncline, which contains the coal field, is peculiar in that on the south side the underlying rocks rise up by pronounced folds and thrust faults, whereas on the north side they are brought to the surface by a simple monoclinial uplift, accompanied at many places by normal faulting. The structure within the coal field partakes of the nature of both these types.

#### ANTICLINES.

Although the field in general may be described as a synclinal trough, in its detail it is folded into a number of minor interlocking synclines and anticlines, which have east-west axes only a few miles in length. The position and extent of these axes are shown on the map (Pl. IX).

One of the best-known anticlines in the whole district is that in Backbone Ridge, between Bonanza and Hackett, which extends from the State line eastward for 7 or 8 miles. The coal-bearing beds which outcrop on both sides of this ridge are steeply tilted and in its axis rocks lying far below the coal horizon are exposed. This anticline is an unsymmetrical fold of the Ouachita Mountain type and represents a thrusting of the rocks from the south over those on the north side of the axis. The strata are broken, and a well-marked thrust fault has been traced along the axis for several miles.

A somewhat similar fold with overthrust of the rocks from the south is indicated by Devils Backbone and Pine ridges, which mark

the southern boundary of the coal field in the region east of Greenwood.

The Prairie View anticliné, in the eastern part of the field, is another important fold, as it brings up the rocks below the coal horizon and forms a barren area. This fold is probably also of the Ouachita type, inasmuch as there is a fault with downthrow to the north along its northern limb.

Most of the other anticlines indicated on the map are more moderate flexures not accompanied by faults, although those of the southern part of the field are usually unsymmetrical, the steeper dips being on the north.

The Massard Prairie anticline, a broad open fold southeast of Fort Smith, and the Hartford or Coops Prairie anticline, south of Mansfield, have been successfully exploited for natural gas.

#### SYNCLINES.

The synclines are as a rule broad, open folds which carry the principal coal horizon only to moderate depths. Generally those of the southern part of the field are unsymmetrical, the dips on the south side being steeper than those on the north. Their axes are marked in many places by high hills or buttes formed by the erosion of flat-lying beds. Poteau, Sugarloaf, Short, and Magazine mountains are of this character, and below them the principal coal horizon attains its maximum depth from the surface in the Arkansas field. Many of the shallower synclines contain extensive areas of coal that are workable under present conditions. These are further described in connection with the coal beds (pp. 142-157).

#### FAULTS.

The faults indicated on the map (Pl. IX) include both normal and thrust types. Eleven faults of large proportions and a number of smaller unimportant ones are known within the coal field, and it is probable that there are others which were not recognized in this somewhat rapid reconnaissance. Most of these are mapped here for the first time and were not discovered by previous surveys. The recognition of features of this kind in a region like the Arkansas coal field, where all the rocks are so similar to each other, is very difficult, and it has been practically impossible to locate them at all points with the accuracy desired. Their positions as shown on the map must therefore be regarded as only approximate.

The best-known fault in the district is that along the axis of Backbone Ridge. This displacement was recognized by the geologists of the Arkansas Survey and is represented on the geologic map published in the preliminary report on the coal field. Its west end in

Indian Territory has also been located. It extends from the boundary eastward for about 8 miles to a point a mile northwest of Greenwood. Measurements made during the last field season indicate that the displacement is nearly 5,000 feet at the State line. This fault is of the thrust type. It occurs in barren rocks and does not affect the economic value of the field. Faults of similar character probably also occur in some places along the southern boundary of the coal field in what is known as Devils Backbone Ridge at Chismville and Pine Ridge farther east.

The Prairie View fault, which extends from sec. 25, T. 8 N., R. 25 W., eastward for about 7 miles to Arkansas River, is probably also of the thrust type, since it is associated with a rather pronounced fold and the downthrow is to the north. The displacement is not less than 500 feet. This fault defines the southern limit of what is called the Prairie View coal field.

The faults which occur along the northern edge of the coal field are of the normal type, with the downthrow usually to the south. They are much more difficult to discover than those described, since the evidence for them is obscure, and they are very troublesome to the geologist who attempts to interpret the structure of the coal field. At their extremities the displacement gradually grows less and disappears so that the beds can be traced continuously around the ends. By many of the faults, however, sandstone beds are brought against other sandstones and shales against shales, so that it is only by the most careful study that the displacement can be recognized or its nature determined. The displacement by these faults is comparatively small, the maximum amount known being only 500 feet.

#### STRATIGRAPHY.

All the rocks of the coal field belong to the upper Carboniferous, or Pennsylvanian series. They present a rather monotonous sequence of sandstones and shales, with little contrast between individual beds. Except the coal beds themselves there are no members that can be identified with certainty by lithologic characters. Limestones, which in many other fields aid the geologist by serving as horizon markers, are here almost totally wanting. Fossil plants and invertebrate animals are fairly abundant at certain horizons, but there was very little change in plant and animal life during the period when these rocks were deposited, and such fossils are therefore of little use in stratigraphic correlations. There is also much variation locally in the rocks, especially in the sandstone lenses, and correlations from one part of the field to another based on lithologic similarity are of little value.

The coal-bearing rocks in Indian Territory comprise several thousand feet of sandstones and shales, which have been divided as follows:

<i>Coal-bearing formations of Indian Territory.</i>		Feet.
Boggy shale.....		2,000
Savanna sandstone.....		1,000
McAlester shale.....		2,000
Hartshorne sandstone.....		200

The coal-bearing rocks of Arkansas are less than 2,000 feet thick and are equivalent to the McAlester shale of Indian Territory. The Hartshorne sandstone at the base of the section is a thin but very persistent formation, which has been traced for 150 miles along the southern edge of the Indian Territory field, but has not heretofore been identified at its northern edge. In Arkansas this sandstone member has been traced eastward from the State line for 75 miles to the eastern extremity of the coal field and has also been identified along the northern edge of the field. Although it is thin and somewhat variable, it is rather more distinctive than most of the members of this series and may be regarded as the most definitely marked formation to be found in the region. The coal-bearing rocks of Arkansas are as follows:

<i>Coal-bearing formations of Arkansas.</i>		Feet.
McAlester group:		
Paris shale—sandy shale containing some thin beds of sandstone and including the Paris coal bed.....		700
Fort Smith formation—shaly sandstone and sandy shale, including the Charleston, Central, and Philpott coals.....		400
Spadra shale <sup>a</sup> —shale including some lenses of sandstone and sandy shale, and overlying the Hartshorne coal.....		500
Hartshorne sandstone.....		100-300

### COAL BEDS.

Coal beds large enough to be worked occur in the coal-bearing rocks in three stratigraphic positions, which will be described as the Hartshorne, Charleston, and Paris horizons. The most important coal beds occur at the base of the Spadra shale, immediately above the Hartshorne sandstone, in a stratigraphic position which is conveniently described as the Hartshorne horizon. The second coal-bearing horizon, which is of minor importance, is stratigraphically from 800 to 900 feet above the Hartshorne coal and will be called the Charleston horizon, since the coal is best known in the vicinity of that town. A third horizon is that of the coal bed mined at Paris, which probably corresponds approximately to the McAlester coal of Indian Territory.

<sup>a</sup> The name Spadra stage applied to this formation was published in 1896, by John J. Stevenson, who credited it to geologists of the Arkansas Survey. See Trans. New York Acad. Sci., vol. 15, 1896, p. 51.

This coal is from 1,200 to 1,400 feet above the Hartshorne horizon. Nearly all the various coals that have been mined in Arkansas can be correlated with one or another of these horizons, though some small lenses of coal, which have been mined for neighborhood use, occur locally at many places in rocks that lie below the Hartshorne sandstone, and it is quite possible that future development will establish the fact that there are small areas of valuable coal at other horizons than those noted.

#### COALS OF THE HARTSHORNE HORIZON.

The coal beds that occur at or near the horizon of the Hartshorne coal are economically the most important both in Indian Territory and in Arkansas. This horizon is at the contact of the Hartshorne sandstone with the shale which overlies it, and in general the coal is taken as the line of demarcation between these formations. There is, however, usually from a few inches to 20 or 30 feet of shale or fire clay between the coal bed and the hard sandstone, a condition due to local variations either in the character of the upper part of the sandstone member or in the exact position of the coal itself. The shale in its lower part is apt to be sandy, and in some places contains lenses of hard sandstone which lie immediately above the coal bed and make it difficult to determine the contact of the Hartshorne and Spadra formations. The coal bed is subject to great local variation in thickness and character. Partings come and go without reference to any known rule, and in some places the coal is wanting. These local conditions and variations are best described under the headings of the various districts in which it is mined.

#### BONANZA AND JENNY LIND DISTRICT.

The Bonanza and Jenny Lind district lies north of Backbone Ridge in Sebastian County and includes several important mines which are located along the southern outcrop of the coal bed near the towns which give the district its name. The position of the outcrop is indicated by the Hartshorne sandstone, which is easily traced along the north side of Backbone Ridge and Biswell Hill to Oak Valley, where it turns southward and connects with the sandstone that underlies the coal at Greenwood and Hackett. From its southern outcrop at Jenny Lind the coal dips to the north at a low angle for about 4 miles, reaching a depth of 600 to 900 feet below the surface. It then rises with a still more gentle slope and outcrops at several points on Massard Prairie, beyond which it dips northward again and passes under Fort Smith. In this district the areas in which the coal is near the surface are indicated by the extent of Long and Massard prairies.

In the basin north of Jenny Lind the greatest depth to coal probably does not exceed 850 feet, while in a large part of the district it is within

500 feet of the surface. At Central, a small town 6 miles northeast of Jenny Lind, coal has been mined from a smaller bed estimated to be about 850 feet above the Hartshorne coal; this bed is described in connection with the Charleston horizon (p. 154). The nature of the Hartshorne coal bed is best known in this district along the outcrop between Bonanza and Jenny Lind, where it has been mined for  $2\frac{1}{2}$  miles northward from the outcrop. It is thick enough for mining along this outcrop line for 10 miles, nearly all the way from Bonanza to Oak Valley, beyond which point it is reported to be too thin for mining. In general the bed consists of two benches of coal with a variable shale parting near the center. It is thickest in a mine near Jenny Lind, where it measures over 6 feet in some places, but thins gradually east and west from this point, being less than 4 feet thick at the State line, 5 miles to the west, and not more than 3 feet thick at an exposure 4 miles northeast of Jenny Lind.

The coal in all these mines has a luster which is somewhat brighter in the upper bench than in the lower. It is not very definitely jointed and the cleat is not considered in mining. In some places a definite system of joints which do not affect the coal is apparent in the harder parts of the roof. The roof and floor generally consist of hard, more or less sandy shale; usually the floor is a little harder than the roof. Neither roof nor floor has any features that are unfavorable to mining, though in one of the mines (No. 18, near Jenny Lind) parts of the roof are apt to fall on account of the jointing.

The only knowledge which we have of the coal for a distance of several miles beyond the northern limit of present mining development is that obtained by drilling. Over a comparatively large area believed to be coal land drill holes have been put down to the coal at intervals rather too great to fully demonstrate the value of the land. About 6 miles north of the Jenny Lind outcrop, however, on Massard Prairie, this coal bed shows again, its outcrops surrounding a barren area in the center of the prairie. Coal has been mined here from strip pits almost continuously for a distance of 3 miles. The bed ranges in thickness from 14 to 30 inches and is divided by a thin parting of shale a little below the middle. In general, the coal of the upper bench is softer and of better quality than that of the lower.

#### GREENWOOD AND HUNTINGTON DISTRICT.

The Hartshorne coal bed is continuous over an extensive region south of Backbone Ridge, in Sebastian County, where a large number of more or less important mines are located along its outcrop. Although the same bed is believed to extend over this whole region, the character of the coal and peculiarities of the bed vary so much locally as to make a number of minor divisions necessary in describing

it. In general, the whole region could be divided by a line running south-southwestward from Greenwood into a western part in which the coal bed is without partings and free from excessive ash, and an eastern part in which the coal bed is thicker but divided and relatively impure.

From Hackett, near the Indian Territory line, the coal outcrop south of Backbone Ridge has been traced eastward to a point several miles beyond Greenwood, where it turns to the north and connects with the outcrop of the Bonanza and Jenny Lind coal bed. From this line of outcrop the bed dips southward into the Greenwood syncline, south of which it rises and outcrops along the flank of Devils Backbone Ridge. This ridge, which extends far to the east in a nearly straight line and marks the southern boundary of the coal field, turns abruptly to the south a few miles southwest of Greenwood and carries the coal outcrop to the heart of a minor anticline between Midland and Montreal, in sec. 13, T. 5 N., R. 32 W. The outcrop line then turns eastward, with the coal dipping to the south, and extends for several miles, to Huntington. This town is situated in a syncline around the end of which the outcrop turns westward, with the coal dipping to the north, and extends in a nearly straight line to Hartford, where it again turns to the east, swinging around the Hartford anticline. The outcrop east of Hartford was followed for only 10 miles, the investigation being then given up because the coal bed, although still of considerable size, was found to be so divided by partings as to make it of questionable value.

From the above description it will be seen that the Greenwood and Huntington district covers a large and roughly rectangular area, including several townships of land on which the almost continuous line of outcrop indicates that the coal bed exists in sufficient size to make it of economic value. In a part of the district, notably that immediately east of the towns of Montreal and Midland, there is an upper coal bed from 40 to 60 feet above the Hartshorne coal, which probably corresponds with the upper Hartshorne coal reported from many points in Indian Territory. Where reported in Arkansas the upper Hartshorne coal is invariably an impure, dirty bed broken by many shale partings and is probably nowhere of economic value. The lower coal bed ranges in thickness from a minimum of 2 feet to a maximum of not less than 8 feet. Its floor is usually only a short distance above the harder beds of the Hartshorne sandstone, but its roof has been found to be variable. Although the roof generally consists of shale, a heavy lens of hard, in many places cross-bedded sandstone, having a maximum thickness of 60 feet, overlies the coal bed for several miles at Montreal and Burma. In the northwestern part of the district the bed is without partings and is from 2 to 3½ feet thick. In the southeastern part it increases in size locally to 6 or 7

feet and is divided by one or more partings of shale. As a general rule, chemical analyses show that the coal is of better quality in the western than in the eastern part of the district.

The coal bed has been opened in a number of mines, small slopes, and strip pits along the whole line of outcrop described and some of the workings have extended back for as much as  $1\frac{1}{2}$  miles. Beyond these workings, however, the only source of information as to the character of the coal consists of a few scattered drill holes. Although it can not be said that the whole district has been prospected sufficiently to prove that it is all underlain by valuable deposits of coal, yet the evidence at hand seems to indicate that there is little doubt that the greater part is valuable coal land. The coal lies at its maximum depth of 1,400 to 2,500 feet below the surface beneath Sugarloaf and Poteau mountains. On the lower lands surrounding the Sugarloaf Mountain it is not probable that the depth of the coal is more than 900 feet at any point, and the average depth to coal probably does not exceed 600 feet. The details in the following paragraphs are given in the order of the various mines and openings at which the coal has been examined along the lines of outcrop.

Along the outcrop line south of Backbone Ridge, from Hackett to Excelsior, the coal bed is without partings and is from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  feet thick. Analyses show that it is freer from ash and probably has a higher calorific value than any of the other coals sampled.

For several miles east of Excelsior the bed is thicker, but is divided and contains a higher percentage of ash. At Greenwood the bed measures 7 feet, with a shale parting which ranges from a fraction of an inch to 6 inches in thickness. Two miles farther east, at the Fidelity mine, the thickness is nearly 8 feet, but the bed contains much bony and shaly matter, and only about 4 feet of coal in one bench is available for mining. East of Fidelity the bed thins rapidly and is not mined.

On the outcrop line which follows Devils Backbone Ridge southeast of Greenwood, small exposures have been found at points several miles east of the town, but no coal has been produced nor have the beds been opened sufficiently to permit accurate measurements. The inclosing rocks are steeply tilted and in places slightly overturned and sheared so that the coal is probably more or less crushed. Small amounts of coal have been obtained from a strip pit in sec. 18, T. 6 N., R. 30 W., at a point where Vache Grasse Creek cuts across Devils Backbone Ridge; but the workings have all been abandoned and it was impossible to learn the thickness of the coal or the detail of its section.

Along the outcrop line running southwestward from Greenwood to Montreal and Midland the coal bed, so far as known, is without partings, and in quality resembles that at Hackett. In general, the

exposures show from 2 to 4 feet of coal. The dips range from  $1^{\circ}$  to  $15^{\circ}$ ; but it seems to be invariably true that where the dip is high at the outcrop it rapidly decreases and the coal bed flattens in depth. The bed changes in character east of Burma, becoming very much thicker and divided by several partings.

An upper bed corresponding to the upper Hartshorne coal of Indian Territory is indicated by drill records in the vicinity of Midland and Burma. This bed, which is 60 feet above the lower one, has a maximum thickness of approximately 5 feet, but is generally shaly or bony, and is described as a "dirty vein."

The coal bed in the Huntington basin is thicker than at Midland and Burma, but it is divided by shale partings, and chemical analyses show that it contains a rather high percentage of ash in the merchantable coal. This character of the bed prevails along the outcrop to the southwest nearly to Hartford, where the bed is not divided. East of Hartford, on the outcrop which lies south of the Hartford anticline, the bed is so divided by partings as to be of little value.

There are two large mines operated from shafts as well as several strip pits in the synclinal basin near Huntington. The coal bed, which is between 7 and 8 feet thick, is in three benches, separated by thin shale partings.

In sec. 32, T. 5 N., R. 31 W., the bed is 8 feet thick, with a parting of several inches of shale near the center, and is known as the "Mammoth vein." It is without partings, and measures  $3\frac{1}{2}$  feet at the town of Hartford, in sec. 10, T. 4 N., R. 32 W., where it is worked from a number of small slopes and two larger ones. Southeast of Hartford, in secs. 13 and 14, T. 4 N., R. 32 W., the bed again resembles that at Huntington and Greenwood in that it consists of several benches of coal with partings between. There are no active mines east of this point, but the coal has been prospected and it is common report that the bed is separated into many benches. At the Chasteen slope, in sec. 18, T. 4 N., R. 31 W., the bed is upward of 8 feet in total thickness, but it is very much divided and contains no bench of coal thicker than  $2\frac{1}{2}$  feet. No measurements were made east of this point, though the outcrop of the coal has been traced for several miles.

#### BATES AND COALDALE DISTRICT.

The coal bed which dips to the south from Hartford and passes under Poteau and Whiteoak mountains comes to the surface again in a line of outcrop parallel with the south flank of Poteau Mountain, where it has been traced from the Indian Territory line eastward for a distance of about 20 miles.

At the State line the bed consists of more than 7 feet of coal divided by two partings of shale. Three miles east of the State line, in sec. 21, T. 3 N., R. 32 W., the coal bed is divided into three benches and

contains an aggregate of 8 feet of coal, the largest bench being 4 feet thick, and the two smaller upper ones not being mined. Nine miles farther east the coal bed still has a thickness of 4 or 5 feet, but is divided into many small benches; the largest of which is only 12 inches thick, and it is not probable that the coal can be successfully mined, though it is possible that part of the bed was not exposed. Croppings of this bed have been observed for 2 miles still farther east, but as it has nowhere been opened no section could be measured, nor have any reports indicating a workable coal bed been received.

The portion of the coal field which extends eastward from Lookout Gap and underlies Whiteoak Mountain was not examined, owing to the short time available for field work. Although the Hartshorne horizon is known to extend over a considerable area here, prospectors' reports indicate that the coal bed is divided and may be of little value. Both north and south of Poteau Mountain the rocks dip at high angles, indicating that the coal is very deep in the center of the syncline. It is probable, however, that all of the coal can be mined from slopes entering the basin from the north and south sides.

#### CHARLESTON AND PARIS DISTRICT.

The coal of the Hartshorne horizon has not been opened nor the thickness of the bed measured east of Auburn for a distance of about 35 miles to what will be described as the Prairie View district. This unexplored region includes the towns of Charleston and Paris, near which coals of higher horizons are mined. The Hartshorne coal should outcrop through the whole length of this region along the northern base of Devils Backbone Ridge and its eastern extension, Pine Ridge. It should also outcrop near the southern base of Mill Creek Ridge on Grand Prairie, which extends from Arkansas River at the mouth of Big Creek eastward to Roseville.

Along the southern outcrop line, on Devils Backbone and Pine ridges, the bed is here and there indicated by coal smut, but it is nowhere exposed and its thickness can not be measured. There are some indications of a fault along the northern outcrop, on Grand Prairie, and it is possible that the coal horizon does not reach the surface, though it can not be at a very great depth. Coal, which is probably in the Hartshorne horizon, is reported in several wells near Vesta, but no definite information regarding it was obtained, as no accurate measurements had been made.

The Prairie View coal bed, described in some detail on page 151, undoubtedly extends westward in depth under the Paris basin, and though the prospecting which has been done indicates that it thins out in that direction, its western limit has not been determined. The coal bed also dips southward from Denning and must pass under part of this area.

From the above facts it will be seen that there is here a large area underlain by rocks of the Hartshorne coal horizon, in which the thickness and value of the coal have never been determined. The outcrops along the north and south sides of this area reveal no coal of commercial importance, but, considering the great local variations that are known to occur in the Hartshorne coal, further prospecting by deep drilling is fully warranted.

#### VAN BUREN AND ALMA DISTRICT.

The region in the vicinity of Van Buren and Alma, north of the river, has not been thoroughly prospected, though it also is underlain by rocks of the Hartshorne coal horizon.

A small coal bed very close to if not identical with the Hartshorne outcrops at several places near Mulberry. West of Mulberry this horizon is at a greater depth, and does not outcrop, since at the northern edge of the field it is cut off by a fault north of which sandstones below the coal-bearing rocks are exposed. The depth of the Hartshorne horizon could not be estimated closely on account of the very obscure stratigraphic evidence, much of the surface being covered with deposits of gravel and sand.

Small coal beds found near Alma and Van Buren are provisionally correlated with the Charleston coal, which is about 800 feet above the Hartshorne horizon. What is probably the Hartshorne bed has been reached in a drill hole near Alma at a depth of 700 feet. It is reported to be 9 inches thick and overlies a sandstone 150 feet thick, provisionally correlated with the Hartshorne sandstone.

#### COAL HILL AND DENNING DISTRICT.

The Coal Hill and Denning district lies north of Arkansas River about 40 miles from the Indian Territory line. Along its north side the coal is cut off by a fault, extending from Denning to a point a few miles east of Coal Hill, north of which the underlying rocks are raised to the surface. Half a mile south of the line of this fault an anticline extends east and west through the district. In the center of this fold the underlying barren rocks are exposed, but near Denning it pitches below the surface and the coal bed is continuous across it. There is also a smaller basin of coal land, having a possible area of 1 square mile, resting upon the Hartshorne sandstone a few miles west of Altus.

Coal has been mined almost continuously from Coal Hill to Denning and for several miles southeastward from Denning along the southern limb of the anticline. The coal ranges in thickness from 1 to 5 feet, and the bed is usually characterized by a parting of shale or clay near the center, which varies greatly within very short distances, being so thick in some parts of the field as to render the

bed of no value. In general this parting increases in thickness in a northerly direction. South of Hartman the coal bed probably extends eastward and is identical with that mined at Spadra, but for several miles there has been no prospecting sufficient to determine its quality and it does not outcrop at the surface.

In the small outlying basin west of Altus there are two coal beds, the lower one averaging 2 feet and the upper one 10 inches in thickness, with 18 feet of sandy shale between them; these are regarded as equivalent to the two benches of the Denning coal bed. The coal resembles the Denning coal, though, being under only slight cover, it is affected by weathering and the joints are iron stained.

A similar bed with a thick parting of more than 12 feet is indicated by outcrops of coal smut on the south side of the river 2 miles west of this basin, in section 23 of the same township. No coal has been mined here. The outcrop indicates a small shallow basin of coal of the Hartshorne horizon resting upon the Hartshorne sandstone.

#### SPADRA DISTRICT.

The Spadra district is also north of Arkansas River and its center is about 10 miles east of Coal Hill. The coal differs slightly from that at Denning in that it is considerably harder and of higher grade chemically. It is sold as semianthracite or Arkansas anthracite coal, being mined almost exclusively for domestic use.

The structure of this field is complicated and its interpretation is rendered very difficult by extensive deposits of sand and gravel which conceal a large part of the surface. Available information, however, is sufficient to show that the continuity of the coal bed is broken by several faults of normal type striking approximately east and west and generally with downthrows to the south. The best known of these faults was first encountered in a mine 2 miles northwest of the Spadra post-office. It extends west-northwestward nearly to the town of Hartman, where it turns a little south of west and continues to the center of the Coal Hill field.

Another fault striking nearly east and west marks approximately the southern limit of present mining operations. It is parallel with and a short distance north of Spadra Hill, a long ridge capped by flat-lying sandstones south of Spadra, and its east end is a few hundred yards north of the railroad at the south base of Big Danger Hill, in sec. 23, T. 9 N., R. 23 W., where its position is indicated by conclusive stratigraphic evidence. The displacement at the mouth of Spadra Creek is at least 200 feet. A small fault which differs from those described in that the downthrow is to the north lies north of the western part of the Spadra field, bringing in a small area of Spadra coal at the old Allen slope, in sec. 18, T. 9 N., R. 24 W.

From Spadra the coal bed extends northward for 3 or 4 miles. It underlies the town of Clarksville at a depth of 400 to 500 feet, but outcrops  $1\frac{1}{2}$  miles northwest of Clarksville at a point noted by the Arkansas Geological Survey as the Harkreader well,<sup>a</sup> from which the outcrop can not be traced eastward with certainty. The Spadra bed has been penetrated by drill holes west of Cabin Creek at a depth of 550 feet, and the same bed probably outcrops in secs. 6 and 7, T. 9 N., R. 23 W., 2 miles north of Cabin Creek.

At the western limit of prospecting in this district the coal bed is 400 feet below the surface, and its depth probably increases farther west.

Coal mines are located along the railroad for a distance of 6 or 7 miles east from Montana post-office, at very short intervals. Nearly all the openings are by shafts reaching the coal at a depth of 200 feet or less. The average thickness of the coal is from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  feet, with a small parting near the center of the bed. In general, the coal dips to the north or northwest at a low angle, usually not more than 2 or 3 per cent.

The underground workings of the mines extend for a maximum distance of 1 mile north from the line of the St. Louis, Iron Mountain and Southern Railway. Records of much of the drilling that has been done north of these mines were not available, but it is common report that the parting increases in thickness toward the north and makes some of the coal unfit for mining. A shaft about  $1\frac{1}{2}$  miles northwest of Clarksville, near the old Harkreader well, was sunk in 1906, but had not reached the coal at the time of the writer's examination. The coal bed outcrops a short distance to the southeast, however, showing a thickness of 18 to 24 inches without parting.

#### PRAIRIE VIEW DISTRICT.

The Prairie View district lies on the south side of Arkansas River, opposite the Spadra district. Attempts to prospect the field and determine the extent of the coal land have been made only within the last few years, during which large areas of land in this district have been purchased or placed under option by the Arkansas Anthracite Company.

In structure this field is a broad syncline having a general east-west axis. Its southern edge is marked by the Prairie View fault and its northern edge, which is contiguous to the southern edge of the Spadra field, by the Big Danger fault, both of which are described elsewhere in this paper. The greatest depth to coal found in the basin is 1,100 feet.

Prospect holes in the northern part of the field indicate that the coal is from 3 to  $5\frac{1}{2}$  feet thick and divided by a shale parting near the

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<sup>a</sup>Ann. Rept. Arkansas Geol. Survey, 1888, vol. 3, p. 24.

center. In the southern part the bed is not divided and is from 1 to 3½ feet thick.

This district is undeveloped and no coal has been mined except for local use. It is not accessible at present from any of the existing railroads, but could be reached by an extension of the Arkansas Central Railroad, which now terminates at Paris. The distance is not more than 15 miles.

#### RUSSELLVILLE DISTRICT.

The Russellville district lies at the extreme east end of the Arkansas coal field as at present recognized, and includes two small areas of coal land, known as the Ouita basin, a few miles north of Russellville, and the Shinn basin, a few miles to the south.

The coal lands in the Ouita basin are estimated to have covered an area of approximately 2 square miles. Although the formation that carries the coal extends westward, coal has not been mined except in the small area noted, and prospecting a few miles farther west, near London, has revealed no coal. The northern, eastern, and southern boundaries of the Ouita basin are determined by the outcrops of the Hartshorne sandstone, which dips under the coal land from all these directions. The depth to coal is not great at any point, and it has been mined from many small slopes, strip pits, and shafts which have been abandoned and have caved in. Probably much of the coal has been left in the ground and will be lost. Moreover, Illinois Creek, a strong stream which heads in the Ozark Mountains, flows across the basin and has no doubt eroded a great deal of the coal bed, so that much of the area included in the basin as mapped does not contain available coal. Owing to the strike, it was impossible to make measurements of the thickness of this coal bed, but reports indicate that it is without parting and has an average thickness of 28 inches. The roof and floor are shale. As reported by the Arkansas Geological Survey, the coal has a thickness of 26 inches, overlain by 4 inches of bony or "wild" coal.<sup>a</sup>

The Shinn basin lies about 2 miles south of Russellville and includes approximately 2 square miles of coal land. Like the Ouita basin, this is bounded on all sides by outcrops of the Hartshorne sandstone. Shafts which have been sunk for mining purposes show that the maximum depth to coal probably exceeds 600 feet. Coal has been mined for many years along the north edge of the basin, where there are a number of old abandoned slopes, but owing to the great depth of the basin only a comparatively small part of the area has been worked out. The coal is somewhat thicker than in the Ouita basin; it averages between 40 and 46 inches, and has an 8 to

<sup>a</sup>A nn. Rept. Arkansas Geol. Survey, 1888, vol. 3, p. 34.

10 inch parting. There are three active mines in the basin, one of which has a shaft 480 feet deep, making it the deepest coal mine in Arkansas.

#### PHILPOTT DISTRICT.

The Philpott district lies in an isolated synclinal trough extending east and west through T. 10 N., Rs. 24, 25, and 26 W., north of the Coal Hill and Spadra fields. It includes a number of prospects and small mines which were operated before the larger mines along the railroad were opened. The coal is softer than that at Spadra and for local use formerly commanded a better price, since it ignites and burns more freely. Analyses show that it is semibituminous and of about the same grade as that at Coal Hill and Denning.

There are two beds of coal separated by 600 to 800 feet of shale. The lower of these, known as the Pickartz bed, from the old Pickartz mine, is correlated on stratigraphic evidence with the Hartshorne coal. This mine is situated in sec. 29, T. 10 N., R. 25 W., and the horizon of the coal has been traced to the eastward for a distance of nearly 18 miles, connecting it with the coal which outcrops on Dicks Branch in sec. 10, T. 10 N., R. 23 W., and Minnow Creek in sec. 20, T. 10 N., R. 22 W.

At the Pickartz mine the coal is reported to be from 21 to 26 inches thick, with a thin shale parting near the floor. The coal exposed at Dicks Branch measures 15 inches and at Minnow Creek 14 inches. The upper bed on which the old Moomaw and Philpott mines were located is described in the next section in connection with the coals of the Charleston horizon.

#### COALS OF THE CHARLESTON HORIZON.

The coals of the Charleston horizon are stratigraphically from 800 to 900 feet above the Hartshorne coal horizon and occur near the upper part of the group of sandstones and sandy shales that constitute the Fort Smith formation. Wherever examined these coals are less than 3 feet thick and are usually too thin for mining, except by stripping. Owing to the erosion of intervening areas it has been impossible to correlate these upper beds in different districts by continuous exposures, and though no individual bed is believed to have ever been continuous over the whole Arkansas coal field, it is thought that they are all within 100 feet of the same horizon. Such upper coals have been mined locally near Fort Smith, Central, Charleston, Caulksville, and Alma, and in the Philpott basin. Their outcrops have been seen in many other places. In general the coal is of good quality and as compared with the Hartshorne coal relatively free

from ash, though on weathering much of it is coated with white efflorescence.

Coals of this horizon are best exposed in the vicinity of Charleston, Franklin County, where they have been worked by stripping at many places indicated on the map (Pl. IX, p. 138). In general, the beds have roofs and floors of sandstone or sandy shale. One of the best exposures is at the west end of Coal Ridge, in sec. 15, T. 7 N., R. 30 W., 2 miles north of Auburn, where the coal occurs in a group of thin sandstones with intervening sandy shales. It has been mined from a succession of small slopes on a bed about 100 feet below the sandstone forming Coal Ridge. The bed is 18 inches thick and is without partings. About 60 feet above the bed mined there is a smaller bed which is of no importance here, but is probably of greater thickness elsewhere. Some of the many outcrops near Charleston represent this small upper bed, while others represent the lower.

East and north of Charleston there are on one or the other of these beds many openings which do not require description in detail, their positions being shown on the map. Two miles east of Charleston, on the Carter place, the bed is reported to be 3 feet thick in a slope from which more or less coal is taken every year. The same coal is probably represented in an old pit in sec. 3, T. 7 N., R. 27 W., 1 mile east of Caulksville, where it is reported to be only 13 or 14 inches thick.

Coal of the same horizon outcrops at a number of places between Charleston and Fort Smith, the best-known locality being in sec. 1, T. 7 N., R. 31 W., near Central, where there are several strip pits, small shafts, and slopes. The bed here has a thickness of about 20 inches without parting. The same coal has been penetrated by wells at a number of points in the region southwest of Central and has been mined from strip pits near Little Vache Grasse Creek and probably at other places.

The coal at the old Herman pit in sec. 2, T. 8 N., R. 22 W., near Fort Smith, is probably also at this horizon. It is said to have been worked before and during the civil war and is noted in the Arkansas Survey reports. Ten inches of good coal overlain by 1 foot of bony coal is exposed in the old workings. The bed is contained in sandy shale resembling that near Charleston.

Coal probably of the same horizon outcrops at several points on the north side of the river near Alma, the thickness of the bed nowhere exceeding 14 inches and usually averaging 9 or 10 inches. The same bed is thought to outcrop on Arkansas River at Moores Rock in T. 8 N., R. 30 W., and it has probably also been found in wells at Van Buren. None of these openings expose a coal of workable thickness.

A coal bed at this horizon probably occurs in Sugarloaf and Poteau mountains, where the exposures seen do not indicate that it has sufficient thickness to make it of commercial value.

At Paris this horizon is from 200 to 400 feet below the surface, and its outcrops north and south of the Paris basin have not been seen. In the Prairie View region, however, a coal bed 9 or 10 inches thick at about the proper distance above the horizon of the Hartshorne coal has been examined at a number of localities, which are noted on the map (Pl. IX). In no place has it been found to be of sufficient thickness to give it economic value under present conditions.

The bed mined at the old Philpott and Moomaw openings in T. 10 N., R. 26 W., also seems to correspond approximately in stratigraphic position with the Charleston bed. It lies in a synclinal basin 4 miles long by 2 miles wide, in which the rocks dip at low angles and the coal is nowhere very deep. At the Philpott slope, in sec. 20, T. 10 N., R. 25 W., the bed is from 18 to 22 inches thick without partings, and a similar thickness is reported from other openings. The coal is semibituminous and analyses of samples taken by the Arkansas Geological Survey indicate that it is comparatively low in ash and is chemically of a somewhat higher grade than the coal from the Pickartz bed.<sup>a</sup> Most of the product of one or two small mines is hauled by wagon to Ozark, where it is sold for domestic use.

#### COALS OF THE PARIS HORIZON.

The coal mined at Paris is from 1,200 to 1,400 feet above the Hartshorne horizon and about 400 feet below the top of the Paris shale. The coal bed is overlain by shaly sandstone and underlain by sandy shale. A few inches of draw slate usually comes down with the coal and there is in many places some fire clay between it and the sandy-shale floor. The bed is without parting and ranges in thickness from 2 to nearly 3 feet where it is worked. The whole area underlain by this coal does not exceed 8 square miles, and in its western part the bed is probably too thin for mining. The coal has a bright luster and a rather indefinite cubical fracture. Chemically it is semibituminous and somewhat higher in hydrocarbon than the average Hartshorne coals in the same region. It is sold principally for domestic use. All the coal mined is hand picked or forked, the slack being left in the gob.

Outside of the Paris district this coal horizon has not been discovered except in the vicinity of Potato Hill, where a thin bed provisionally correlated with it has been mined by stripping at several localities. West of Potato Hill, in sec. 23, T. 6, R. 27, the coal, as reported, is 14 inches thick and has been worked for local supply within the

<sup>a</sup> Ann. Rept. Arkansas Geol. Survey, 1888, vol. 3, p. 43.

last year. A similar coal outcrops in several localities near Pine Hill, but it is not mined to any extent and its thickness is not great enough to warrant development.

The same coal should outcrop in Sugarloaf, Poteau, and Magazine mountains, and it has probably been seen by prospectors and others in each of the first two localities, though it has not been reported from the last. On stratigraphic and paleobotanic evidence it is provisionally correlated with the McAlester coal of Indian Territory.

#### COALS BELOW THE HARTSHORNE HORIZON.

Coal beds have been reported from many localities in the shales and sandstones underlying the Hartshorne, to which the name Atoka formation has been applied. These lower coal beds are not continuous for any great distances and are thin except in small areas.

In the western part of the field such coal has been reported to the writer at only one locality, which is in the center of the Backbone anticline about 2 miles northeast of Hackett. The bed is between 500 and 1,000 feet below the Hartshorne sandstone and is not more than a few inches in thickness. Coal is also reported by the Arkansas Geological Survey <sup>a</sup> in the neighborhood of Booneville on Fletcher Creek, the locality being known as the Carlan drift. Although not personally examined, this coal is also believed by the writer to be several hundred feet below the Hartshorne sandstone.

A small bed of coal which has been mined from strip pits for local use outcrops on a bench on the north side of Rich Mountain 4 miles southwest of Ellsworth, in T. 7 N., R. 24 W. It is estimated to be from 300 to 400 feet below the Hartshorne sandstone. What is believed to be the same bed of coal has been penetrated by two drill holes near Shoal Creek in T. 7 N., R. 23 W., where it is 400 feet below the Hartshorne coal horizon and has a thickness of nearly 4 feet, but is divided by shale partings.

Similar coal beds outcrop at several localities south of the Shinn basin, in the Russellville district. The rocks here strike approximately east and west and dip to the north under the Shinn basin at high angles. It is probable that two beds are represented, one about 400, the other from 800 to 1,000 feet below the Hartshorne. Prospecting with diamond drills was in progress here during the summer of 1906, though at the time the region was visited no coal thick enough to work under present conditions had been discovered.

In the region south and southeast of Dardanelle the same beds have been worked occasionally since the days before the war. Some old excavations in sec. 35, T. 6 N., R. 21 W., north of Centerville, expose from 18 to 20 inches of coal at the outcrop. Several drill holes which have been sunk on this bed indicate that it is at least

<sup>a</sup> Ann. Rept. Arkansas Geol. Survey, 1888, vol. 3, pp. 23, 59, 80.

2½ feet thick in some places. The structure is such that this bed should dip northward into an extensive synclinal basin, and should crop out again a few miles south of Dardanelle. Its northern outcrop, however, has not been recognized. Near the center of this syncline a higher bed of coal has been opened in one or two wells and is reported to have a thickness of 14 to 15 inches. These beds are estimated to be about 400 feet and from 800 to 1,000 feet, respectively, below the Hartshorne sandstone. What is probably equivalent to the lower bed has been mined near Chickalah, south of Mount Nebo, and its occurrence west of Spring Mountain has been noted in the report of the Arkansas Geological Survey, but neither of these localities was examined. A coal that must also belong to one of the lower horizons has been reported near Atkins, in T. 7 N., R. 18 W., and near Galla Rock, in T. 6 N., R. 20 W.

Several thin coal beds occurring in rocks below the Hartshorne outcrop north of the Coal Hill district and also in the vicinity of Ozark, but none of these are of workable size where exposed.

From present indications further investigation of such beds in the vicinity of Russellville and Dardanelle is certainly justified and will probably result in extending the boundaries of the coal field as at present defined.

#### CHARACTER OF THE COAL.

The Arkansas coals usually have a bright luster when freshly mined, though parts of some of the beds in a few places are described as dull. There is as a rule no pronounced cleavage parallel to the bedding, but the vertical cleavage or cleat is complex and somewhat indefinite. Except possibly in a very few mines the cleat is not considered in mining, entries and rooms being driven without regard to any inherent structure, though the many cleavage planes affect the value of the coal, making it fragile. As mined, all these coals yield from 10 to 40 per cent of slack, the proportion of which is probably an index of the relative hardness of the coal at the different mines. Mine-run coal in the Jenny Lind, Greenwood, and Huntington districts, at the west end of the field, contains from 20 to 40 per cent of slack, whereas in the Russellville district, at the east end of the field, the slack does not average more than 10 per cent. This condition is, however, in part due to the method of mining, a lower percentage of slack being produced by hand or pick mining than by shooting off the solid.

The coals from the Jenny Lind and the Huntington and Greenwood districts, at the west end of the field, are classed as high-grade bituminous and semibituminous; those from the Coal Hill and Denning and the Paris districts are semibituminous, and those from the Spadra and the Russellville districts, at the east end of the field, are

semianthracite. One of the chief advantages of Arkansas coal is that in burning it produces relatively little smoke.

The agents of the fuel-testing plant at the Louisiana Purchase Exposition in 1904 collected mine and car samples from four representative mines in various parts of the Arkansas field. In sampling the mines a systematic method was followed in all cases, making the samples as nearly uniform as possible.<sup>a</sup>

The same method was observed by the Geological Survey party during the last season in collecting samples from the various mines. Proximate analyses were made at the fuel-testing plant of all the samples collected, and ultimate analyses and other special tests were made of a few representative samples from the various districts. The results obtained with the fuel-testing plant samples have already been published, and a full account of the subsequent analyses will appear in the bulletin from which this paper is abstracted.

For purposes of comparison the proximate analyses of representative samples of Arkansas coal have been recalculated to an air-dried basis and are given in the following table:

*Analyses of coal samples from Arkansas.*

[F. M. Stanton, analyst.]

District and character of coal	Bates-Coal-dale; bituminous. Greenwood-Huntington; bituminous and semibituminous.								
Nearest town	Bates.	Hartford.	Huntington.	Burma.			Montreal.		Fidelity.
Laboratory No.	3505.	3500.	1114.	3154.	3158.	3155.	3150.	3152.	3175.
Analysis of sample as received:									
Prox. Moisture	3.37	4.12	3.24	2.44	2.65	3.54	3.01	2.57	2.26
Prox. Volatile matter	24.44	18.15	17.46	16.85	15.70	14.89	15.75	15.48	15.79
Prox. Fixed carbon	66.40	69.97	66.69	74.98	74.52	74.88	75.93	76.17	71.91
Prox. Ash	5.79	7.76	12.61	5.73	7.13	6.69	5.31	5.78	10.04
Ult. Sulphur	.87	.98	1.24	2.57	2.86	1.21	.93	2.05	1.20
Ult. Hydrogen			4.15						
Ult. Carbon			74.09						
Ult. Nitrogen			1.44						
Ult. Oxygen			6.47						
Calorific value determined:									
Calories			7,294						
British thermal units			13,129						
Loss of moisture on air drying	2.50	3.40	2.10	1.60	1.90	2.70	2.20	1.80	1.60
Analysis of air-dried sample:									
Prox. Moisture	.89	.75	1.17	.85	.76	.86	.83	.78	.67
Prox. Volatile matter	25.07	18.79	17.83	17.13	16.01	15.30	16.10	15.76	16.05
Prox. Fixed carbon	68.10	72.43	68.12	76.20	75.96	76.96	77.64	77.57	73.08
Prox. Ash	5.94	8.03	12.88	5.82	7.27	6.88	5.43	5.89	10.20
Ult. Sulphur	.89	1.01	1.27	2.61	2.92	1.24	.95	2.09	1.22
Ult. Hydrogen			4.00						
Ult. Carbon			75.68						
Ult. Nitrogen			1.47						
Ult. Oxygen			4.70						
Calorific value determined:									
Calories			7,450						
British thermal units			13,410						
Fuel ratio	2.72	3.86	3.82	4.45	4.75	5.05	4.87	4.92	4.55

<sup>a</sup> Report on the operations of the coal-testing plant: Prof. Paper U. S. Geol. Survey No. 48, 1906, pt. 1, p. 33.

Analyses of coal samples from Arkansas—Continued.

District and character of coal	Greenwood - Huntington; bituminous and semibituminous.			Bonanza-Jenny Lind; bituminous and semibituminous.			Charleston; bituminous.	Paris; semibituminous.		
Nearest town	Greenwood.	Excelsior.	Hackett.	Bonanza.	Jenny Lind.	Fort Smith.	Auburn.	Paris.		
Laboratory No.	3173.	3157.	3497.	1160.	1115.	3153.	3372.	3218.	3174.	
Analysis of sample as received:										
Prox.	Moisture	3.21	3.64	3.55	2.23	1.60	3.18	2.19	3.80	2.77
	Volatile matter	14.84	16.57	17.16	16.02	17.40	14.64	14.00	15.96	14.69
	Fixed carbon	72.66	76.00	75.46	72.55	73.09	76.06	72.15	75.86	73.47
	Ash	9.29	3.79	3.83	9.20	7.91	6.12	11.66	4.38	9.07
Ult.	Sulphur	3.12	.83	.96	1.87	1.42	1.51	2.06	2.21	2.79
	Hydrogen	3.75			4.24					4.02
	Carbon	78.37			78.83					78.71
	Nitrogen	1.52			1.38					1.46
Oxygen	3.95			4.48					3.95	
Calorific value determined:										
Calories	7,549			7,639	7,868					7,652
British thermal units	13,588			13,750	14,162					13,774
Loss of moisture on air drying										
	2.40	3.00	2.80	1.50	.80	2.40	1.40	2.60	2.20	
Analysis of air-dried sample:										
Prox.	Moisture	.83	.66	.77	.74	.81	.80	1.23	.59	
	Volatile matter	15.20	17.03	17.66	16.26	17.54	15.00	14.20	16.39	
	Fixed carbon	74.45	78.35	77.63	73.66	73.68	77.93	73.17	77.89	
	Ash	9.52	3.96	3.94	9.34	7.97	6.27	11.83	4.49	
Ult.	Sulphur	3.20	.85	.99	1.90	1.44	1.58	3.09	2.27	
	Hydrogen	3.56			4.13					
	Carbon	80.30			80.03					
	Nitrogen	1.56			1.40					
Oxygen	1.86			3.20						
Calorific value determined:										
Calories	7,735			7,756	7,931				7,824	
British thermal units	13,923			13,961	14,275				14,084	
Fuel ratio	4.90	4.59	4.40	4.52	4.20	5.20	5.15	4.75	5.00	

District and character of coal	Denning-Coal Hill; semibituminous.			Spadra; semianthracite.			Russellville; semianthracite.		
Nearest town	Coal Hill.		Altus.	Spadra.		Clarks-ville.	Russellville.		
Laboratory No.	1130.	3370.	3371.	3368.	3407.	3369.	3177.	3176.	
Analysis of sample as received:									
Prox.	Moisture	1.38	3.41	3.77	2.11	2.15	1.72	2.33	2.07
	Volatile matter	14.76	12.10	13.96	11.42	10.82	10.46	10.60	9.81
	Fixed carbon	76.91	78.41	79.35	77.83	76.87	79.50	77.67	78.82
	Ash	6.95	6.08	2.92	8.64	10.16	8.32	9.40	9.30
Ult.	Sulphur	1.52	4.05	.74	1.99	2.30	2.49	1.81	1.74
	Hydrogen								3.62
	Carbon								80.28
	Nitrogen								1.47
Oxygen								3.59	
Calorific value determined:									
Calories	7,961			7,693		7,704			7,612
British thermal units	14,330			13,853		13,867			13,703
Loss of moisture on air drying									
	.70	2.40	2.80	1.00	1.40	.70	1.60	1.40	
Analysis of air-dried sample:									
Prox.	Moisture	.68	1.03	1.00	1.12	.76	1.03	.74	.68
	Volatile matter	14.87	12.39	14.36	11.54	10.97	10.53	10.77	9.95
	Fixed carbon	77.45	80.35	81.64	78.61	77.96	80.06	78.94	79.94
	Ash	7.00	6.23	3.00	8.73	10.31	8.38	9.55	9.43
Ult.	Sulphur	1.53	4.15	.76	2.01	2.33	2.51	1.84	1.76
	Hydrogen								3.51
	Carbon								81.42
	Nitrogen								1.49
Oxygen								2.39	
Calorific value determined:									
Calories	8,017			7,693		7,758			7,720
British thermal units	14,431			13,853		13,965			13,896
Fuel ratio	5.21	6.48	5.68	6.82	7.11	7.59	7.33		8.04

## CONDITIONS OF MINING AND DEVELOPMENT.

*Production.*—The development of the coal industry in Arkansas on a commercial scale was started about 1870, and the production increased to a maximum of 2,229,172 short tons in 1903. A slight decline in the production after 1903 was caused by the competition of fuel oil from Texas, but present conditions indicate that the demand for Arkansas coal is again increasing.

*Method of mining.*—Coal was first obtained in Arkansas by striping, and a few pits of this kind are still in operation, though most of the coal is mined from deeper workings reached either by slopes or shafts. The majority of these mines are shallow, averaging less than 200 feet in depth. A 480-foot shaft in the Shinn basin, at the east end of the field, reaches the maximum depth.

The room and pillar system prevails, with some local modification throughout the field, the pillars not being drawn. The actual mining of the coal is generally done by shooting it off the solid face of the bed. Undercutting by hand is the method employed in a few mines where the coal is of unusually good quality. No mining machines are used in the field.

In the larger mines haulage from the rooms is by mules and in the main gangway either by mules or cable. One of the mines at Bonanza is equipped with electric motors.

Ventilation in the larger mines is accomplished by fans, and in the smaller ones by fire boxes. There is comparatively little gas, and accidents from this cause are relatively rare.

*Minimum thickness of workable coal.*—The minimum thickness of coal mined for shipment is slightly over 2 feet, and some coals as thin as 18 inches are mined for local markets.

*Preparation of coal for market.*—The coal is sold either as mine run, including both lump and slack, or, most commonly, it is passed over screens which separate it into lump and slack. At a number of the smaller mines the lump coal is separated by hand with a fork, and the slack is left in the gob.

*Labor.*—Practically all the coal is mined under contract at a definite rate per ton, established by an agreement between the operators and the miners' union. There are no nonunion miners in the field. During 1904 and 1905 the Arkansas coal-mining industry was not interrupted by the strikes which prevailed in other States, but in 1906 all the principal mines were shut down from the first of April to the first of July.