COAL AND LIGNITE.

RHODE ISLAND ANTHRACITE.[1]

By GEORGE H. ASHLEY.

INTRODUCTION.

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

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

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

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

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

LOCATION OF THE COAL FIELD.

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

THE ROCKS OF THE AREA.

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

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

THE ANTHRACITE BEDS.

In the great thickness of shale and sandstone there are many layers of carbonaceous shale and locally beds of anthracite. Little is yet known of the extent of these beds. At Portsmouth a single bed has been followed on the surface and underground for several thousand feet, and near Providence a carbonaceous belt, containing 10 or more beds of anthracite or graphite, has been traced with interruptions from the vicinity of the boys' school at Sockanosset northward, west

of Providence and Pawtucket, to a point beyond Valley Falls. Whether or not any single bed has such an extent is not known.

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

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

THE ANTHRACITE.

PHYSICAL CHARACTER.

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

CHEMICAL COMPOSITION.

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

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

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

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

Newport County.

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

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

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

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

Providence County.

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

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

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

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

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

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

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

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

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

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

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

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

STEAMING TESTS.

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

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

HOUSEHOLD USE.

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

BRIQUETTING TESTS.

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

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

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

METALLURGIC USE.

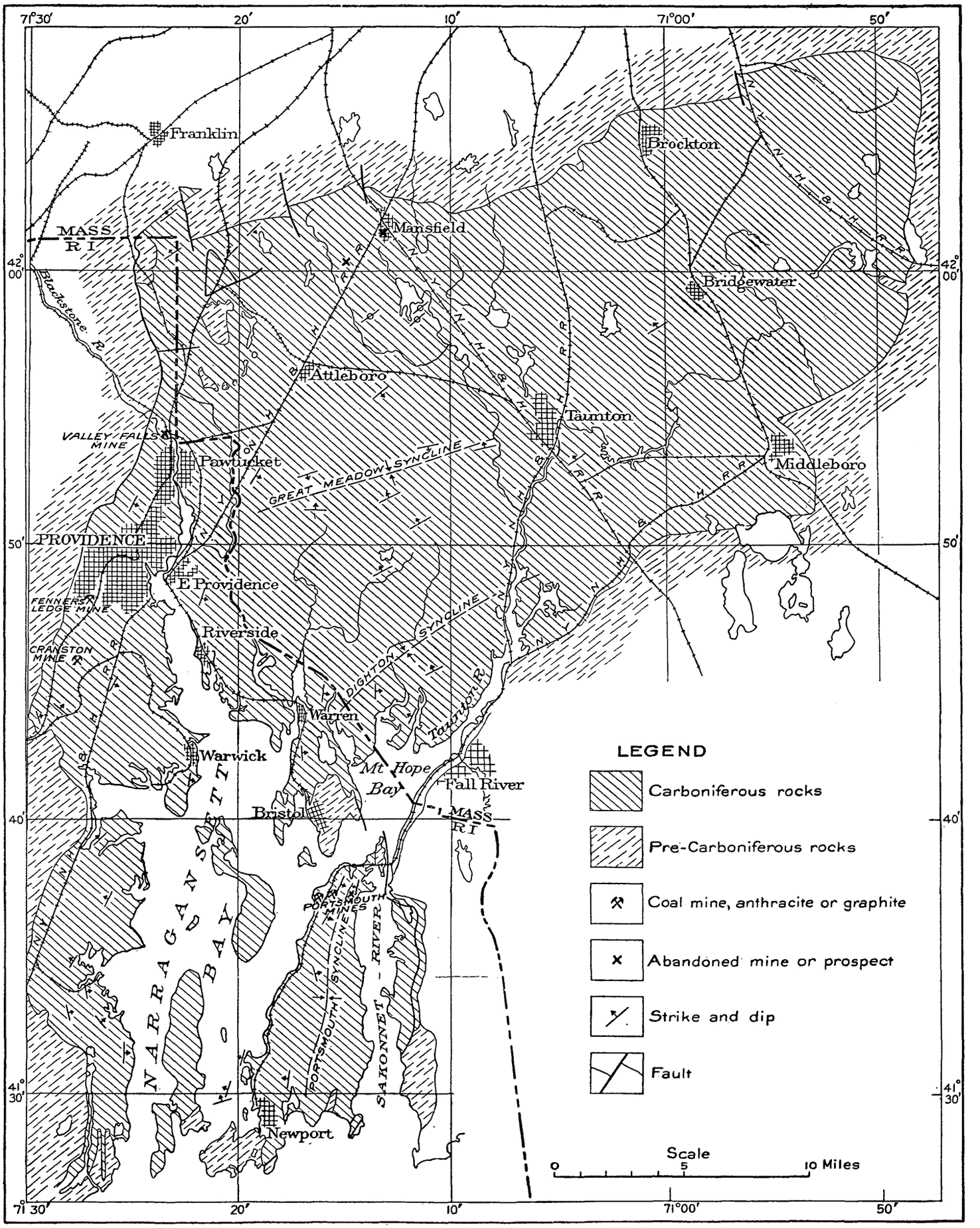
In the past Rhode Island anthracite has been used successfully in the smelting of copper and iron. At one time it was even shipped to Pittsburgh. It has not, however, been used for this purpose during the last 30 years and it does not seem probable that it could compete with coke for use in the modern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

USE BY CONVERSION INTO GAS.

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

In general the detailed figures given in the bulletin now in preparation show conclusively that Rhode Island anthracite is difficult to handle and that the cost of handling, on account of the large amount

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



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

By G. H. Ashley.

COKING COAL IN POWELL MOUNTAIN, SCOTT COUNTY, VIRGINIA.

By MARIUS R. CAMPBELL.

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

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

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

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

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

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

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

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

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

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

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

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

By CHARLES BUTTS.

INTRODUCTION.

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

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

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

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

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

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

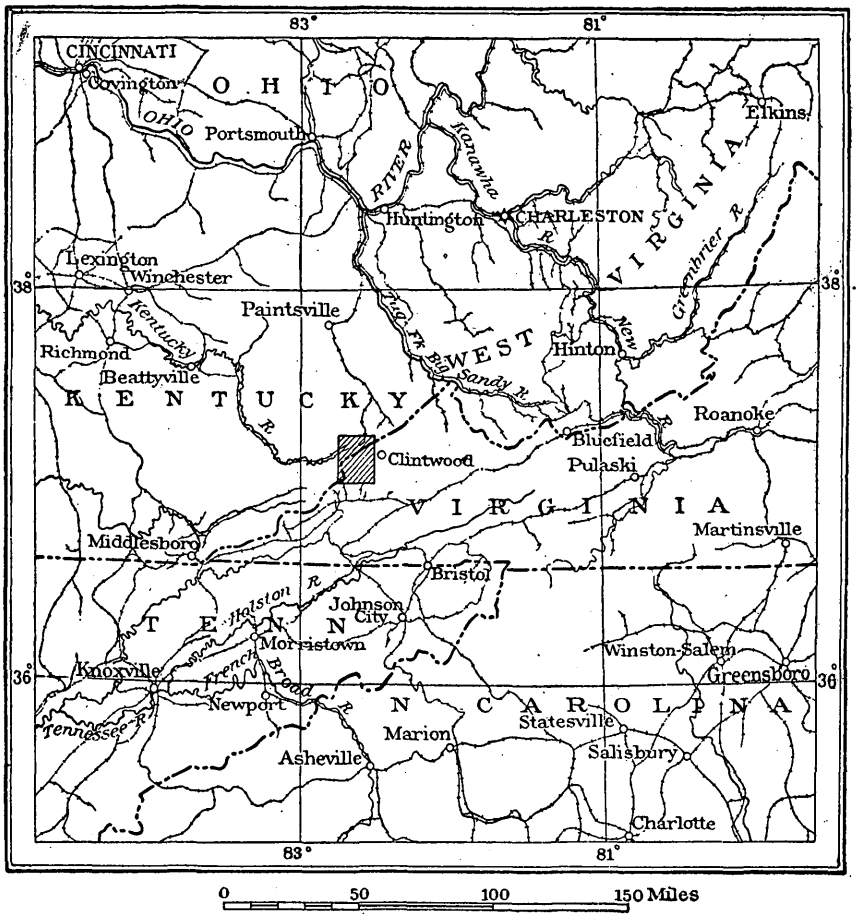


FIGURE 6.—Index map showing location of the Pound quadrangle of Virginia and Kentucky.

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

As shown by the map (fig. 6), the Pound quadrangle, which coincides with the southeastern quarter of the old Whitesburg 30-minute quadrangle, lies partly in eastern Kentucky and partly in south-

western Virginia. The line between the two States follows the crest of Pine Mountain nearly to the western boundary of the quadrangle, where it turns south along the watershed between Cumberland and Pound rivers. The quadrangle is bounded by parallels 37° and 37° 15′, and by meridians 82° 30′ and 82° 45′. Its area is about 240 square miles and it lies entirely in the Appalachian coal region.

TOPOGRAPHY.

RELIEF.

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

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

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

DRAINAGE.

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

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

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

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

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

ACCESSIBILITY.

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

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

The part of the quadrangle that lies in Virginia is still poorly provided with transportation facilities. The territory drained by Guest River could easily be reached by railroad from Norton, but the Pound River drainage area presents serious obstacles to railroad construction. To build a railroad from the south would involve steep grades or an expensive tunnel at the head of Indian Creek. The railroad

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

GEOLOGY.

STRATIGRAPHY.

DIVISIONS OF THE ROCKS.

The rocks that outcrop in the Pound quadrangle belong to the Devonian and Carboniferous systems. The Devonian rocks, the lowest and oldest exposed in the quadrangle, outcrop only on the west escarpment of Pine Mountain in Kentucky, and consist of about 800 feet of dark to black shale, comprising the black Chattanooga shale of this region and the lower part of the Grainger shale. The Carboniferous system is divided into the Mississippian series (lower Carboniferous) below and the Pennsylvanian series (upper Carboniferous or "Coal Measures") above. Each of these series is made up of a number of formations, which are described below.

MISSISSIPPIAN SERIES.

The Mississippian series in this area is 1,500 to 1,600 feet thick and comprises, in ascending order, the upper part of the Grainger shale, the Newman limestone, and the Pennington shale. The upper or Mississippian part of the Grainger shale is composed chiefly of green shale and brownish sandstone, but in the upper 50 feet there is considerable red sandstone. The Mississippian part of the Grainger shale appears to be 400 to 500 feet thick. It is succeeded above by the Newman limestone, which is about 300 feet in thickness, oolitic and thick bedded in the lower half, but thinner bedded and continuing only a few oolitic layers in the upper half. The Newman is overlain by the Pennington shale, which is about 800 feet thick and is

composed of red and green shale, thin-bedded fine-grained green sandstone, and one persistent stratum of hard siliceous sandstone 100 feet thick.

The Mississippian rocks outcrop only on the northwest front of Pine Mountain in Kentucky, and dip southeast under the coal measures in Virginia. The Mississippian part of the Grainger shale is exposed on the Pound Gap road and also on the Blowing Rock road, some 2 or 3 miles northeast of the east margin of the quadrangle. The red sandstone layers are especially well shown on the Blowing Rock road at the part known as the Red Winds. The Newman limestone is exposed on the Pound Gap road and outcrops as a cliff for much of the distance along the mountain front. The Pennington shale is fairly well exposed on the Pound Gap road immediately west of the summit. Its siliceous sandstone member outcrops as a cliff near the road, and about one-half mile north of the road it makes another cliff, known as the Raven Rock. The Pennington was penetrated at the depth of about 2,000 feet in diamond-drill boring No. 1 on Cranesnest River near the mouth of Lick Fork, a short distance east of the quadrangle. (See Pl. IX, section 1.)

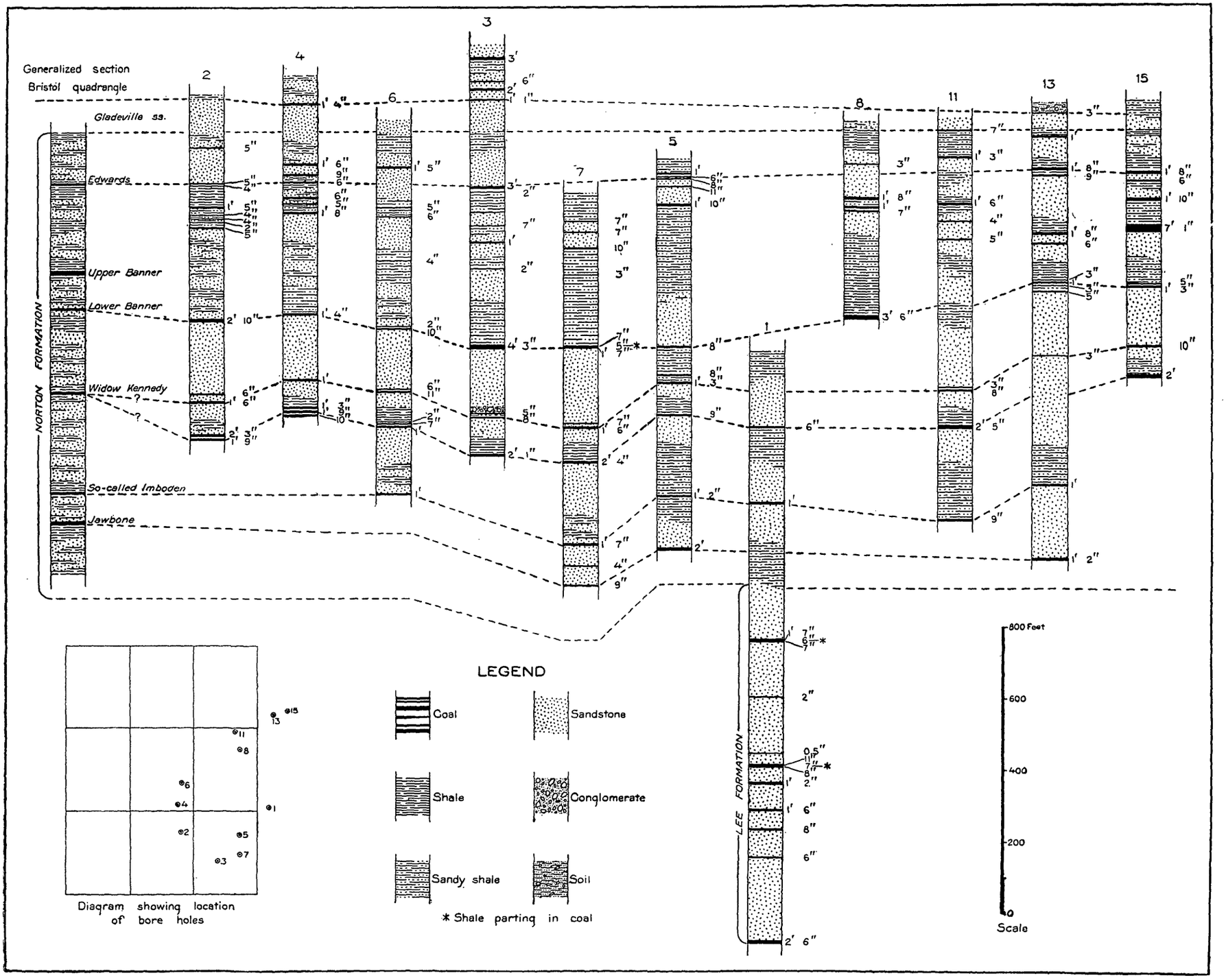
PENNSYLVANIAN SERIES IN THE VIRGINIA AREA.

The Pennsylvanian series in the Virginia area is 4,800 feet thick and consists of shale and sandstone that contain 46 or more coal beds. These rocks, all of Pottsville age, were divided by Campbell[1] into the following formations, named in ascending order: Lee formation, Norton formation, Gladeville sandstone, Wise formation, and Harlan sandstone. The character of the rocks, the sequence of formations, and the number, position, and succession of coal beds are shown in the columnar section accompanying this report (Pl. XI, p. 68). This section is partly generalized, but the section of the Lee is taken from the log of a bore hole on Cranesnest River, just outside the east margin of the quadrangle, and the part of the section of the Wise formation above the Bolling (5-foot) coal beds and the section of the Harlan sandstone were measured at the head of South Fork of Pound River, the section extending from the base of Black Mountain to the summit. The Black Mountain section of the Pennsylvanian is probably the thickest in the Appalachian province outside of the Coosa and Cahaba troughs in Alabama.

LEE FORMATION.

The Lee formation, as delimited by the writer in the well boring on Cranesnest River (Pl. IX, section 1), is 1,030 feet thick. It is predominantly sandstone, which at the top and bottom of the for-

[1] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, pp. 33-36, 1893.



SECTIONS OF DIAMOND-DRILL HOLES IN THE POUND QUADRANGLE AND VICINITY, KENTUCKY AND VIRGINIA, AND GENERALIZED SECTION OF THE BRISTOL QUADRANGLE.

The bore holes were drilled and the records furnished by the Clinchfield Coal Corporation and bear the serial numbers of the company.

mation is conglomeratic. At the base lies about 230 feet of massive conglomeratic sandstone, which forms the crest of Pine Mountain, where it outcrops for long distances as a cliff. Above the basal sandstone occurs 250 feet of alternating shale and sandstone, in which there are six coal beds at about equal stratigraphic intervals and from 6 inches to 2 feet 2 inches thick. Three of these beds are workable, being 1 foot 2 inches, 1 foot 6 inches, and 2 feet 2 inches thick. Above this group of coal beds the well log shows 550 feet of sandstone containing a coal bed 2 inches thick 225 feet above its base and a bed 1 foot 7 inches thick 400 feet above its base, the two beds being 700 and 875 feet, respectively, above the bottom of the formation. The upper 160 feet of the Lee is a hard siliceous conglomeratic sandstone, the pebbles being small and scattered. This stratum, which dips southeastward, forms the lower part of the southeast slope of Pine Mountain, and its outcrop on the slope is marked by a subordinate ridge or line of knobs parallel with the general direction of the crest of the mountain.

The Lee formation outcrops in a zone about 2 miles wide, which extends diagonally across the quadrangle from the northeast corner. Its base forms the crest of Pine Mountain, and, owing to the southeastward dip, the outcrops of successively higher beds of the formation are encountered on the descent of the southeast slope. In reality the presence of a mountain ridge here is determined by the inclined beds of this hard resistant sandstone and conglomerate. Besides this main area of outcrop the Lee is exposed in a long, narrow outcrop low down on the northwest escarpment of Pine Mountain, in contact with the Devonian or with the Mississippian part of the Grainger shale on the east, and with coal-bearing rocks, probably equivalent to the Wise formation, on the west. This narrow area is an outcrop of a segment of the Lee, which was broken off and thrust upward along a fault, as described in the section on geologic structure. The massive sandstone strata of the formation are well exposed in the "Breaks of Sandy," 12 miles northeast of the Pound quadrangle, where the Lee forms canyon walls nearly 1,000 feet high.

NORTON FORMATION.

Thickness and character.—A fairly reliable determination of the thickness of the Norton formation is made by combining the upper part of the section of the bore hole on Cranesnest River (Pl. IX, section 1) with the surface section of a high knob immediately adjacent to the hole. The contact between the Lee and the Norton, as the log is interpreted, is 879 feet above sea level and the horizon of the bottom of the Gladeville sandstone, which is the top of the Norton formation, is approximately 2,070 feet above sea level. The thickness of the Norton is therefore 1,191 feet.

The character of the Norton formation is well shown in the group of bore-hole sections in Plate IX, from which the generalized columnar section of the formation in this quadrangle is taken. Its most striking feature is the irregularity in the number and position of the coal beds, a feature which makes difficult a satisfactory brief general description of the formation. In general the formation is made up of shale and sandstone with coal beds, the more valuable of the coal beds lying approximately 190, 320, 410, 560, 730, and 930 feet above the bottom of the formation. Eighty feet below the Gladeville lies the top of a conglomeratic sandstone 50 feet thick, which may prove to be the same as the Bearwallow conglomerate of the Tazewell quadrangle, 30 miles east of this area.

In the Pound quadrangle the Norton formation outcrops in a belt about 1½ miles wide that extends diagonally across the quadrangle parallel to Pine Mountain and is bounded roughly on the northwest by the base of the mountain and on the southeast by Pound River. Along the southeast boundary it dips beneath younger rocks and remains under cover as far as Cranesnest River and Birchfield Creek, where it is again exposed, forming the lower part of the valley walls. A narrow area is also exposed along the upper course of Indian Creek. The formation disappears beneath Sand Ridge and Black Mountain and is concealed in the southern part of the quadrangle, but outcrops several miles south of the quadrangle along the southern margin of the coal field.

Correlation of coal beds.—The correlation of the Norton coals of this area with the Norton coals of the southern margin of the Virginia coal field as classified by Campbell[1] is more fully discussed on pages 185–186, and only a brief statement of conclusions need be given here. The coal bed lying 190 feet above the bottom of the Norton formation is the Jawbone; the one at 320 feet is the so-called Imboden; the coal at 410 feet apparently is not present in the section given in the Bristol folio; the coal at 560 feet is equivalent to the Widow Kennedy bed; and the coal bed at 730 feet above the bottom of the formation is the Lower Banner bed. The Upper Banner coal is not present unless it is represented by the group of thin coal beds 250 to 270 feet below the Gladeville sandstone, including the 7-foot bed in well No. 15, east of the quadrangle. The Edwards-Imboden horizon is represented by another group of thin coal beds 150 feet below the Gladeville sandstone. The coal just below the Gladeville sandstone appears to be the Yellow Creek bed, which is mined east of Wise, 2 miles south of this quadrangle.

Nearly all the coal beds of the Norton formation, except the thick bed in boring No. 15 (Pl. IX), are less than 3 feet thick, and most of

[1] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: U. S. Geol. Survey Bull. 111, pp. 33-36, 1893; U. S. Geol. Survey Geol. Atlas, Estillville folio (No. 12), 1894; idem, Bristol folio (No. 59), 1899.

them are less than 2 feet thick. Several sections of bore holes show a number of thin coal streaks associated with the thicker beds, and this suggests that, owing to rapid sedimentation, the continuity of accumulation of vegetal matter in this area was more or less interrupted during the deposition of the coal beds, and that these conditions resulted in the formation of a number of thin beds at the different coal horizons instead of one thick bed, such as occurs at the same horizon at Toms Creek, Norton, and other places along the southern margin of the Virginia coal field, although the total accumulation of vegetal matter may have been about equally great at all these places.

GLADEVILLE SANDSTONE.

The Gladeville sandstone was named by Campbell from Gladeville, now Wise, a town 2 miles south of the quadrangle, which is built on the outcrop of the sandstone. On account of its importance as a horizon marker it is rather fully described.

The Gladeville underlies Sand Ridge and is exposed on Steele Fork of Cranesnest River, and on Birchfield and Indian creeks. It underlies Bowlecamp Knob, and a few feet of the top of the sandstone outcrops along Mullin and Dotson Forks of Bowlecamp Creek as far as Pound River. It is also exposed on Camp Creek and Georges Fork. The outcrop follows the general course of Pound River across the quadrangle, the sandstone rising northwestward toward Pine Mountain and underlying only the higher knobs near the river. It is a very persistent bed and exceedingly serviceable as a key rock. On the map its outcrop is shown by the stipple pattern between the lines representing the outcrops of the Glamorgan and Yellow Creek coal beds or their horizons.

At Wise the Gladeville sandstone is hard, white, and siliceous and appears to be about 100 feet thick. In all the region north of Sand Ridge, however, it is less purely siliceous and thinner than at Wise. It contains more argillaceous matter and more feldspar and mica, and its thickness does not exceed 60 feet.

WISE FORMATION.

Character and distribution.—The Wise formation includes a mass of shale and sandstone 2,070 feet thick, with many coal beds lying between the Gladeville sandstone below and the Harlan sandstone above. It includes at least 19 distinct coal beds, and it is probable that there are others which have not yet been discovered. The Wise formation constitutes the surface rock in most of that portion of the quadrangle lying south of Pound River. North of the river it also caps some hills and ridges, and southeast of Birchfield Creek it occurs only on the hills, the Norton formation outcropping in the valley bottoms and well up on the hillsides.

Glamorgan coal.—Immediately above the Gladeville sandstone lies the Glamorgan coal, named from Glamorgan, just beyond the south margin of the quadrangle, where the bed is mined. It attains its maximum known thickness in the hills south of the heads of Birchfield Creek and Dotson Fork, northeast of Glamorgan. On Birchfield Creek and Dotson Fork of Bowlecamp Creek the bed is divided by partings, but there is generally a bench 2 feet or more thick. Along Pound River northeast of Pound a persistent thickness of 2½ to 3 feet is shown at numerous openings, but here also the bed includes several partings.

Above the Glamorgan coal occurs 230 feet of shale and sandstone containing five coal beds. The sandstone is highly siliceous, hard, and white, differing in these respects from the prevailing type of sandstone in this region, which is softer, more highly feldspathic, and micaceous. The sandstone bed at the top, just above the uppermost of the five coal beds (Clintwood coal) and in places in contact with that bed, is especially noteworthy, for it is persistent over a large area and either outcrops as a ledge or makes a distinct shelf along the hillside, by which the position of the outcrop of the underlying coal can be determined. All these sandstones and associated coal beds are exposed along the road on Guest River from the south margin of the quadrangle to a point 1½ miles north of Lipps. The first important coal bed above the Glamorgan occurs 60 feet above the Gladeville sandstone. The bed is 2 feet or more thick and appears to persist over the southeastern quarter of the quadrangle.

Blair coal.—About 40 feet above the bed that occurs 60 feet above the Gladeville sandstone lies a coal bed here named the Blair, because it was opened by a man of that name on Lick Branch, 3 miles above the mouth of Indian Creek. This coal is also persistent in the southeastern part of the quadrangle and appears to range from 2 to 5 feet in total thickness.

Clintwood coal bed.—The Clintwood coal lies 100 feet above the Blair coal and 200 to 250 feet above the Gladeville sandstone. It is named from the town of Clintwood, about 1½ miles east of the quadrangle. On Georges Fork and Lick Fork of the Cranesnest River drainage the Clintwood is 6 to 12 feet thick, including partings. Elsewhere it is thinner, though persistent throughout the quadrangle. As noted above, everywhere in the quadrangle the Clintwood is overlain by a sandstone 20 to 40 feet thick, which either rests on the coal bed or is separated from it by only a few feet of shale.

Above the sandstone just mentioned there is a coal bed that has a maximum thickness of 2 feet, or at least such a bed is present in certain localities. It is succeeded by 150 to 200 feet of soft shale, which, over a large area, is followed by about 50 feet of coarse feldspathic and micaceous sandstone.

Bolling coal beds ("Five-foot" bed).—Above the top of the coarse micaceous sandstone, which is about 250 feet above the Clintwood coal, lie two coal beds 20 to 40 feet apart, the upper one being designated the "Five-foot" bed on the outcrop maps of the Clinchfield Coal Corporation. The name Bolling is here applied to both beds because they have been opened near the head of Pound River by several persons of that name. The Lower Bolling coal is 18 inches to 4 feet thick, and the Upper Bolling is 3 to 5 feet thick. The two beds are separated by 20 to 40 feet of shale. These coal beds underlie Black Mountain, Buck Knob, and Bowlecamp Knob, and their horizon is a little below the tops of several knobs and ridges in the southeast corner of the quadrangle. Above the Upper Bolling lies 50 to 80 feet, or in places a greater thickness, of coarse micaceous sandstone, which for long distances outcrops as a low cliff or forms a low escarpment. This sandstone persists throughout the area underlain by the Bolling coals. On South Fork of Pound River the coarse sandstone is overlain by about 140 feet of shale and sandstone, capped by a 40-foot bed of sandstone.

Standiford coals.—Within 100 feet above the Bolling coals there are one or more thin coal beds, and about 260 feet above these coals two beds occur, 20 feet apart, which are here called the Standiford coals because they are mined near the head of South Fork of Pound River by a man of that name. At the type locality the lower Standiford coal is 2 feet 6 inches and the upper about 3 feet thick. These coals appear to underlie the Black Mountain and Buck Knob region, but it is probable that they have been removed by erosion in the country farther east, except possibly in a small area near the top of Bowlecamp Knob.

Taggart coal.—On South Fork of Pound River the strata for 90 to 100 feet above the Standiford coals seem to be chiefly sandstone, and above this sandstone occur two thin coal beds separated by 6 feet of shale, the upper bed being 3 feet and the lower bed 2 feet 6 inches thick. On Roaring Fork of Powell River the name Taggart is applied to a bed believed to be the same as the double bed above described, and that name is adopted here. On Roaring Fork the bed, which has been thoroughly prospected, is double at some points, and one section examined by the writer contains four coal beds in the space of about 75 feet, as shown in the section at location 68 (p. 49). It is supposed that at least the upper two beds of this section represent the horizon of the Taggart coal, the two benches of coal being separated by 20 feet of shale and sandstone. At most points where it has been prospected only one bench is recorded, either because only one bench is present or because only one of two or more benches possibly present was discovered.

Low Splint coal.—The name Low Splint is applied to a coal bed about 200 feet above the Taggart, on the head of Roaring Fork. At

the head of South Fork of Pound River a bed opened on the George Phillips place, 160 feet above the Taggart, is correlated with the Low Splint. It appears to be persistent, and to range in thickness from 2½ to 4 feet, but as it lies high in the hills it is present only in Black Mountain and Buck Knob. It is probably the Buck Knob bed of the Clinchfield Coal Corporation.

Phillips coal.—The Low Splint bed is succeeded by 260 feet of shale and sandstone, in which no coal was seen in this region, and at the top of this shale and sandstone lies a coal bed named the Phillips coal because it has been opened at the Ambrose Phillips place, at the head of South Fork of Pound River, where it is reported to be 26 inches thick and to be all coal.

In the 390-foot interval between the Phillips and the Pardee coal beds, at the head of South Fork of Pound River, the rocks comprise shale and sandstone that contain thin coal beds as follows: An 18-inch bed of coal 80 feet above the Phillips, a 1-foot bed 210 feet above the Phillips, a 2-foot bed 225 feet above the Phillips, and a 6-inch bed 340 feet above the Phillips, or 50 feet below the Pardee bed. Between 210 and 225 feet above the Phillips coal occurs an 8-inch limestone bed, which is the only limestone found in the entire Pennsylvanian section except some nodules in the shales on Elkhorn Creek in Kentucky.

Pardee (Limestone) coal.—The Pardee bed, 390 feet above the Phillips bed, or 1,670 feet above the Gladeville sandstone, is mined at Pardee just west of the southwest corner of the quadrangle. This coal is the Limestone coal bed of the Kentucky Geological Survey reports and the Parsons bed of the Virginia Coal & Iron Co. At Pardee, and for a mile or two to the east within the Pound quadrangle, the bed contains about 10 feet of solid coal, but farther east and northeast it is in places divided by thick partings into two or three benches. It lies 2,800 to 3,100 feet above sea level, and therefore outcrops near the summit of Black Mountain and its radiating spurs. Above the Pardee bed lies about 100 feet of shale overlain by rather coarse grained but flaggy sandstone 300 feet thick, making 400 feet in all to the next higher coal bed, which is known in this region as the High Splint coal.

High Splint coal.—The High Splint coal is 400 feet above the Pardee bed and is a genuine splint coal 4 to 5 feet thick. It occurs so high in the hills that it underlies only a small area on Black Mountain.

HARLAN SANDSTONE.

Above the High Splint coal just described appears to be a few feet of shale, which is followed above by a massive cliff-making sandstone, in places conglomeratic, which is 40 feet thick and which is taken as the basal stratum of the Harlan sandstone. The Harlan sandstone, which extends from the High Splint coal bed to the top of the

highest summits of Black Mountain, is a little over 400 feet thick. It is mostly coarse, thick-bedded to massive sandstone but contains shale beds with at least two coals of unknown thickness, fragments only being seen at two places. One of these coal beds is 100 and the other 300 feet above the High Splint bed.

PENNSYLVANIAN SERIES IN THE KENTUCKY AREA.

Formations present.—In Kentucky the rocks above the Lee formation correspond to the Norton formation and the lower part of the Wise formation of Virginia, and the part corresponding to the Wise probably also represents the Breathitt formation of Campbell[1] in the western part of the Appalachian coal field of Kentucky. (See columnar section, Pl. XI, p. 220.) On account of uncertainty as to the identification of boundaries in Kentucky it is thought best not to attempt a separation of the formations at this time, and it may be found expedient to treat all the rocks above the Lee as a unit in Kentucky. The Lee formation does not outcrop in the part of the quadrangle that lies in Kentucky except as a long narrow block along the Pine Mountain fault. (See p. 182.) The lower 600 feet of rocks corresponding to the Norton formation likewise do not outcrop, but according to Stone,[2] who studied the region farther north on Elkhorn Creek and Big Sandy River, they are composed of shale and sandstone with three coal beds, none of which is over 3½ feet thick. These beds were named by Stone, in ascending order, the Elswick, Auxier, and Milliard beds, and they are 70, 280, and 440 feet, respectively, above the top of the Lee.

Bingham coal.—According to Stone,[3] the Bingham coal lies 600 feet above the top of the Lee. A coal 2½ feet thick outcropping on Shelby Creek for 1½ miles south of the north border of the quadrangle is here regarded as the Bingham. It does not outcrop elsewhere in the quadrangle, but its extension under cover is probably shown in drill holes in which a coal bed was encountered 400 feet below the Upper Elkhorn bed.

Lower Elkhorn coal.—The Lower Elkhorn coal lies 200 feet above the Bingham, and other thin coal beds are associated with it within 40 feet both above and below it. It is 2 to 4 feet thick and has a characteristic laminated bench by which it can be identified. It outcrops on Elkhorn Creek and its tributaries northeast of the mouth of McPeak Branch and also at the headwaters of Beefhide Creek.

Coal 140 feet above the Lower Elkhorn.—The rocks for 140 feet above the Lower Elkhorn bed are largely sandstone, and above this

[1] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, London folio (No. 47), 1898.

[2] Stone, R. W., Coal resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull. 348, 1908.

[3] Idem, pp. 25-26.

sandstone lies a coal bed 2 feet thick, which is exposed at Consolidation No. 201 mine. A coal bed 4 feet thick and 150 feet above the Lower Elkhorn on Pigeon Branch in the northeastern part of the quadrangle is probably the same bed.

Above the coal bed last described occurs about 70 feet of sandstone that may correspond to the Gladeville sandstone of Virginia. As the Upper Elkhorn coal bed, which is about 40 feet above the top of this sandstone, is, according to Stone,[1] 1,000 feet above the Lee formation, the thickness of the rocks that possibly correspond to the Norton formation of Virginia is 930 feet in this part of Kentucky. Within 20 feet above the sandstone just described lie two coal beds, both of which are generally thin so far as seen, but one of which appears to be 2 to 3 feet thick on Elkhorn Creek 1 mile above Jenkins. The Upper Elkhorn bed lies 30 feet above the upper of these coals and is separated from it by shale.

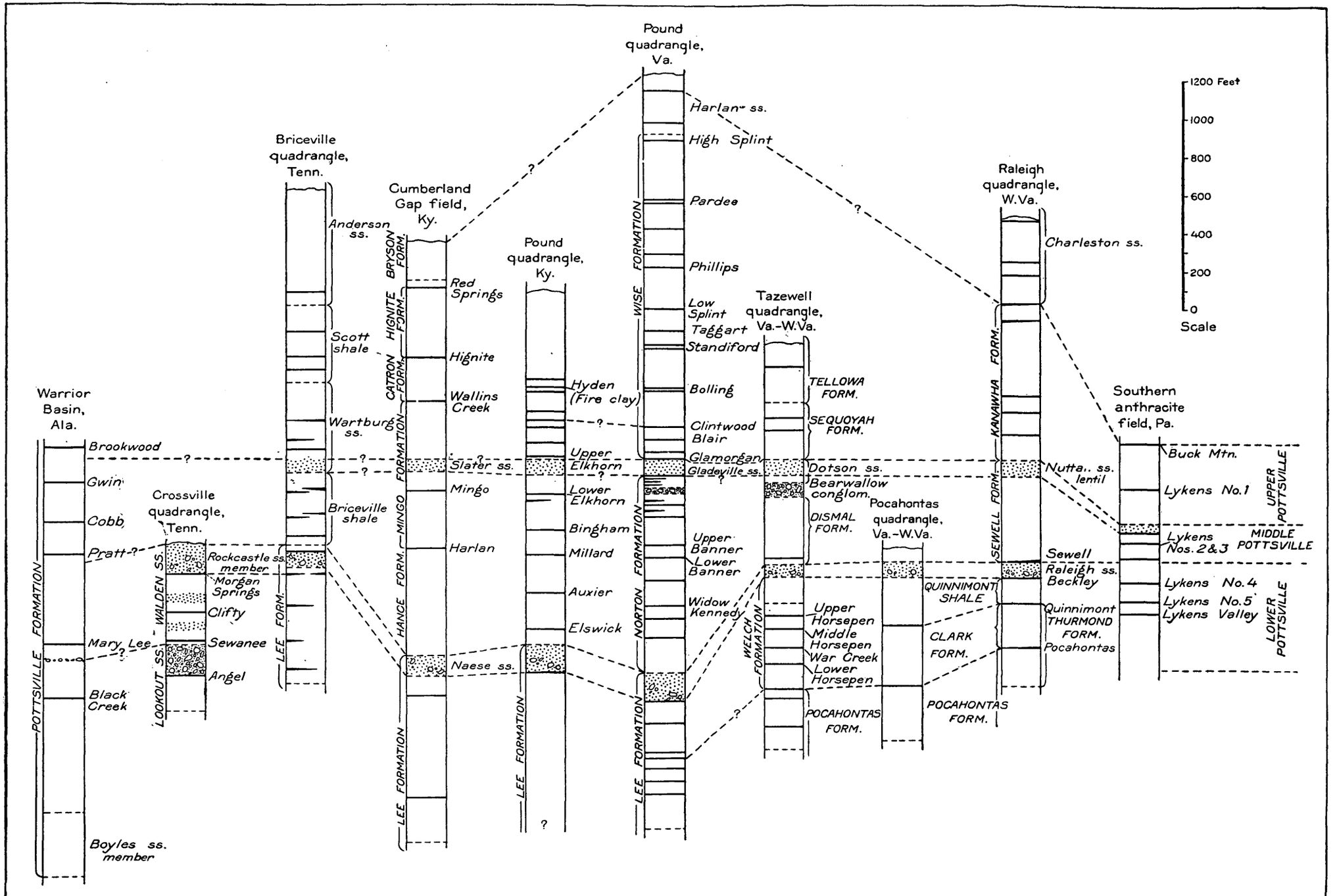
Upper Elkhorn coal.—The Upper Elkhorn bed is the thickest and most important coal bed in the part of this quadrangle that lies in Kentucky. In the northwestern part it is 4 feet thick; elsewhere its prevailing thickness is 6 to 8 feet, and throughout most of the area in which this thickness prevails it has near the middle a clay parting 1 inch to 1 foot thick. If the sandstone 50 feet below this coal is the Gladeville of Virginia, the Upper Elkhorn bed corresponds in position to the unnamed bed 60 feet above the Gladeville in Virginia (described on p. 173) and the thin coals at the top of the sandstone correspond to the Glamorgan coal.

Coals between the Upper Elkhorn and Hyden (Fire Clay) bed.—For a distance of 400 feet above the Upper Elkhorn bed there are shales and sandstones that include a number of coal beds as follows: A coal, generally about 1 foot thick, 70 feet above the Upper Elkhorn bed and separated from it by shale; a dirty coal bed, 2 to 3 feet thick, in sandstone, 175 feet above the Upper Elkhorn; a bed 3 feet 4 inches thick 200 feet above the Upper Elkhorn; a bed 2 feet thick 240 feet above the Upper Elkhorn; and a bed 2½ feet thick 340 feet above the Upper Elkhorn.

Hyden (Fire Clay) coal.—A bed probably persistent throughout the Kentucky area, and called the Hyden or Fire Clay bed in the reports of the Kentucky Geological Survey,[2] lies 400 feet above the Upper Elkhorn bed. Its thickness appears to be generally 3 to 4 feet, but it reaches a thickness of over 6 feet on Meadow Fork in the western part of the quadrangle. A persistent parting of flint clay renders its identification certain over a large area in eastern Kentucky. As it occurs high in the hills, it underlies comparatively small areas. At

[1] Stone, R. W., op. cit., p. 37.

[2] Kentucky Geol. Survey Bull. 13, 1912.



SECTIONS SHOWING CORRELATION OF POTTSVILLE FORMATION ALONG THE EAST SIDE OF THE APPALACHIAN COAL FIELD.

the points examined there is a thin bed above and another below the Hyden bed, and reports indicate that these beds are also persistent.

Fortunately, all these beds above the Upper Elkhorn are exposed along the new highway between Elkhorn Creek and McRoberts, and the part of the generalized section in Kentucky including them is taken directly from this road section.

Above the Hyden bed lie 500 feet of strata which are mostly sandstone, in places finely conglomeratic. The conglomeratic phase was seen only in certain bowlders, and, to judge from the distribution of these bowlders, the small quartz pebbles occur in pockets at some horizon high in the mass. The ridges in the northwest part of the quadrangle are capped by this sandstone, which in many places makes a cliff.

GENERAL CORRELATION OF THE FORMATIONS.

From incomplete paleobotanic studies David White refers all the coal measures of Virginia and easternmost Kentucky and the region southwestward into Alabama to the lowest division or Pottsville group of the Pennsylvanian series. The type location of the Pottsville group is Pottsville in the southern anthracite field of Pennsylvania. The Pottsville is for convenience subdivided by White into lower, middle, and upper Pottsville, the subdivisions being based primarily on the presence in each division of certain distinctive species of fossil plants. Some of the subdivisions of the Pottsville may be distinguished over large areas by lithologic characters, as, for example, the Lee formation in Virginia and Tennessee, which is shown by the paleobotanic evidence to coincide nearly if not completely with the lower Pottsville. In localities where the subdivisions are not lithologically distinct the boundary between any two may be marked by a particular stratum which is widely identifiable, especially where one of the formations marks an extension of the sea over the land. Thus throughout the southern part of the Virginia and West Virginia coal fields the boundary between the lower and middle Pottsville as paleobotanically determined is approximately marked by the Raleigh sandstone. Where lithology fails as a criterion for fixing boundaries or where localities are widely separated, as those in different coal fields or basins, it is necessary to resort to the fossil plants.

The probable stratigraphic equivalence of the Pottsville formations and coal beds in the Pound quadrangle to those of other areas along the eastern border of the Appalachian coal field is indicated in the plate of sections (Pl. X). In this plate the correlations of formations and beds between districts or basins distant from the Pound quadrangle are based on partial studies of the fossil floras by White, and are regarded by him [1] as provisional and subject to revision when either

[1] White, David, Appalachian coal field: U. S. Geol. Survey Prof. Paper 71, pp. 430–455, 1912.

the paleobotanic material of the formations is more completely studied or, where possible, the beds are stratigraphically traced from point to point in detail and the depositional characteristics of the formations are more fully recognized. The correlations of the formations and beds in and near the Pound quadrangle are made by the present writer.

As already noted, the Lee formation is lower Pottsville. This formation extends southwestward into Tennessee and is equivalent to the Lookout and the greater part of the Walden sandstone of southern Tennessee. Northeastward the Lee corresponds to the Pocahontas, Welch, and Raleigh formations of the Tazewell quadrangle; to the Pocahontas, Clark, Quinnimont, and Raleigh formations of the Pocahontas quadrangle; to the Thurmond, Quinnimont, and Raleigh formations of the Raleigh quadrangle; and approximately to the lower 800 feet of the Pottsville of the southern anthracite field of Pennsylvania, including "Lykens No. 4" coal.

The Norton formation is classed by White as middle Pottsville, and the overlying Gladeville sandstone is regarded by him as probably near the horizon of the Corbin conglomerate lentil of the Lee formation as the strata are mapped in the London folio, the London quadrangle lying in Kentucky 75 miles due west of the Pound quadrangle. The Gladeville seems to represent the Slater sandstone member of the Mingo formation of the Cumberland Gap region, and lies within the limits of the Wartburg sandstone in the Wartburg quadrangle, Tennessee. Northeastward the Gladeville is supposed to be represented by the Dotson sandstone of the Tazewell quadrangle and the Nuttall sandstone lentil at the top of the Sewell formation in the Raleigh quadrangle. The Sharon conglomerate member of the Pottsville (upper Pottsville) of western Pennsylvania is also regarded as lying at about the same stratigraphic horizon, though it is thought that it may be higher. It is not maintained that the sandstone strata at the different points are parts of one continuous stratum or that they are exactly at the same stratigraphic horizon and of precisely the same age, but it is fairly well established on stratigraphic and paleobotanic grounds that they do not vary greatly from the same horizon and age throughout.

Southwestward from the Virginia coal field the Norton formation is represented by beds between the Rockcastle conglomerate member and the base of the Corbin conglomerate lentil of the Lee formation as mapped in the London folio; by the Hance and the lower three-fifths of the Mingo formation of the Cumberland Gap region, and by the Briceville shale and possibly by the lower part of the Wartburg sandstone of the Briceville and Wartburg quadrangles, in Tennessee. Northeastward the Norton correlates with the Dismal and Bearwallow formations of the Tazewell quadrangle; with all the Sewell

formation below the Nuttall sandstone lentil in the Raleigh quadrangle, and with that part, 200 feet thick, of the Pottsville of the southern anthracite field extending roughly from 370 to 570 feet below the Buck Mountain coal bed and including the Lykens coal beds Nos. 2 and 3 near the middle.

The Wise formation is shown by the fossil plants to be upper Pottsville. It represents the greater part at least of the Breathitt formation of the London quadrangle of Kentucky. It also represents the Bryson, Hignite, Catron, and probably the upper two-fifths of the Mingo formation of the Cumberland Gap field, and the upper part of the Wartburg sandstone, with the Scott shale, and the greater portion, at least, of the Anderson sandstone of the Wartburg and Briceville quadrangles. Beds of Wise age are also included in the Sequoyah and Tellowa formations of the Tazewell quadrangle, the Kanawha formation of the Raleigh quadrangle, and in the upper 370 feet of the Pottsville of the southern anthracite field, Pennsylvania. The Kanawha formation, which together with the Nuttall sandstone lentil of the Sewell formation presents the most typical section of the upper Pottsville in southern West Virginia, apparently represents also the equivalent of the lower part of the Harlan sandstone of the Estillville quadrangle.

STRUCTURE.

GENERAL FEATURES.

By geologic structure is meant the "lay" or attitude and arrangement of the rocks considered as extensive strata composing the earth's crust. Stratified rocks are deposited in a nearly horizontal attitude. Over most of the area of the Pound quadrangle, however, they are not now horizontal but are very gently inclined, though in some places, as along the west escarpment of Pine Mountain, they dip steeply. There are also breaks, called faults, which extend to great depths and along which the strata on one side have been raised to higher levels than the corresponding strata on the other side or even thrust over on top of them.

In the great period of movement during which the rocks of the Appalachian region were tilted and broken, a large wrinkle or anticline was produced along the eastern side of the coal region, about 20 miles west of the margin. The rocks lying between this wrinkle and the margin of the field were compressed into a troughlike synclinal fold which extends from northern Tennessee to Big Sandy River. Toward the northern extremity the fold is less pronounced than it is farther to the southwest, and in the Pound quadrangle it is so broad and flat as to be scarcely recognizable.

The great upward wrinkle or anticline that bounds this trough on the northwest was compressed so severely that the rocks broke,

forming a fault. In the Pound quadrangle this fault and the inclined strata bounding it on the east are the dominating features of the geologic structure. Northwest of the fault the rocks are comparatively undisturbed, and they lie approximately in the horizontal attitude in which they were deposited.

FOLDS AND FAULTS.

Pine Mountain fault.—The Pine Mountain fault is the major structural feature of the region. It extends in a nearly straight line diagonally across the quadrangle, near but somewhat above the west base of Pine Mountain in Kentucky. The fault is compound. There are two breaks, which, for the purpose of description, may be conceived as having occurred at different times. By the earlier break a thin wedge of conglomeratic sandstone extending several miles both northeast and southwest of Jenkins was thrust into contact with rocks 1,200 feet higher than the top of the Lee. Also in the northeastern corner of the quadrangle and extending a mile beyond its edge a mass of hard siliceous conglomeratic sandstone (Lee) that lies in a vertical attitude has been pushed, probably by the earlier fault, half a mile westward over flat-lying rocks stratigraphically 1,000 feet, at least, above the top of the Lee. Later another break occurred along which the displacement differs. On the west side of the quadrangle the Mississippian part of the Grainger shale is in contact with the wedge of the Lee, brought up by the earlier fault; 3 miles east of the west margin the fault brings the black Devonian shale into contact with the Lee, and in the northeast quarter of the quadrangle the movement was so great that the upper 800 feet of the black shale has been thrust over the earlier fault plane and is in contact with Pennsylvanian rocks 2,000 feet above the base of the Lee, the total displacement here being about 4,000 feet. Sections A–B, C–D, and E–F (Pl. X) illustrate the structural and stratigraphic relations brought about by these faults.

Pound syncline.—From Pine Mountain the rocks dip southeastward to an axis following the general course of Pound River, and named the Pound syncline. The southeastward dip on the west escarpment of Pine Mountain is generally steep, but ranges from 20° to nearly vertical. Along the crest of Pine Mountain the dip is 20° to 40°. At the east base it is 10° and diminishes thence gradually to zero at the axis of the Pound syncline.

Buck Knob anticline and Indian Creek syncline.—In the southeastern part of the quadrangle south of the Pound axis the rocks in general dip northwest to that axis, but near Buck Knob the general northwest dip is interrupted by a subordinate anticline that extends nearly north and south through Buck Knob and is called the Buck Knob anticline. The existence of this low anticline involves a corresponding syncline, the axis of which is parallel to the anticline and to Indian

Creek, which lies one-half to 1 mile to the west. This syncline is here named the Indian Creek syncline. On the east side of this syncline steep dips occur locally. At Glamorgan the dip is 10° W., and three-fourths of a mile north, at the intersection of the highway with the tramroad, it is 40° W. On the west side of Indian Creek, 5 miles above the mouth, the Clintwood coal and overlying sandstone dip 10° W. On the Buck Knob axis north of the knob the Bolling coals are about 2,200 feet above sea level; on the Indian Creek axis they are about 2,000 feet, the eastward dip being 200 feet in 2 miles; and on the Pound axis, west of Dewey, the same coals are about 1,900 feet above sea level, giving a west dip from the Buck Knob to the Pound axis of 300 feet. Apparently both the Indian Creek and Buck Knob folds flatten out and become imperceptible to the east of Dewey; southward both axes rise but maintain the same relative position, the Bolling coals on the south margin of the quadrangle being as nearly as can be determined 2,700 feet above sea level on the Buck Knob anticline and 2,500 feet in the Indian Creek syncline.

SUMMARY.

Aside from these comparatively subordinate folds, the general structure of the part of the quadrangle which lies in Virginia is that of a broad and comparatively shallow unsymmetrical trough. At the southeast corner of the quadrangle the Gladeville sandstone is 2,500 feet above the sea and descends thence to about 1,500 feet above the sea along the Pound axis, the average dip being about 1°. Along the crest of Pine Mountain the Gladeville would, if restored, lie 5,000 feet above sea level, so that the total dip is 3,500 feet from the crest of the mountain to the axis of the Pound syncline, an average dip of 18°.

In Kentucky the rocks dip gently and nearly uniformly northwestward about 300 feet from the base of Pine Mountain to the northwest corner of the quadrangle, as shown by a great number of spirit-level determinations on the Upper Elkhorn coal beds. The elevation of this bed is 1,600 feet above sea level along the west side of the Pine Mountain fault, except in the extreme southwestern corner of the Kentucky area, where it drops to less than 1,500 feet. Low domes on which this bed rises to 1,640 and 1,720 feet occur between Cane and Joes branches, and also near the mouth of Marshall Branch, but with these exceptions it dips with a nearly uniform gradient to about 1,350 feet above sea level on Rockhouse Creek, in the northwest corner of the quadrangle.

DETAILED DESCRIPTION OF THE COAL BEDS.

On account of the uncertainty of correlation between the parts of the quadrangle that lie in Virginia and Kentucky the coal beds of the two areas are separately described.

COAL IN THE VIRGINIA AREA.

A comprehensive idea of the number, thickness, and sequence of the coal beds in the Virginia part of the Pound quadrangle can be obtained by an examination of the generalized columnar section for that area (Pl. X, p. 178).

COAL BEDS OF THE LEE FORMATION.

In this area very little is known of the coal beds of the Lee formation, which outcrop only along the southeast slope of Pine Mountain. Elsewhere they are buried deeply beneath overlying formations and have been penetrated at only one point by a diamond drill. On the outcrop along the eastern slope of Pine Mountain the surface is heavily timbered. No prospecting appears to have been done in this unfavorable belt, and, as natural exposures of the coal beds are few, opportunities to examine the beds are very rare indeed. Only on the Pound Gap road, where the formation has been exposed in road making and by the wear incident to a highway, was any coal seen in outcrop.

However, considerable coal is known to exist in the Lee in beds 14 inches or more thick and at depths not exceeding 2,000 feet. The most definite knowledge of the number, thickness, and stratigraphic relations of these beds is derived from the record of a drill hole on Cranesnest River, 1 mile east of the quadrangle and a short distance below the mouth of Lick Creek. (See section 1, Pl. IX, p. 170, in which details of the beds are shown.) In this well a coal 2 feet 6 inches thick is shown near the base of the Lee and eight beds 2 inches to 2 feet 2 inches thick are shown within the Lee. Six of these beds are grouped in the 300 feet just below the middle of the formation. As shown in Plate X, the Pocahontas coal appears to be represented in this group of beds.

On the Pound Gap road five beds are exposed. In the well section the greater number of beds is grouped just below the middle of the formation. In the road section the greater number, so far as shown, seems to be above the middle of the formation.

The lowest bed in the Pound Gap road section is imperfectly exposed 500 feet east of the summit at location 1.[1] It is about 200 feet above the base of the Lee and has a thickness of 2 feet 6 inches. Farther down on the east slope of the mountain, near the abandoned narrow-gage railroad station, four beds are exposed at locations 2, 3 4, and 5. At locations 2 and 3 the following sections were measured:

[1] Numbers refer to locations on the map (Pl. XI, p. 220).

Sections of coal bed on Pound Gap road.

Location 2.

	Ft.	in.
Coal, dirty		6
Clay		1
Coal, dirty		8
Clay, white.		
	1	3

Location 3, at narrow-gage railroad station.

	Ft.	in.
Shale and sandstone	10	
Clay, carbonaceous		7
Coal		3
Clay		2
Coal		2
Shale	20	
Total coal		5

The carbonaceous clay at this point is crowded with fern pinnules.

At location 4, which is 500 feet nearly east of location 3, a bed has been prospected superficially and 18 inches of clean coal was exposed. This bed is probably but a short distance above the bed at location 3. At location 5, near location 4, another bed 3 inches thick and 20 feet above the bed at location 4 is exposed.

COAL BEDS OF THE NORTON FORMATION.

General character.—The coal beds of the Norton formation are the principal beds mined along the southern margin of the Virginia coal field from Dump Creek to Big Stone Gap, but in the Pound quadrangle they are not so well developed as farther south. This feature is shown by diamond-drill borings in the southeast part of the quadrangle and by such few exposures as are known along the outcrop of the formation between Pound River and Pine Mountain.

Sections of the diamond-drill borings are shown on Plate IX (p. 170). The wells are too few and too widely separated to give full information regarding the coal beds, but they seem to afford a fairly reliable indication of the general condition and possible value of the Norton coal beds in the eastern half of the quadrangle. They reveal a great number of coal beds, but most of them are only a few inches thick. Every well, however, shows one or more beds 14 inches or more thick and less than 1,000 feet below the surface. In a few borings thicker beds were penetrated, for example, a bed 2 feet 10 inches thick at a depth of 629 feet in well No. 2; a bed 4 feet 3 inches thick at 832 feet in well No. 3; a bed 2 feet 5 inches thick at 847 feet in well No. 11; and a bed 7 feet 1 inch thick at 351 feet in well No. 15, which is, however, 2 miles east of the quadrangle. Details of the section of the thicker beds are shown in the figures. The ultimately workable coal is therefore considerable, although such coal will not be available until after the exhaustion of the thicker and more easily accessible coal beds of the country.

Correlation.—The identification of the individual coal beds of these sections and their correlation with the beds of the Norton formation along the southern margin of the field, where they seem to be more

constant in number and position, are rather uncertain. For the purpose of comparison with the better-known section to the south the generalized (average) section from the Bristol folio is given on Plate IX (p. 170). The tentative correlations are indicated by the broken lines on Plate X. The sections are arranged on the horizon of the bottom of the Gladeville sandstone, which is identified throughout the region with a reasonable degree of certainty. All the coal beds recognized in the Toms Creek region appear to be present in the Pound quadrangle, except the Upper Banner, which is the most important bed in the Toms Creek region. The Jawbone and so-called Imboden beds appear to be persistent but thin. There are two persistent beds 100 feet apart in proximity to the horizon of the Kennedy coal, and it is uncertain which is the true Kennedy. The Lower Banner is persistent and at some points has considerable thickness, as in boring No. 3, but more generally it is thin or so broken by partings as to be worthless. In boring No. 3 the section is as follows:

Section of Lower Banner coal in drill hole No. 3, Birchfield Creek.

	Ft.	In.
Shale.		
Coal	3	6
Clay		3
Coal		6
	4	3

In boring No. 8 the bed is 3 feet 6 inches thick, but the coal is intimately mixed with shale and is probably worthless.

It is possible that the persistent group of thin coal beds below the Edwards coal or group represents the Upper Banner, which is separated from the Lower Banner by more than twice the thickness of rocks separating the two beds on the southern outcrop of the Norton formation. If this rather doubtful supposition is correct, the 7-foot bed in boring No. 15 might be regarded as representing the Upper Banner coal.

The upper group of thin beds represents the Edwards or, as is supposed, the horizon of the true Imboden coal. In boring No. 3 this group is 3 feet thick with a thin parting; elsewhere it is widely parted.

Outcrops.—At only a few places in the quadrangle or just outside its eastern and western margins were exposures of any of the coal beds of the Norton formation seen. On Rumley Branch, about 2 miles north of Flat Gap, at location 6, a bed of clean coal 2 feet thick has been opened and worked on a small scale. About 2 miles south of Osborns Gap, toward the eastern side of the quadrangle, at locations 7, 8, and 9, coal 18 inches in thickness is exposed, and about 1 mile farther east, at location 10, a blossom indicates a thin coal. All these coal beds seem to lie in the lower half of the Norton formation.

On Cumberland River, one-half mile beyond the western margin of the quadrangle, a bed of clean coal 30 inches thick has been worked on the Ira Sturgill place. On Pine Creek, three-fourths of a mile west of the east boundary of the quadrangle, at location 11, a bed 1 foot 9 inches thick is exposed at creek level. These outcrops occur apparently near the middle of the Norton formation and the bed possibly represents one of the Banner coals.

On North Fork of Pound River, about 1 mile west of Donkey, at location 12, a bed is opened that has the following section:

Section of coal bed 1 mile west of Donkey, at location 12.

	Ft.	in.
Shale.		
Coal		10
Bone		3
Coal	1	9
Sandstone.		
	2	10

At location 13, one-half mile west of location 12, two thin coal streaks are exposed in the bottom of a ravine. These coals appear to be 150 to 200 feet below the Gladeville sandstone and therefore at the horizon of the Edwards or Imboden coal.

Yellow Creek coal.—One-half mile beyond the western margin of the quadrangle a coal bed is exposed just beneath the Gladeville sandstone. The same bed is exposed at the schoolhouse one-half mile west of Flat Gap (location 14). The sections at these localities are as follows:

Sections of Yellow Creek coal bed.

One-half mile west of quadrangle on Cumberland Valley road.

	Ft.	in.
Sandstone.		
Coal		5
Clay		1
Coal	2	4
Clay.		
	2	10

At schoolhouse on Cumberland River one-half mile west of Flat Gap (location 14).

	Ft.	in.
Sandstone.		
Coal		5½
Shale		2
Coal		9
Clay.		
	1	4½

The same bed has also been opened on a small stream at a point 1 mile northeast of Flat Gap (location 15) but could not be seen. It has also been exposed in grading the railroad along North Fork of Pound River at a point 2 miles southwest of Donkey (location 16), where it has the following section:

Section of coal bed 2 miles southwest of Donkey, at location 16.

	Ft.	in.
Coal	1	1
Clay		1½
Coal		6
	1	8½

Other beds.—The only other locality at which Norton coals are known in outcrop sufficiently near this quadrangle to be considered is on the new road between Wise and Clintwood, 1½ miles south of Cranesnest River and one-third of a mile east of the quadrangle margin, where the coal beds have been exposed in grading. Nine coal beds are exposed in a vertical distance of about 350 feet below the Gladeville sandstone, but only one bed, about 250 feet below the sandstone, is of possible workable thickness. Its section is given below:

Section of coal on new Wise-Clintwood road, about 2 miles south of Cranesnest River.

	Ft.	In.
Shale.		
Coal		10
Clay		4½
Coal	1	6
Sandstone.		
	2	8½

The other beds are all thin and worthless. This section is in full agreement with the upper part of the diamond-drill sections.

The facts in hand appear to warrant the conclusion that though the Norton coal beds of this quadrangle are of less value than they are along the southern margin of the Virginia coal field, drilling has demonstrated that there are considerable areas of workable coal in the different beds underlying this area. Exploitation of these coals, however, can only be safely undertaken after the location and extent of the workable areas have been determined by thorough prospecting with the diamond drill.

COAL BEDS OF THE WISE FORMATION.

The Wise formation contains a greater amount of coal in workable beds than any of the other formations of the quadrangle. The full thickness of the formation is present only in Black Mountain in the southwestern corner of the quadrangle, because east of that area a progressively greater thickness of the formation has been eroded.

Glamorgan coal.—Immediately above the Gladeville sandstone lies the Glamorgan coal bed, named from the town of Glamorgan, located just south of the quadrangle opposite the head of Indian Creek. The bed is best developed in the hills to the north and northeast of Glamorgan. In the Glamorgan mine, which extends 7,000 feet northeastward toward Birchfield and Dotson creeks, the bed is divided into two benches by a parting which is one-fourth inch thick at 7,000 feet from the mouth, 1 inch at 6,000 feet, 10 feet or more at 1,000 feet and 30 feet thick at the mine mouth. At 6,000 and 7,000 feet from the mine mouth the bed has the following section:

Sections of Glamorgan coal bed in the Glamorgan mine.

Section 7,000 feet from mouth.

Shale.	Ft.	in.
Coal[1] (one-fourth inch parting near middle)	3	8
Bone		1
Coal[1]		7
Shale.		
	4	4

Section 6,000 feet from mouth.

Shale.	Ft.	in.
Coal[2]	1	9
Bone		1
Coal[2]	1	10
Bone		1½
Coal[2]		8
	4	5½

On account of the split described above only the lower bench is mined in the first 1,000 feet along the main entry of the mine, and nowhere else in the quadrangle is the bed known to be so thick as in the deeper part of the Glamorgan mine. On the new Wise-Clintwood road near the eastern margin of the quadrangle (location 17) the bed is 2 feet 1 inch thick.

On Indian, Dotson, and Birchfield creeks and on the forks of Bowlecamp Creek the Glamorgan coal is 1 foot 6 inches to 2 feet 6 inches thick, including partings.

On Birchfield Creek, 2 miles above the mouth of Dotson Fork, at locations 18 and 19, the thickness of the bed is 1 foot 9 inches and 2 feet 4 inches, respectively. On the west side of Indian Creek, three-fourths of a mile below Riley School (location 20), the bed has been opened and shows the following section:

Section of Glamorgan coal on Indian Creek, three-fourths of a mile below Riley School, at location 20.

Shale.	Ft.	in.
Clay, with coal streaks		4
Coal	2	
	2	4

The clay with coal streaks in the roof is characteristic of the bed northeast of Pound.

Along the lower course of Indian Creek, in the vicinity of Pound, and on the lower courses of the three forks of Bowlecamp Creek, the Glamorgan bed is split into two or three thin beds of no value. Toward the head of Dotson Fork of Bowlecamp Creek, at locations 21 and 22, it is in better condition, as shown by the following sections, which also show its irregularity in short distances:

Sections of the Glamorgan coal bed near the head of Dotson Fork of Bowlecamp Creek.

Location 21.

Shale.	Ft.	in.
Coal	1	6
Shale	8	
Coal		6
Sandstone, Gladeville.		
	10	

Location 22.

Sandstone.	Ft.	in.
Coal	2	2½
Shale		2
Coal		2
Clay.		
	2	6½

[1] Included in sample, analysis 15101, p. 218.

[2] Included in sample, analysis 15100, p. 218.

One mile northeast of Pound the bed is barely of workable thickness, but it improves farther northeast along the river, as shown by the sections at location 23, on Mill Creek, 1 mile northeast of Pound, and at location 24, on Camp Creek near its mouth.

Sections of Glamorgan coal bed on Mill and Camp creeks.

Location 23, on Mill Creek.			Location 24, on Camp Creek.		
Shale.	Ft.	in.	Shale.	Ft.	in.
Coal		6	Coal		6½
Clay	1	2	Clay	1	4
Coal		10½	Coal	3	2
Bone		2	Clay		½
Coal		3	Coal		¾
Clay.			Clay.		
	2	11½		5	1¾

These sections show the range in thickness and character of the bed in this part of the quadrangle. Its improvement continues northeastward as far as Freeling, about a mile east of the edge of the quadrangle.

Along North Fork of Pound River, southwest of Pound, to a point within 2 miles of Flat Gap post office the presence of the Glamorgan coal is shown by several exposures and openings, but so far as definite knowledge of it could be obtained it is not of workable thickness.

Coal bed 50 to 70 feet above the Gladeville sandstone.—A persistent coal bed lies 50 to 70 feet above the Gladeville sandstone and is generally about 2 feet thick over a considerable area. This bed is exposed on Guest River for a mile north of the quadrangle boundary, on the South Fork of Pound River to the vicinity of Dewey, on the forks of Bowlecamp Creek, and along the new Wise-Clintwood road. Three-fourths of a mile northeast of Dewey (location 25) and at Glady School, at the mouth of Glady Creek (location 26), the following sections were measured:

Sections of coal bed 50 to 70 feet above the Gladeville sandstone.

Location 25.			Location 26.		
Shale.	Ft.	in.		Ft.	in.
Coal, dirty		4	Coal		10
Coal, clean	1	3	Parting, slaty, thin coal	1	8
Coal, bony		7	Coal, bony		6
Clay.					
	2	2		3	

Along South Fork of Pound River, between Glady School and Donkey, at least four coal beds that lie close together appear to occur at about the horizon of the bed here described, but the exact identification is doubtful.

On Mullins Fork, 2½ miles above the mouth, at location 27, this bed seems best developed, as shown by the following section:

Section of coal bed on Mullins Fork, 2½ miles above its mouth, at location 27.

	Ft.	in.
Shale.		
Bone		6
Coal	1	3
Clay	1	2
Coal	1	10
	4	9

Near the head of Dotson Fork of Bowlecamp Creek, at location 28, the bed is 38 inches thick and consists of clean coal, On the new Wise-Clintwood road, at locations 29 and 30, the bed has an upper bench of coal 1 foot 6 inches thick, underlain by thin coal streaks and clay partings 1 to 2 feet thick.

On Guest River, between Lipps and a point a mile northwest along the road, five coal beds dip northward and pass in succession below the road level. By projecting the beds into a plane as nearly as possible according to the dip, the following section is obtained:

Section of coal beds along Guest River road, for 1 mile north of Lipps.

	Ft.	in.
Coal, reported thickness	2	
Sandstone, hard, siliceous	20	
Interval, not exposed	20	
Coal, Clintweed (?)	2	
Sandstone	10	
Shale	10	
Coal, Clintwood split (?)	2	3
Sandstone	15	
Interval, not exposed	10	
Sandstone	5	
Interval, not exposed	20	
Coal, Blair (?)	2	
Sandstone, partly hard, siliceous	40	
Coal, reported thickness 3½ feet (next above Glamorgan bed); thickness seen	2	
	160	3

This section includes the group of coal beds between the Gladeville sandstone and the Clintwood bed (described on p. 174), except that it does not extend down to the Glamorgan coal. This bed, however, shows in the road at the quadrangle boundary one-half mile south of Lipps.

The coal next above the Glamorgan bed is opened at Lipps (location 31), but the opening is partly closed. Two feet of solid coal was seen and the bed is reported to be 3½ feet thick.

Blair coal.—On Lick Branch of Indian Creek, 3 miles above its mouth, a coal bed of good thickness has been opened on the Blair property and therefore named the Blair bed. At this place it has the following section:

Section of Blair coal bed at the Blair opening on Lick Branch of Indian Creek, at location 32.

	Ft.	in.
Shale.		
Coal	2	
Shale	10	
Coal	1	2
Coal, shaly		3
Coal	1	3
Coal, shaly	1	8
Coal	1	
Total coal, lower bed	5	4

There are really two beds here, separated by 10 feet of shale, and it is possible that the lower represents the bed 50 to 70 feet above the Gladeville sandstone previously described, the situation being similar to that on South Fork of Pound River between Glady School and Donkey. (See p. 190.) On McFall Fork, at location 33, the bed is split by many partings, as shown below:

Section of Blair coal bed on McFall Fork at location 33.

	Ft.	in.
Shale, black at bottom.		
Coal		6
Parting		½
Coal		2½
Clay		5½
Coal		11
Bone		2
Coal		3
Clay (2 feet).		
	2	6½

On Mullins Fork, 2½ miles above its mouth, at location 34, the bed has been opened and consists of clean coal 2 feet 2 inches thick. On the new Wise-Clintwood road, at location 35, the following section was measured:

Section of Blair coal bed on the Wise-Clintwood road at location 35.

	Ft.	in.
Shale.		
Coal	1	2
Clay	1	6
Coal		7
	3	3

In the southeast portion of the quadrangle this bed is 2 to 5 feet thick, including partings.

On the head of Dotson Fork of Birchfield Creek, at locations 36 and 37, the Blair bed is over 5 feet thick and its section is very similar to that at the Blair opening (location 32), described above.

On Guest River just north of Lipps, at location 38, the bed is composed of clean coal 2 feet or more thick. (See section, p. 191.)

Clintwood coal bed.—The Clintwood coal is a thick bed throughout the region bounded roughly by Pound River and Birchfield and Indian creeks and extending eastward to Clintwood, 2 miles east of this quadrangle, from which place the bed takes its name. It persists as a thinner and parted bed over the rest of the quadrangle, where the rocks at its stratigraphic horizon have not been eroded. It is thickest on Georges and Lick forks, where it is made up of two or more benches of coal separated by clay partings, some of which are 1 foot or more thick. In other parts of the quadrangle it seems to be split into two distinct beds separated by a considerable thickness of shale and sandstone. It everywhere maintains a nearly uniform distance of 200 feet above the Gladeville sandstone, and over a large part of its area it is overlain by a hard siliceous sandstone by which its outcrop may be determined.

The bed has been extensively prospected by the Clinchfield Coal Corporation throughout the area of its best development. A few sections out of many are given below to show its thickness and character. On the head of Lick Fork, at location 39, the bed is 15 feet thick, as shown below:

Section of Clintwood coal bed on head of Lick Fork, at location 39.

	Ft.	in.
Shale.		
Coal and bone		3
Coal	1	2
Clay (average)	1	3½
Coal	3	1½
Clay		1½
Coal		3½
Bone		2½
Coal	6	10¾
Shale		9½
Coal	1	3½
	15	5¼

This appears to be about the maximum thickness of the bed.

The general condition shown by the section just given holds for the Georges Fork region, although there is considerable range in the total thickness of the bed and in the number and thickness of its component parts. The clay partings in this region are a serious detriment to the

value of the bed. North of the ridge north of Georges Fork the bed decreases in thickness and deteriorates in general character as shown in the following two sections:

On a small stream just east of Camp Creek, at location 40, and on Pound River, 1¼ miles south of Phipps, at location 41, the bed is made up as follows:

Sections of Clintwood coal bed east of Camp Creek and 1¼ miles south of Phipps.

Location 40, west of Camp Creek.

Sandstone.	Ft.	in.
Coal		10
Clay		10
Coal	1	8
Clay		½
Coal		4
Clay		½
Coal	1	5
Clay.		
	5	2

Location 41, 1¼ miles south of Phipps.

Shale.	Ft.	in.
Coal	1	4
Clay	3	2
Coal		9
Clay		1
Coal		9
Clay.		
	6	1

The bed is thus of less value at location 41 than at location 40.

North of Birchfield Creek, 1½ to 2 miles west of the quadrangle boundary, at locations 42 and 43, the bed is in good condition and is immediately overlain by sandstone.

Section of Clintwood coal bed north of Birchfield Creek and 1½ miles west of quadrangle boundary, at location 42.

Sandstone (40 feet).	Ft.	in.
Coal		8½
Clay		½
Coal	3	2½
Clay		½
Coal		2
Bone		4
Clay	1	6
Coal	1	
Clay		5
Coal		2
Bone		1½
Coal		1½
Bone		1½
Coal		8
Clay (5 feet).		
	8	7½

The bed at this point carries 3 feet 11 inches of workable coal at top, the remainder of the bed being practically worthless.

At location 43, 1½ miles southwest of location 42, the bed is 3 feet 10 inches thick and has a clay roof and floor.

Surface indications of the Clintwood bed were seen at a number of places in the southeastern corner of the quadrangle south of Birchfield

Creek and on its headwaters, but no good exposures were found from which its thickness and character could be determined. It rises to the top of the ridges and knobs in the southeast corner. On Indian Creek, 3 miles above its mouth, at location 44, the bed is directly overlain by heavy sandstone, is broken by many partings, and is about worthless.

Section of Clintwood coal bed on Indian Creek, 3 miles above its mouth, at location 44.

	Ft.	in.
Sandstone.		
Coal	2±	
Clay	1	9
Coal		6
Clay		1
Coal		3
Clay		5
Coal		3
Clay		6½
Coal		6
Clay (?).		
	6	3½

Another bed, 1 foot or more thick, that may be split from the Clintwood, lies 30 feet below the bed shown in the preceding section.

In all the region west of Indian Creek and on Pound River southwest of Pound, the Clintwood bed, including partings, is generally a little over 3 feet thick and commonly has a 2-foot bench of solid coal. At location 45 just west of Donkey, the Clintwood shows the following section:

Section of Clintwood coal bed just west of Donkey, at location 45.

	Ft.	in.
Sandstone.		
Coal	1	11
Clay		10
Coal		10
	3	7

At this place the bed lies in the bottom of the Pound syncline, which here forms a narrow trough, the southeast limb of which dips 30° NW.

On North Fork of Pound River, three-fourths of a mile northeast of Flat Gap post office, at location 46, the Clintwood bed has been opened and is reported 18 inches to 2 feet thick, but it could not be seen. Near the west margin of the quadrangle, one-half mile south of Cumberland River in Kentucky, at location 47, the Clintwood bed has been opened and shows the section given below. On Guest River, three-fourths of a mile north of Lipps, at location 48, the Clintwood seems to be represented by two beds 20 feet apart under heavy siliceous sandstone, as shown in the following section.

Sections of the Clintwood coal bed at locations 47 and 48.

Location 47, one-half mile south of Cumberland River near west margin of quadrangle.

	Ft.	in.
Shale.		
Coal	2	
Clay		2
Coal		3
Clay		1
Coal		7
Clay (1 foot exposed).		
	3	1

Location 48, on Guest River, near Lipps.

	Ft.	in.
Sandstone	30	
Coal	2	
Shale and sandstone	20	
Coal	1	
Clay		1
Coal	1	2
Clay (3 feet).		
	54	3

The Clintwood bed has been opened at several places on the east branch of Guest River, but it is apparently thin and of little value.

The general chemical composition of the Clintwood coal was not well determined because there was no opportunity in the quadrangle to collect unweathered samples for analysis. Samples were collected from working banks at Clintwood and southward, the analyses of which are given as Nos. 14766 and 14767 in the table on page 218. These analyses show a high-grade coal.

Coal bed at top of sandstone above Clintwood coal.—Locally a workable coal bed occurs at the top of the sandstone above the Clintwood coal. It is generally a thin bed, for ordinarily only shale is seen in the 200 feet above the sandstone. The best development of this bed, so far as observed by the writer, is on Mullins Fork, at location 49.

Section of coal bed on the west side of Mullins Fork, at location 49.

	Ft.	in.
Coal		6+
Clay	1	
Coal	2	
	3	6+

This bed shows on the hilltops near Hurricane, on the new Wise-Clintwood road, but no good section of it was obtained. It is also exposed on the road west of Flat Gap post office near the west side of the quadrangle, at location 50, where it is 2 feet thick.

Thin coal.—On the head of North Fork of Pound River about 1 mile southwest of Flat Gap post office, at location 51, a coal bed about 150 feet above the Clintwood and 1 foot thick has been opened on a small scale.

BOLLING COAL BEDS.

The names Upper and Lower Bolling are here applied to two beds 20 to 40 feet apart, the upper one of which is also known as the Five-foot coal. The Lower Bolling is 250 to 300 feet above the Clintwood bed. The name is adopted because one or both beds are worked at several places in the southwestern part of the quadrangle

by members of the Bolling family. The beds underlie an unbroken area of about 25 square miles in the quadrangle west of Guest River and south of North Fork of Pound River. They also underlie an extensive area in the Buck Knob region and a number of smaller areas on the high knobs east of Indian Creek and south of Georges Fork. In the areas east and northeast of Indian Creek the beds are generally in their best condition.

Sections fairly typical for this region were measured north of the head of McFall Branch, at location 52.

Section of Bolling coal beds north of head of McFall Branch, at location 52.

Upper bed.	Feet.	Lower bed.	Ft.	in.
Shale (5 feet).		Shale (4 feet).		
Coal	4	Coal	3	4
Clay.		Bone		3
Interval 40 feet.		Clay.		
			3	7

These coal beds are present on the high hills between the heads of Indian and Birchfield creeks, probably on other knobs in the southeast corner of the quadrangle, and on the high knob between the two branches of Guest River southeast of Pinnacle Gap.

Between Indian Creek and Guest River in the Buck Knob region one or both of the coal beds are of good thickness, except on the long spur north of Buck Knob. Between Indian and Glady creeks, at location 53, the beds are exposed as shown below:

Section of Bolling coal beds between Indian and Glady creeks, at location 53.

Upper bed.	Ft.	in.	Lower bed.	Ft.	in.
Shale.			Shale.		
Coal		3½	Coal	3	
Shale	1	6½	Clay		5
Coal		½		3	5
Shale		5			
Coal	3	4½			
Interval 18 feet.					
	5	8			

The upper bed shows shale and coal in the upper part, a feature that is common in the bed farther west.

On the spur north of Buck Knob, at location 54, a number of pits on both beds show only 1 to 2 feet of coal. This condition is shown in the following section, which may be regarded as typical for the locality:

Section of Bolling coal beds on spur north of Buck Knob, at location 54.

	Ft.	in.
Coal, upper bed	1±	
Interval 18 feet.		
Coal, lower bed	1	5
Clay.		
	2	5±

South of Buck Knob the Upper Bolling bed changes to a somewhat "rashy" and laminated character in its upper part, as shown by the following section, measured at location 55:

Section of Upper Bolling coal bed 2 miles southeast of Buck Knob, at location 55.

	Ft.	in.
Shale.		
Coal, laminated	1	3
Coal, soft, shaly		3
Coal, hard, bright	2	
Clay.		
	3	6

At this place a bed reported to be 18 inches thick lies 70 feet below the Upper Bolling. This is probably the Lower Bolling, but the distance between them is abnormally large.

On the upper courses of both North and South forks of Pound River the Bolling coal beds are of fair thickness and quality, the upper bed being about 4 feet and the lower bed 2½ feet thick.

At J. E. Bolling's place, 1½ miles west of Dewey (location 56), both beds are opened and have the following section:

Section of Bolling coal beds 1½ miles west of Dewey, at location 56.

Upper bed.	Ft.	in.
Shale.		
Coal	2	
Coal, bony		2
Coal	1	9
Interval 20 feet.		
	3	11

Lower bed.	Ft.	in.
Coal	2	6
Shale.		

At location 57, about 1 mile southwest of Flat Gap post office on the land of W. A. Bolling, both beds have been opened and show the following sections:

Section of Bolling coal beds on W. A. Bolling's land, about 1 mile southwest of Flat Gap post office, at location 57.

Upper bed.	Ft.	in.
Shale.		
Coal and bone		4
Clay		6
Coal	1	6
Clay		½
Coal	1	7½
Shale 15 feet.		
	4	

Lower bed.	Feet.
Coal (reported 3 feet exposed)	2

On the west side of the quadrangle, 1 mile south of Cumberland River, in Kentucky, at location 58, both beds have been opened, but only the lower bed was accessible.

Section of the Lower Bolling coal bed on the J. H. Mullen estate, on west side of quadrangle, 1 mile south of Cumberland River, in Kentucky, at location 58.

Upper bed.	Feet.
Coal (reported 3+ feet exposed).....	2

Lower bed.	Ft.	in.
Coal [1].....	2	3
Clay.....		2
Coal [1].....	1	6
Clay.....		4
Coal [1].....		4
	4	7

On Powell River, on the south margin of the quadrangle, at location 59, a bed believed to be one of the Bolling coals has been opened and shows the following section:

Section of one of the Bolling coal beds on Powell River, near margin of quadrangle, at location 59.

Shale.	Ft.	in.
Coal.....		8
Clay.....		1
Coal.....	1	8
	2	5

On account of their extent and comparative uniformity as workable beds throughout, the Bolling coals rank among the most valuable coal beds of the Virginia part of the Pound quadrangle.

STANDIFORD COAL BEDS.

The Bolling coals are succeeded above by 260 feet of barren shale and sandstone. On South Fork of Pound River a thin coal bed 80 feet above the Bolling coal was seen at two places, but east of Indian Creek a fully exposed section extending 150 feet above the Bolling coal beds is without coal and no bed of value is known anywhere in the interval.

The Standiford coal beds are named from a man named Standiford, who has worked both beds on South Fork of Pound River. The beds are 20 feet apart at the type locality and constitute a pair in all respects similar to the Bolling coals.

The Standiford coal beds are present only in the Buck Knob and Black Mountain regions west of Guest River, and their area is therefore much less than that of the Bolling beds.

On the David Sturgill place at the head of South Fork of Cumberland River, at location 60, the Lower Standiford bed is worked. At this bank the bed has a shale roof and clay floor and consists of 3 feet 2 inches of clean coal. The analysis of a sample representing the entire bed is given as No. 15172 in the table on page 219. A few rods east of the Sturgill bank, at location 61, is an opening into the Upper

[1] Included in sample, analysis 15173, p. 219.

Standiford bed, in which the coal is 2 feet 6 inches thick and has a sandstone roof and clay floor. The beds here are about 20 feet apart.

At the Standiford place on South Fork of Pound River, at location 62, the upper bed is opened on the east side and the lower on the west side of the valley.

The lower bed at this point has a thickness of 31 inches of clean coal and the upper bed has the section shown below:

Section of the Upper Standiford coal at the Standiford place, on South Fork of Pound River, at location 62.

	Ft.	in.
Shale (6 feet).		
Coal	2	2
Parting		½
Coal		11½
Clay.		
	3	2

A bed identified as the Upper Standiford outcrops about 2,235 feet above sea level on the road both north and south of Fox Gap between Guest and Pound rivers. This bed is 2 to 4 feet thick, including partings, and is underlain by purple shale.

The rocks rise southeastward down Guest River and carry the outcrop of the coal beds upward into the hillsides, which makes it probable that the Standiford coals are among those prospected by the Clinchfield Coal Corporation between the Low Splint (Buck Knob) and Bolling coals on the north and south sides of Buck Knob.

On Critical Fork of Guest River two beds exposed at location 63 are regarded as the Standiford coals, although on account of a rather strong westward dip the distance between them seems greater than that known elsewhere.

Section of Standiford coal beds on Critical Fork of Guest River, at location 63.

Upper bed.	Ft.	in.
Shale.		
Bone		3
Coal		2
Clay, bone, and dirty coal		2
Coal	3	5
Clay		2
Coal		3
Clay.		
Interval 40 ± feet.	4	5

Lower bed.	Feet.
Shale.	
Coal (exposed)	2

On Powell River, at location 64, a bed regarded as one of the Standiford coals is exposed in the stream.

Section of one of the Standiford coal beds on branch near head of Powell River, at location 64.

	Ft.	in.
Coal		1
Clay		½
Coal	1	9½
	1	11

It appears from the foregoing account that the Standiford coal beds are of workable thickness throughout the Black Mountain and Buck Knob regions. They should also be present near the summit of Bowlecamp Knob.

TAGGART COAL BED.

About 80 feet above the Standiford coals lies a bed known locally as the Taggart bed, which appears to be the same as the Keokee bed of the Kentucky reports. It has been extensively prospected by the Virginia Coal & Iron Co. on the head of Roaring Fork of Powell River, where it ranges from a bed of solid coal 3½ feet thick to a bed 6 feet thick that contains a shale parting. A bed, supposedly the Taggart, exposed at one place on South Fork of Pound River, at location 65, has the section given below. On the hill south of Critical Fork of Guest River the section of the Taggart bed at location 66 is also given.

Sections of the Taggart coal bed.

Location 65, on South Fork of Pound River.	Ft.	in.
Shale.		
Coal	2	10
Shale	6	
Coal	2	6
Clay.		
	11	4

Location 66, on hill south of Critical Fork.	Ft.	in.
Shale.		
Bone		3
Coal		11
Clay		2
Coal		10½
Clay.		
	2	2½

On Powell River, at locations 67 and 68, the bed is in good condition, as shown by the following sections:

Sections of the Taggart coal bed on Powell River.

Location 67.	Ft.	in.
Coal	2	10
Bone		1½
Coal	1	5
	4	4½

Location 68.	Ft.	in.
Coal	3	7
Shale	10	
Sandstone	10	
Coal	3	
Sandstone	40	
Coal	3	6
Shale and unexposed	10	
Coal	1	
	81	1

A few feet away the upper coal bed of the above section is 4 feet 5 inches thick, all coal. Probably the upper bed is the Taggart and the lower beds are either not present or not exposed in other sections.

On Roaring Fork of Powell River the following sections furnished by the Virginia Coal & Iron Co. have been selected as typical from many others.

Sections of the Taggart coal bed on Roaring Fork of Powell River.

Location 69.

	Ft.	in.
Shale.		
Coal	2	11
Shale	3	10
Coal	2	
Shale		8
Coal		4
Clay.		
	9	9

Location 70.

	Ft.	in.
Shale.		
Coal	4	2
Clay.		

Attention is called to the similarity of the section at location 69 to the section of the same bed at location 65 on South Fork of Pound River.

On Whitley Fork, in the southwest corner of the quadrangle, at location 71, the bed is 37 inches thick.

LOW SPLINT AND ASSOCIATED COAL BEDS.

Low Splint coal.—The name Low Splint is applied by the Virginia Coal & Iron Co. and by the Kentucky Geological Survey to a bed about 220 feet above the Taggart bed.

The Low Splint bed is opened at the George Phillips place, on South Fork of Pound River (location 72), where it shows the section given below. In a ravine a short distance east of the new road north of Fox Gap, at location 73, the Low Splint bed is opened, and the section at this place is also given.

Sections of the Low Splint coal bed at locations 72 and 73.

Location 72, on the George Phillips place on South Fork of Pound River.

	Ft.	in.
Shale.		
Coal	2	1
Clay		1½
Coal		6½
Clay.		
	2	9

Location 73, east of new road north of Fox Gap.

	Ft.	in.
Shale.		
Coal		8
Bone		½
Coal	2	4½
Clay		2
Coal, slaty		3
Coal		9
Clay		3
Coal	1	2
Clay.		
	5	8

A coal bed prospected on Buck Knob by the Clinchfield Coal Corporation and called by it the Buck Knob bed is probably the Low Splint.

On the head of Critical Fork, at location 74, a bed that seems likely to be the Low Splint shows 23 inches of coal that contains a parting and is reported to have also a lower bench.

The Low Splint at an opening south of Powell River (location 75) shows the following section:

Section of Low Splint coal bed south of Powell River, at location 75.

	Ft.	in.
Shale.		
Coal		1
Bone		1
Coal	3	4
	3	6

The Low Splint bed has been thoroughly prospected on Roaring Fork by the Virginia Coal & Iron Co., and two representative sections are given below:

Sections of Low Splint bed on Roaring Fork.

Location 76, on west side.

	Ft.	in.
Shale.		
Coal	1	7
Shale		3
Coal	1	1
Shale		3
Coal		4
	3	6

Location 77, on head of river.

	Ft.	in.
Shale.		
Coal	2	9
Shale.		

Phillips coal.—At the head of South Fork of Pound River, near the house of Ambrose Phillips, a coal bed 260 feet above the Low Splint bed and provisionally named the Phillips bed, has been opened at location 78. It is reported to be a splint coal 2 feet 2 inches thick, all clean coal at this location. On the head of Critical Fork of Guest River (location 79) a bed reported to be 4 feet thick appears to lie at the horizon of the Phillips coal. Near by the same bed is at least 2 feet thick but is not fully exposed. The Phillips coal may be the same as the Dean coal of Kentucky.

Coal bed 80 feet above the Phillips coal.—At the Phillips place (location 80) an 18-inch bed not observed elsewhere occurs 80 feet above the Phillips coal.

Coal bed 215 feet above the Phillips coal.—At the head of South Fork of Pound River, at location 81, a bed is exposed 215 feet above the Phillips bed. A bed regarded as the same as that at location 81 is exposed on the head of Critical Fork (location 82). The sections at locations 81 and 82 are as follows:

Sections of coal bed 215 feet above the Phillips bed.

Location 81, on head of South Fork of Pound River.

	Ft.	in.
Shale.		
Coal	1	4
Shale		6
Coal		6
Clay		2
Coal	1	7
Clay.		
	4	1

Location 82, at head of Critical Fork.

	Ft.	in.
Sandstone.		
Coal	1	2
Clay		2
Coal, hard	2	
	3	4

PARDEE (LIMESTONE OR PARSONS) COAL BED.

The Pardee coal bed takes its name from the Pardee mine, which lies just beyond the southwest corner of the quadrangle. It is called the Limestone bed in reports of the Kentucky Geological Survey because of the occurrence of a persistent limestone 50 to 100 feet above it to the west of this quadrangle in Kentucky. It is also called the Parsons bed by the Virginia Coal & Iron Co.

The Pardee bed lies 385 feet above the Low Splint bed. It is 7 to 10 feet thick where unbroken by partings but differs greatly in short distances owing to the occurrence of partings of clay or shale which in places attain a thickness of several feet. It underlies only a small area near the top of Black Mountain. It is mined at the Pardee mine and has been very thoroughly prospected around the head of Roaring Fork by the Virginia Coal & Iron Co.

A section of the bed obtained on South Fork of Pound River, at location 83, is as follows:

Section of Pardee coal bed on South Fork of Pound River, at location 83.

	Ft.	in.
Coal	1	6
Clay		3½
Coal	1	7
Clay		½
Coal		7
Clay		3
Coal		½
Clay		½
Coal		4
Clay		1
Coal	1	1½
Clay		2
Coal		11
	6	11½

The following sections, measured at locations 84, 85, and 86, near the head of Roaring Fork, have been selected from those furnished by the Virginia Coal & Iron Co.:

Sections of Pardee coal bed near head of Roaring Fork.

[Furnished by the Virginia Coal & Iron Co.]

Location 84, between Roaring Fork and Powell River.

	Ft.	in.
Shale.		
Coal	2	
Shale	12	
Coal	1	2
Shale	20	
Coal	1	2
	36	4

Location 85, near head of Straight Fork.

	Ft.	in.
Shale.		
Coal	6	6
Shale.		

Location 86, near head of Straight Fork.

	Ft.	in.
Shale.		
Coal	4	6
Shale		7
Coal	2	7
Shale		½
Coal	1	6
Shale		3
Coal	1	9
	11	2½

The Pardee coal is rather hard and its composition is that common to the Virginia and eastern Kentucky coals, as shown by analysis No. 15099 in the table on page 218, which represents the entire bed, 9 feet 7 inches thick.

HIGH SPLINT COAL.

Practically 400 feet above the Pardee bed lies the High Splint bed, well known to the west of this region in Kentucky. It is a genuine splint coal 4 to 5 feet thick, underlying a small area near the top of Black Mountain. On the north side of the mountain at the head of South Fork of Pound River, at location 87, the following section was obtained:

Section of High Splint coal bed at head of South Fork of Pound River, at location 87.

	Ft.	in.
Sandstone.		
Coal	3	4
Bone		1
Coal	1	
	4	5

The following sections, measured at locations 88 and 89, are taken from those furnished by the Virginia Coal & Iron Co. They were obtained in the course of extensive prospecting around the head of Roaring Fork of Powell River.

Section of High Splint coal at location 88, on point of ridge between Powell and Roaring forks.

	Ft.	in.
Shale.		
Coal	2	4
Shale		2
Coal		6
	3	

At the head of the right fork of Roaring Fork (location 89) three sections measured within a distance of 1,000 feet are of interest on account of the irregularity which they exhibit.

Section of High Splint coal at location 89, head of right fork of Roaring Fork.

Section No. 1.

	Ft.	in.
Shale.		
Coal	1	2
Shale	1	2
Coal		2
Shale		9½
Coal	1	10
Shale.		
	5	1½

Section No. 2.

	Ft.	in.
Shale.		
Coal	1	10
Shale	4	9
Coal	1	2
Shale.		
	7	9

Section No. 3.

	Ft.	in.
Shale.		
Coal	4	5

The condition shown by these sections is exceptional.

This coal appears to be of excellent quality and is said to burn very freely. No samples of unweathered coal could be obtained

for analysis. Except for the local irregularity shown by the three sections at location 89 the bed is uniform in thickness and character, maintaining a general thickness of 4 to 4½ feet all around the head of Roaring Fork. At only one place does its thickness fall as low as 3 feet 4 inches, except at its extreme southeastern part, where it is thin and much parted, as shown by the section at location 88.

COAL BEDS ABOVE THE HIGH SPLINT BED.

On Black Mountain, at two places at least, coal was seen above the High Splint bed, but the beds were not well exposed and no information was obtained about their thickness or character.

COAL IN THE KENTUCKY AREA.

The number and sequence of coal beds exposed in the part of the Pound quadrangle that lies in Kentucky are shown in the columnar section for Kentucky on Plate XI. The Bingham, Lower Elkhorn, Upper Elkhorn, and Hyden (Fire Clay) beds are the only beds that are named, but several unnamed beds of some value are associated with those that are named.

Bingham coal.—The lowest coal bed exposed in the Kentucky part of the Pound quadrangle, identified as the Bingham bed,[1] is seen at location 124 along the railroad on Shelby Creek, 1 mile south of the north edge of the quadrangle. The bed is here composed of solid coal 2½ feet thick. It is not exposed elsewhere in the quadrangle.

Thin coal beds below the Lower Elkhorn bed.—Along the new railroad to Jenkins, between Shelby Gap and McPeak Branch, two coal beds within 50 feet below the Lower Elkhorn bed are exposed at a few places. The first coal is 10 to 25 feet below the Lower Elkhorn and is 12 to 14 inches thick; the second is about 50 feet below the Lower Elkhorn and, at the place observed (location 125), is 18 inches thick. They were not seen elsewhere.

Lower Elkhorn coal.—The Lower Elkhorn bed is best known along Elkhorn Creek and its western tributaries in the country northeast of McPeak Branch. It dips southwestward under the bed of Elkhorn Creek at the mouth of McPeak Branch and under Middle or Straight Branch of Beefhide Creek 1 mile above the mouth of the branch. It does not outcrop west of a line connecting the points described unless a bed which outcrops on Kentucky River between Holbrook Branch and Laurel Fork is the Lower Elkhorn.

Throughout most of the territory in which the Lower Elkhorn coal outcrops it is 3 to 3½ feet thick and has in the middle a highly characteristic bench of bright, soft, flaky coal of impure composition. On Pigeon Branch, near the north edge of the quadrangle, at location

[1] Stone, R. W., Coal resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull. 348, 1908.

126, the bed is 2 feet 8 inches thick, contains the layer of flaky coal, and is shaly in the middle. At location 127, on Big Branch, 1½ miles southwest of Pigeon Branch, and at location 128, at the mouth of a branch one-half mile south of location 127, the following sections were measured:

Sections of Lower Elkhorn coal bed at locations 127 and 128.

Location 127, on Big Branch.

Sandstone.	Ft.	in.
Coal, one-fourth inch layers with "rash" partings		2
Coal		4
Parting		½
Coal	1	3½
Coal, bony		10
Shale, coaly	1	6
	4	2

Location 128, near Elkhorn Creek, 3 miles southwest of northeast corner of quadrangle.

Sandstone.	Ft.	in.
Coal		6
Coal, shaly	2	
Coal, bottom not seen		11+
	3	5+

At location 129, on Shelby Creek 2 miles south of the quadrangle edge, the bed is 2 feet 4 inches thick, and at Ratliff's bank on Elkhorn Creek, 5 miles northeast of Jenkins (location 130), the bed is 3 feet thick. The sections at locations 129 and 130 are as follows:

Sections of the Lower Elkhorn coal bed at locations 129 and 130.

Location 129, on Shelby Creek 2 miles south of the quadrangle edge.

Sandstone.	Ft.	in.
Coal, laminated	1	3
Coal, irregularly jointed	1	1
	2	4

Location 130, at Ratliff's bank on Elkhorn Creek, 5 miles northeast of Jenkins.

Sandstone.	Ft.	in.
Coal [1]		8
Coal, laminated [2]	1	
Coal [1]	1	4½
	3	½

The coal was sampled at this mine, the laminated part and the remainder being sampled separately. At location 132, on Johns Fork 1½ miles south of the quadrangle edge, the Lower Elkhorn bed is 2 feet 9 inches thick and has a 2-inch laminated layer near the middle. On Kentucky River, between Holbrook Branch and Laurel Fork, a bed 2 feet thick and 250 feet below the Upper Elkhorn bed outcrops along the road. This may be the Lower Elkhorn, although its characteristic laminated bench was not observed. A coal, apparently thin and of no value, which shows at water level on Kentucky River and on Boone Fork near its mouth, is possibly also the Lower Elkhorn.

On Straight or Middle Fork of Beefhide Creek, at location 131, a bed 2 feet 8 inches thick lies 220 feet below the Upper Elkhorn coal and apparently has not the laminated bench. This bed may be the

[1] Analysis No. 14970, p. 219. [2] Analysis No. 14971, p. 219.

Lower Elkhorn, but the shorter distance below the Upper Elkhorn and the absence of the laminated bench are features that suggest that it may be the bed 60 feet above the Lower Elkhorn on Elkhorn Creek described below.

Coal bed 60 feet above the Lower Elkhorn coal.—On Elkhorn Creek one-fourth of a mile west of Shelby Gap, at location 133, a thin coal bed 60 feet above the Lower Elkhorn coal is exposed at the top of a railroad cut. A bed about 1 foot thick and about 220 feet below the Upper Elkhorn bed, which shows on Long Fork of Shelby Creek just off the north edge of the quadrangle, and a bed 1 foot thick and about 185 feet below the Upper Elkhorn bed, which outcrops in the bed of Potter Fork, about 1 mile above Boone Fork, at location 134, are referred to the same horizon.

Coal bed 120 feet below the Upper Elkhorn bed.—In a railroad cut at the tipple of Consolidation No. 201 mine a coal 2 feet thick and about 120 feet below the Upper Elkhorn bed is exposed. On Bens Branch, near Consolidation No. 202 mine, at location 135, the same bed has the following character:

Section of coal bed on Bens Branch at location 135.

	Ft.	in.
Sandstone.		
Coal	1	3
Bone		1
Coal, hard		6
Coal		6
Sandstone.		
	2	4

At location 136, on Little Laurel or Fishpond Branch of Kentucky River, this bed outcrops in the same position relatively to the Upper Elkhorn bed and appears to be fairly thick, but more definite knowledge of the bed at that point was not obtainable. On Kentucky River one-half mile below the mouth of Boone Fork, at location 137, a bed 15 inches thick is referred to this horizon, and a 2-foot bed that outcrops on Millstone Creek just east of the edge of the quadrangle is probably the same.

On Pigeon Branch, near location 126 on the Lower Elkhorn bed, a bed of clean coal 4½ feet thick occurs about 150 feet above the Lower Elkhorn bed. This bed appears also to be the same as that 120 feet below the Upper Elkhorn. It is a valuable bed in the Pigeon Creek region and perhaps also westward toward Shelby Creek.

Coal beds 40 and 50 feet below the Upper Elkhorn bed.—On Elkhorn Creek, at the tipple of Consolidation No. 205 mine, and also in a railroad cut near McRoberts, at location 138, two coal beds are exposed below the Upper Elkhorn coal, as shown in the following sections:

Sections of coal beds 40 and 50 feet below the Upper Elkhorn bed.

Tipple of Consolidation No. 205 mine.

Coal, Upper Elkhorn.	Feet.
Shale	40
Coal	2
Shale	10
Coal	1
	53

Location 138, near McRoberts.

Coal, Upper Elkhorn.	Ft.	in.
Shale	40	
Coal	1	4
Shale	20	
Coal	2	4
Clay	4	
	67	8

The upper one of these beds appears to be 3 feet thick in a road cut on Elkhorn Creek a short distance above No. 205 mine. One of the beds is exposed in a railroad cut near Consolidation No. 204 mine and one has been opened at two places on Pine Creek near the west edge of the quadrangle, at location 139, where it is 28 inches thick and has a sandstone roof and clay floor.

Upper Elkhorn coal.—The Upper Elkhorn is the great coal bed in this part of Kentucky. It ranges from 6 to 8 feet thick over all that part of the area between Shelby Creek and Boone Fork of Kentucky River. West of Boone Fork it decreases in thickness to 4 feet or less on Rockhouse Creek. East of Boone Fork it is nearly everywhere divided near the middle by a soft flaky clay parting that has a maximum thickness of 1 foot. Exceptionally, as at No. 201 mine, this parting is a little more than 2 feet thick. On Rockhouse and Millstone creeks the parting is not present and the bed consists of a single bench.

The 4-foot bed on Rockhouse Creek was regarded by Hodge [1] as a different bed from the Upper Elkhorn, but thorough and continuous prospecting by the Consolidation Coal Co. has shown beyond question that the coal on Rockhouse Creek is the Upper Elkhorn.

A few selected sections given below exhibit the general range of thickness and character of the bed.

Sections of Upper Elkhorn coal bed at locations 140 and 141 and at Consolidation No. 201 mine.

Location 140, near Shelby Gap.

Shale.	Ft.	in.
Coal	1	1
Clay		4
Coal	2	9
Clay.		
	4	2

Location 141, at Haynes opening near head of left fork of Marshall Branch.

Shale.	Ft.	in.
Coal	1	1
"Rash"		3
Coal	2	6
Clay	1	
Coal	3	
	7	10

Consolidation No. 201 mine.

Shale.	Ft.	in.
Shale, cannel		3
Coal	3	4
Clay	1	3
Coal	3	8
	8	6

[1] Hodge J. M., Kentucky Geol. Survey Bull. 11, 1910.

Possibly there is another bench of coal in the section at location 140 below the lower clay, as in the section measured at the Haynes opening.

The lower 15 inches of the bed at the Consolidation No. 201 mine is partly hard splint coal. The occurrence of splint coal in the lower part of the Upper Elkhorn bed prevails widely in the region.

Sections of Upper Elkhorn coal bed in Consolidation No. 204 mine.

Section at mouth of mine.

Shale.	Ft.	in.
Coal	3	10
Clay, 5 to 7 inches, average		5½
Coal	4	3
	8	6½

Section at face of main east entry 1,700 feet from mouth of mine.

	Ft.	in.
Coal [1]	3	7
Clay		3
Coal [1]	3	8½
	7	6½

Section at face of main entry 1,700 feet from mouth of mine.

	Ft.	in.
Coal [2]	4	
Clay		5
Coal [2]	4	
	8	5

Sections of Upper Elkhorn coal bed at various locations.

Location 142, on Laurel Fork of Kentucky River 4½ miles southwest of Jenkins.

Shale.	Ft.	in.
Coal	2	4
Clay		4
Coal	3	4
	6	

Location 143, on bottom Fork of Kentucky River.

Shale.	Ft.	in.
Coal	2	
Clay		4½
Coal	1	2
Clay		3½
Coal	1	8
	5	6

Location 144, on Pine Creek near west edge of quadrangle.

Shale.	Ft.	in.
Coal	2	1
Clay		4
Coal	1	
	3	5

Location 145, on small branch of Millston Creek, 1 mile north of Kentucky River.

Shale.	Ft.	in.
Coal	1	10
Clay		1
Coal	4	9
	6	8

Location 146, at the Isaac Potter opening on Potter Fork.

Shale.	Ft.	in.
Coal	2	
Clay		2
Coal	2	7
Clay		3½
Coal	4	5½
	9	6

At Consolidation No. 214 mine at McRoberts.

Shale.	Ft.	in.
Coal	3	8
Clay		2
Coal	3	4
	7	2

[1] Included in sample for analysis No. 14904, p. 219.

[2] Included in sample for analysis No. 14905, p. 219.

Section of Upper Elkhorn coal bed at various locations—Continued.

Location 147, on west side of Beefhide Creek near quadrangle edge.

Shale.	Ft.	in.
Coal	1	6
Clay		5
Coal	3	6
	5	5

Location 148, on Long Fork near north edge of quadrangle.

Shale.	Ft.	in.
Coal	3	5
Clay		3½
Coal	2	3
	5	11½

Location 149, on Boone Fork.

Shale.	Ft.	in.
Coal	2	1
Clay		2
Coal	3	10
	6	1

Location 150, on Rockhouse Creek at edge of quadrangle.

Sandstone.	Ft.	in.
Coal	3	5

Location 151, on Meadow Branch of Millstone Creek.

Shale.	Ft.	in.
Coal, clean	4	9

The thickness at the Isaac Potter opening (location 146) seems to be the maximum for the bed in this region.

The Upper Elkhorn is a very high grade bituminous coal, especially adapted to the manufacture of gas. On Elkhorn Creek, according to the analyses of the Consolidation Coal Co., it is uncommonly low in ash. Analyses 14904 and 14905, though numerically inadequate, indicate its probable range of composition. The composition shown in analysis 14904 probably more nearly represents its prevailing character than that shown in analysis 14905.

The principal defect of the bed in this vicinity is its weak roof. Immediately over the coal lies a few feet of soft shale which is very likely to fall with the top coal and which on account of its crumbling character can not be economically separated from the coal. This feature makes it necessary to leave 1 foot to 15 inches of the top coal for roof. It is hoped that a large part of this roof coal may be recovered on the abandonment of the worked-out parts of the mines.

The coal is mined extensively at Jenkins and McRoberts by the Consolidation Coal Co., and most of the output is shipped to Michigan for consumption in by-product coke ovens. It seems to be excellently adapted to such use.

Coal bed 20 feet above the Upper Elkhorn coal.—Near location 149, on Boone Fork; at location 150, on Rockhouse Creek; and at location 151, on Millstone Creek, an 18-inch coal lies 20 feet above the Upper Elkhorn bed.

Coal bed 60 feet above the Upper Elkhorn coal.—On the new road between Elkhorn Creek and McRoberts a coal bed 60 feet above the Upper Elkhorn bed has been exposed. Above Consolidation No. 207 mine it is 1 foot thick and above No. 214 mine it is 8 inches thick.

Coal bed 175 feet above the Upper Elkhorn coal.—On the new road just mentioned a coal bed 175 feet above the Upper Elkhorn bed at

No. 207 mine has been exposed. At that place it is worthless, as shown by the section below.

Section of coal bed 175 feet above the Upper Elkhorn coal, on new road above No. 207 mine.

	Ft.	in.
Sandstone.		
Coal		2½
Clay		2½
Coal		1
Clay	1	
Coal		11
Clay	2	5
	4	10

Near the head of Elkhorn Creek, at location 152, this bed shows the following section:

Section of coal bed near head of Elkhorn Creek, at location 152.

	Ft.	in.
Sandstone.		
Coal		2
Clay		2
Coal		4
Clay		4
Coal	1	4
	2	4

At this place the bed is about 160 feet above the Upper Elkhorn.

Coal bed 200 feet above the Upper Elkhorn coal.—At No. 207 mine in the new road to McRoberts a bed that contains 3 feet 4 inches of clean coal is exposed 200 feet above the Upper Elkhorn coal. A bed near this horizon appears to be persistent in the region.

On the west side of the ridge above No. 214 mine the bed also shows 3 feet 4 inches of coal. A bed opened at the head of Wrights Fork (location 153) and reported to be 2 to 2½ feet thick may be this bed or the one discussed under the next heading. A bed opened on the head of Rockhouse Creek just beyond the north boundary of the quadrangle, near location 154, is regarded as this bed. At this place 25 inches of clean coal was seen and the thickness may be greater. Fossil ferns collected from the bed at this point indicate the horizon of the Clintwood coal of Virginia.

Coal bed 240 feet above the Upper Elkhorn coal.—A bed containing 2 feet 2 inches of clean coal is exposed on the new road to McRoberts, about 240 feet above the Upper Elkhorn at No. 207 mine. This bed has not been recognized elsewhere.

Coal bed 340 feet above the Upper Elkhorn coal.—On the new road to McRoberts a bed 340 feet above the Upper Elkhorn and almost 30 inches thick, apparently clean coal, shows on both sides of the summit and about 120 feet below it.

Hyden (Fire Clay) coal bed.—A thick coal bed lies 400 feet above the Upper Elkhorn bed, as determined at widely separated points in the region. This bed is characterized by a parting of flint clay, from which it has been named the Fire Clay bed in reports of the Kentucky Geological Survey.[1] It is also called the Hyden bed, and that name is adopted here.

The best exposure of the Hyden bed in this area is at the opening of M. B. Tolliver on Meadow Branch near the west side of the quadrangle, at location 155. On the new road to McRoberts the bed is exposed at location 156 on the west side of the summit and 71 feet below it. The sections at locations 155 and 156 are as follows:

Sections of Hyden coal bed at locations 155 and 156.

Location 155, at M. B. Tolliver's bank on Meadow Branch.

	Ft.	in.
Shale.		
Shale, black, fissile (1 foot).		
Coal	3	5
Clay, flint		4
Coal, splint at top	1	5
Coal, cannel		3
Clay		1
Coal, splint		9
	6	3

Location 156, on west side of summit on new road to McRoberts.

	Ft.	in.
Shale.		
Coal	3	2
Clay, flint		5
Coal	1	1
	4	8

At the opening of W. M. Yonts, one-half mile northwest of Baker post office, at location 157, and near the head of Long Fork, at location 158, the bed is made up as follows:

Sections of Hyden coal bed at locations 157 and 158.

Location 157, opening of W. M. Yonts, one-half mile northwest of Baker post office.

	Ft.	in.
Shale, black (4 inches).		
Coal	1	
Pyrite		1
Coal	1	6
Coal, with streaks of clay and bone		8
Clay, flint		1½
Coal, splint, thin clay partings and bony; thickness, 6 to 10 inches, average		8
	4	½

Location 158, near the head of Long Fork.

	Ft.	in.
Coal	2	6
Clay, flint		4
Coal	1	6
	4	4

A coal bed high on the hill at the head of Big Branch in the northeast corner of the quadrangle, at location 159, reported to be 4 feet thick is certainly the Hyden bed. Reports are current of a bed at this horizon at other places in the area and leave no doubt of its persistence, probably as a workable bed.

[1] Kentucky Geol. Survey Bull. 11, 1910.

Coal beds above the Hyden.—On the new road to McRoberts, just below the summit on the east side, at location 160, a coal is exposed 50 feet above the Hyden bed. Its section is as follows:

Section of coal bed 50 feet above the Hyden bed on new road to McRoberts, at location 160.

	Ft.	in.
Shale.		
Bone		1
Coal		3
Bone		3
Clay		5
Coal	2	
	3	

Mr. M. B. Tolliver reports a coal 6 feet thick above the Hyden bed at his opening, at location 155, and the presence of a bed in that position is indicated by a bloom above the opening. On the high ridges in the northwest corner of the quadrangle 500 feet of strata overlie the Hyden bed. According to Bulletin 11 of the Kentucky Geological Survey, at least three coal beds occur in this interval, but no exposures of any of these beds were discovered by the writer although the beds are probably present.

QUANTITY OF ULTIMATELY AVAILABLE COAL.

The quantity of ultimately available coal in the Pound quadrangle has been computed with the results shown in the following table:

Tonnage of available coal in the Pound quadrangle.

Bed.	Thickness.	Area.	Tonnage.[a]
VIRGINIA.	*Ft. in.*	*Sq. mi.*	
High Splint	3 10	1.60	7,060,000
Pardee	7 6	4.80	41,470,000
First coal below Pardee	2	6.57	15,130,000
Second coal below Pardee	1	8.17	9,520,000
Phillips	2	9.62	22,160,000
Low Splint	3 2	13.92	50,830,000
Taggart	4	17.19	79,210,000
Upper Standiford	3	20.15	69,640,000
Lower Standiford	2 6	20.15	58,000,000
Upper Bolling	3 4	39.19	150,300,000
Lower Bolling	2 4	39.19	105,200,000
First coal above Clintwood	2	75.92	174,900,000
Clintwood (thick)	7 3	17.91	149,580,000
Clintwood (thin)	3 8	58.00	245,200,000
Blair	2 8	91.29	279,750,000
Coal 70 feet above Glamorgan	2 6	99.61	285,700,000
Glamorgan (thick)	2 7	59.80	179,100,000
Glamorgan (thin)	2	49.20	113,350,000
Total Wise formation			2,136,080,000
Norton formation	7 2	137.72	1,137,550,000
Lee formation	7 4	137.72	1,162,920,000
Total coal in Virginia			4,436,550,000

[a] Estimated on the basis of 1,152,000 tons to the square mile for each foot in thickness of coal.

Tonnage of available coal in the Pound quadrangle—Continued.

Bed.	Thickness.	Area.	Tonnage.
KENTUCKY.	*Ft. in.*	*Sq. mi.*	
Hyden	4 5	13.13	66,820,000
Two beds	4	39.20	180,630,000
Upper Elkhorn [a]	6 1½	42.98	303,380,000
Do.[a]	4	6.77	31,200,000
One bed	1	49.75	57,310,000
Do	4 10	3.18	14,650,000
Between the Lee and Lower Elkhorn	11	68.11	842,110,000
Lee	7	68.11	549,240,000
Total coal in Kentucky			2,304,640,000
Grand total			6,741,190,000

[a] Computed for separate areas containing different thicknesses of coal.

In the above table the results are given to the nearest 10,000 tons. The minimum thickness of a coal bed considered in a commercial sense as ultimately minable is 14 inches, and the maximum depth for that thickness is taken as 1,700 feet. On this basis the comparatively meager data for the Norton and Lee formations in Virginia indicate a total thickness of 7 feet 2 inches of coal in the Norton and 7 feet 4 inches in the Lee. That is, the amount of coal fulfilling the conditions of depth and thickness stated above equals a single bed 7 feet 2 inches thick in the Norton and another 7 feet 4 inches thick in the Lee, the areal extent of these beds being considered as equal to the area underlain by the Norton formation. In the Kentucky area the coals of the Lee and of the strata between the Lower Elkhorn coal and the top of the Lee approximately equivalent to the Norton of Virginia have not been tested.

In Bulletin 12 of the Kentucky Geological Survey coals that aggregate about 10 feet in thickness are described in the Lee where it outcrops on the western border of the eastern coal field in Kentucky, and on the basis of this fact, together with the known occurrence of about 7 feet of workable coal in the Lee of Virginia, it is assumed that the Lee in the Kentucky part of the Pound quadrangle contains at least 7½ feet of workable coal. Stone[1] describes four coal beds aggregating 11 feet in thickness in the rocks between the Lee formation and the Lower Elkhorn coal in the Big Sandy drainage area, 10 miles northeast of the Pound quadrangle. The occurrence of these beds in that area forms the basis of the assumption of a total thickness of 11 feet of coal in these rocks in the part of the Pound quadrangle in Kentucky.

In Virginia the average thickness of the High Splint, Pardee, Low Splint, Taggart, Bolling, Clintwood (where it is 7 feet 3 inches thick), and Glamorgan (where it is 2 feet 7 inches thick) is based on an

[1] Stone, R. W., Coal resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull 348, 1908.

adequate number of detailed measurements and can be accepted as reliable. The thickness of the other beds is less certain. In Kentucky the average thickness of only the Upper Elkhorn coal is adequately determined. The thickness of the Lower Elkhorn is based on a number of good measurements obtained northeast of Marshall Branch, and the thickness of each coal above the Upper Elkhorn is based on only a small number of accurate measurements.

In both Virginia and Kentucky, beds other than those included in this estimate were seen at one or a very few points, but of these so little is known that they were not considered. This fact, together with the fact that the beds included in the estimate are as likely to average somewhat thicker as they are to average thinner, supports the belief that the total estimated tonnage, enormous though it be, does not exceed the actual amount of ultimately minable coal in the Pound quadrangle.

CHEMICAL COMPOSITION OF THE COALS.

The chemical composition of some of the coals of the region is shown in the table of analyses (pp. 218–219). Only a small number of samples were taken because, as deep mines are few, opportunities for obtaining fresh unweathered coal are rare. Most of the samples from local mines are probably somewhat affected by weathering. However, the composition of such samples approximates that of fresh coal closely enough for rough comparisons.

The samples were collected as follows: From the fresh face of the bed, or as nearly fresh as could be obtained, a uniform cut was made from top to bottom of sufficient size to yield 5 pounds to the foot after rejecting all partings that would not be included in the coal as marketed. This coal was pulverized and quartered in the mine until there was left sufficient coal of a size that would pass through a half-inch mesh to fill a 2-quart galvanized-iron can. This was sealed with adhesive tape and mailed to the laboratory of the Bureau of Mines for analysis.

The coals of this quadrangle are all bituminous and in composition resemble the coals of the eastern side of the Appalachian field from Russell County, Va., to Alabama, except those of Lookout Mountain. Analyses show that samples from Russell, Dickenson, Wise, and Lee counties, Va., and from eastern Kentucky are much alike in average composition. All the samples from the Pound quadrangle are low in sulphur and moisture, and all but those from the Pardee and Bolling beds are notably low in ash. Samples from a larger number of localities are, however, needed in order to obtain more satisfactory data. It should be added that the calorific determinations that are based on samples from country banks, or on weathered samples, do not show the full heat value of the fuels.

The coals of this quadrangle all differ from the coals of the Pocahontas region in respect to content of volatile hydrocarbons and fixed carbon. The coals of that region which generally have less than 20 per cent volatile and more than 70 per cent fixed carbon are classed with the semibituminous coals, like those of the Clearfield district of Pennsylvania. On the other hand, the coals described in this report contain more than 30 per cent of volatile matter. The high volatile content of the coals of the Pound quadrangle invites consideration of by-product processes in coking.

With the exception of the semibituminous coal of Lookout Mountain in Georgia and Alabama, the coals of this region are suitable for any of the uses to which the coals south of the Pocahontas region are put. For domestic use, including the grate, for the generation of steam and for coke and gas they will probably compare favorably with most of the coal mined for such uses in the southern Appalachian field.

Their coking qualities are mostly unknown. The Imboden bed at Stonega, southwest of the quadrangle, is regarded as one of the best coking coals of the country. This bed is supposed to be the same as the Edwards bed in the Norton formation. The Glamorgan coal mined at Glamorgan makes good coke and the output of the mine is largely utilized in this way. It is quite probable that some of the other Norton coals also possess good coking qualities.

Analyses of coals from the Pound and Clintwood quadrangles in Virginia and Kentucky.

[Made by the Bureau of Mines, A. C. Fieldner, chemist in charge.]

Virginia.

Laboratory No.	Name of mine and location.	Collector.	Coal bed.	Air-drying loss.	Form of analysis.[1]	Proximate.				Ultimate.					Heating value.		Page.
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.	
14766	Mine of John A. Yeates, 1 mile southwest of Clintwood.	W. A. Nelson.....	Clintwood.....	1.2	A	2.2	34.2	60.4	3.2	0.85	.....	.....	.....	.....	8,110	14,590	196
					B	1.0	34.6	61.2	3.2	.86	.....	.....	.....	.....	8,205	14,770	
					C	.....	34.9	61.8	3.3	.87	.....	.....	.....	.....	8,290	14,920	
					D	.....	36.1	63.9	.....	.90	.....	.....	.....	.....	8,570	15,420	
14767	Mine of Elbert Powers, 3 miles southeast of Clintwood.	.....do.....	.....do.....	3.3	A	4.3	29.4	62.1	4.2	1.02	.....	.....	.....	.....	.....	.....	196
					B	1.0	30.4	64.2	4.4	1.05	.....	.....	.....	.....	.....	.....	
					C	.....	30.7	64.9	4.4	1.07	.....	.....	.....	.....	.....	.....	
					D	.....	32.1	67.9	.....	1.12	.....	.....	.....	.....	.....	.....	
15099	Pardee No. 1 mine of Blackwood Coal & Coke Co., Pardee.	Chas. Butts.....	Pardee.....	1.0	A	2.3	33.8	54.7	9.21	1.56	4.99	74.46	1.57	8.21	7,420	13,360	205
					B	1.3	34.2	55.2	9.30	1.58	4.93	75.21	1.59	7.39	7,495	13,490	
					C	.....	34.6	56.0	9.43	1.60	4.85	76.20	1.61	6.31	7,595	13,670	
					D	.....	38.2	61.8	.....	1.77	5.35	84.13	1.78	6.97	8,385	15,100	
15100	Glamorgan No. 3 mine of Stone Gap Colliery Co., Glamorgan.	.....do.....	Glamorgan....	1.6	A	2.6	33.1	59.3	5.0	1.37	.....	.....	.....	.....	7,895	14,220	189
					B	1.1	33.6	60.2	5.1	1.39	.....	.....	.....	.....	8,025	14,450	
					C	.....	34.0	60.9	5.1	1.41	.....	.....	.....	.....	8,115	14,600	
					D	.....	35.8	64.2	.....	1.49	.....	.....	.....	.....	8,550	15,390	
15101	.....do.....	.....do.....	.....do.....	2.0	A	3.2	31.3	59.1	6.37	.87	5.27	78.02	1.65	7.82	7,730	13,910	189
					B	1.3	31.9	60.3	6.50	.89	5.15	79.61	1.68	6.17	7,885	14,200	
					C	.....	32.3	61.1	6.58	.90	5.08	80.65	1.71	5.08	7,990	14,380	
					D	.....	34.6	65.4	.....	.96	5.44	86.33	1.83	5.44	8,550	15,390	
15174	Mine of Reuben Bolling, 2 miles east of Flat Gap.	.....do.....	Upper Bolling.	5.8	A	6.9	30.4	54.6	8.1	.95	.....	.....	.....	.....	7,210	12,980	.....
					B	1.2	32.3	57.9	8.6	1.01	.....	.....	.....	.....	7,655	13,780	
					C	.....	32.6	58.6	8.8	1.02	.....	.....	.....	.....	7,745	13,940	
					D	.....	35.8	64.2	.....	1.12	.....	.....	.....	.....	8,485	15,280	

14904	Jenkins No. 4 mine of Consolidation Coal Co., Jenkins.	Chas. Butts	Upper Elkhorn.	1.9	A	3.9	33.8	54.8	7.5	0.51					7,460	13,430	210
					B	2.1	34.5	55.8	7.6	.52					7,605	13,690	
					C		35.2	57.0	7.8	.53					7,765	13,970	
					D		38.2	61.8		.57					8,420	15,150	
14905	do	do	do	1.7	A	3.6	35.8	58.0	2.59	.51	5.39	80.06	1.52	9.93	7,910	14,240	210
					B	2.0	36.4	59.0	2.63	.52	5.29	81.44	1.55	8.57	8,050	14,490	
					C		37.2	60.1	2.69	.53	5.18	83.09	1.58	6.93	8,210	14,780	
					D		38.2	61.8		.54	5.32	85.38	1.62	7.14	8,440	15,190	
14970	Mine of Joel Ratliff, 5 miles northeast of Jenkins.	do	Lower Elkhorn.	3.1	A	4.8	33.7	57.8	3.7	.82					7,690	13,840	207
					B	1.8	34.8	59.6	3.8	.85					7,935	14,290	
					C		35.4	60.7	3.9	.86					8,080	14,550	
					D		36.9	63.1		.90					8,410	15,140	
14971	do	do	do	3.6	A	5.1	28.8	48.2	17.9	.68					6,365	11,450	207
					B	1.6	29.9	50.0	18.5	.71					6,600	11,880	
					C		30.3	50.8	18.9	.72					6,710	12,080	
					D		37.4	62.6		.89					8,270	14,880	
15172	Mine of David Sturgill, 1½ miles south of Flat Gap.	do	Lower Standiford.	2.8	A	4.1	35.2	55.7	5.0	1.74					7,725	13,910	199
					B	1.3	36.2	57.3	5.2	1.79					7,950	14,310	
					C		36.7	58.1	5.2	1.81					8,055	14,500	
					D		38.7	61.3		1.91					8,500	15,300	
15173	Mine of J. H. Mullin, 3 miles southwest of Flat Gap.	do	Lower Bolling.	2.6	A	4.0	31.8	53.0	11.2	.97					7,140	12,850	199
					B	1.4	32.6	54.5	11.5	1.00					7,330	13,200	
					C		33.1	55.3	11.6	1.01					7,435	13,380	
					D		37.4	62.6		1.14					8,415	15,150	

[a] A, Analysis of the coal as received; B, analysis of the coal after drying at a temperature a little above the normal; C, Theoretical composition of the coal after all moisture has been eliminated; D, Coal substance after all ash and moisture have been theoretically removed. This is supposed to represent the true coal substance after the most significant impurities have been removed. Forms C and D are obtained from the others by recalculation.

MINING CONDITIONS.

The coal beds of the region are nearly flat or gently inclined. Level haulways are possible throughout most of the field, permitting the use of electric haulage. It seems likely that all the beds of the Wise formation can be reached by drift mines, but it will be necessary to sink shafts to the coals of the Norton and Lee formations. As a rule the beds have a good roof, except the Upper Elkhorn bed in Kentucky, which has a weak roof, as described on page 211. The mines that have been opened appear to be free from gas or water in troublesome quantities.

The country has an abundant supply of mine-timber, and the water supply for making steam and other uses will probably always be ample. The construction of railroads will be the most expensive factor in mining enterprises. That subject has been discussed on pages 168–169.

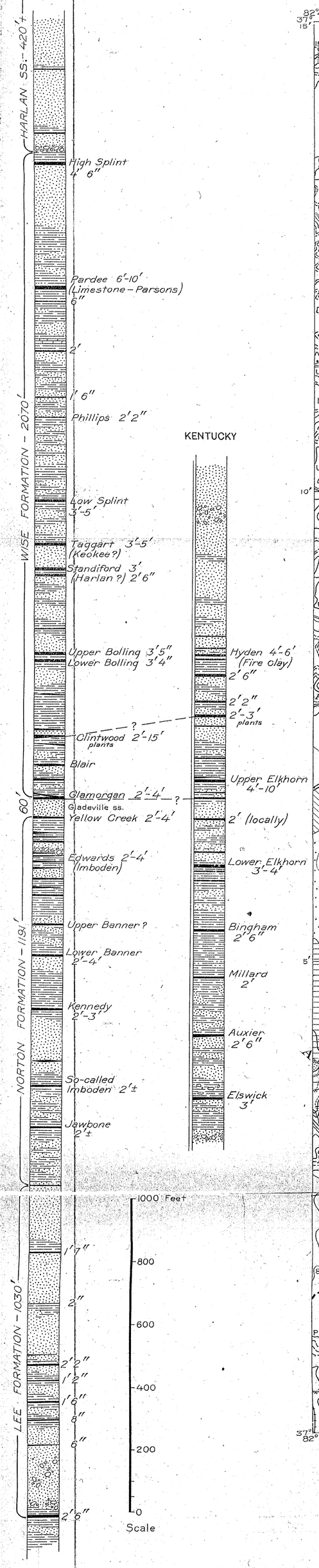
DEVELOPMENT.

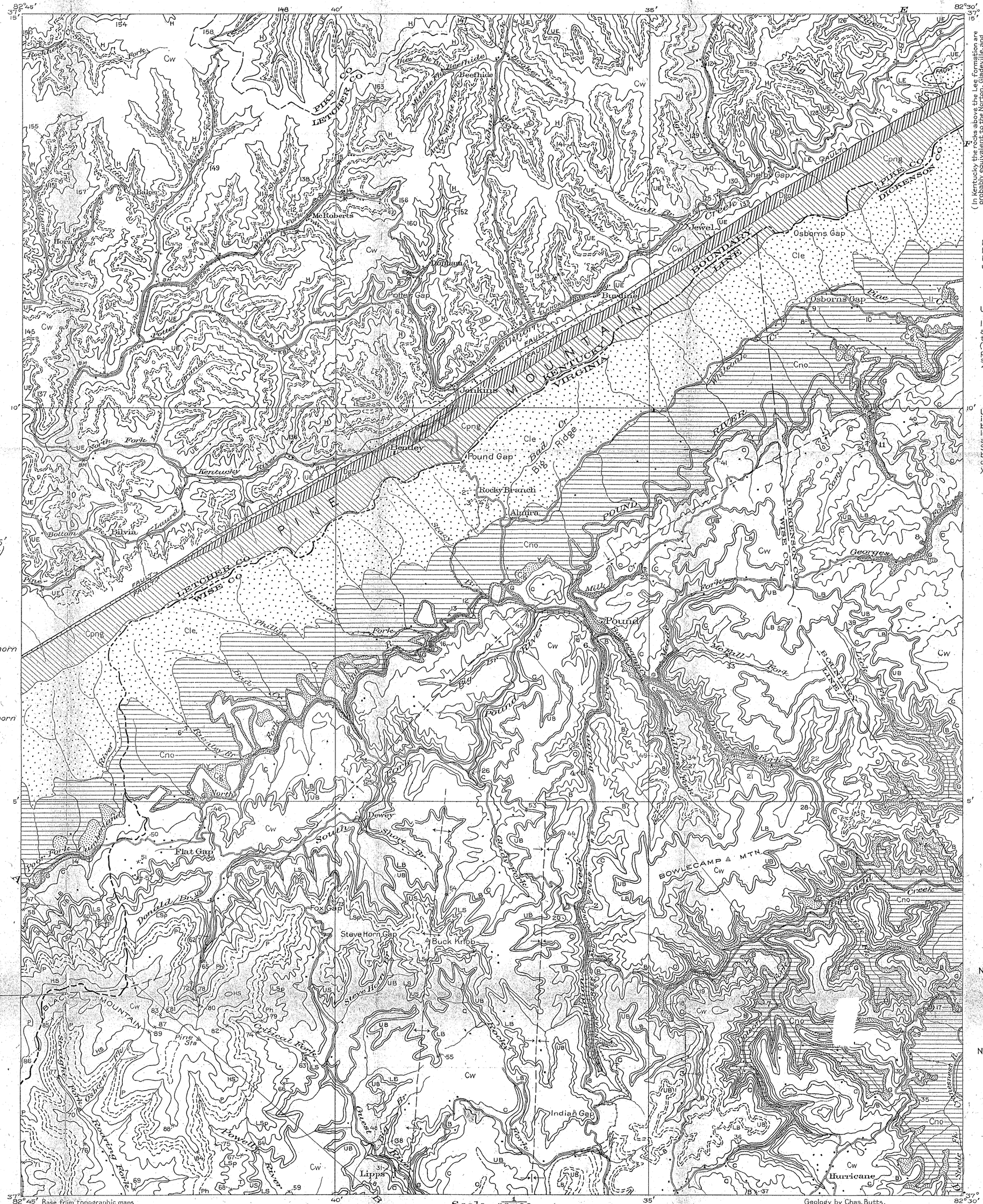
The region until recently was entirely undeveloped. Within the past three years, however, developments on a large scale have been begun by the Consolidation Coal Co. on the Upper Elkhorn bed in Kentucky and 14 shipping mines are in operation, yielding a large output. In the Virginia area only the Glamorgan mine is operating, though here and there a local mine supplies the surrounding neighborhood. Most of the best coal land is in the possession of the large coal companies, who have ascertained the coal resources by thorough prospecting, and developments on a large scale may be expected in the near future.

SUMMARY.

It was ascertained by this survey that the maximum thickness of the coal-bearing rocks of the area is 4,800 feet. This thickness is attained in Black Mountain and is probably the maximum thickness for the coal measures of the Appalachian coal field outside the Coosa and Cahaba coal fields of Alabama.

The coal resources of the lower 2,000 feet of these rocks could not be thoroughly investigated, but it is known from borings and scattered exposures of coal beds on the outcrops of these rocks that there are about a dozen beds, 14 inches to 4 feet thick, at depths of less than 2,000 feet, and all this coal is considered to be ultimately available. In the upper 2,800 feet of rocks are 16 coal beds that range from 18 inches to 10 feet in thickness, all but one of which are known to be 2½ feet or more thick over large areas. The areal extent of the individual beds ranges from 2 or 3 square miles to more than 100 square miles, the extent depending on the irregularity in the thickness of the beds and their position in the hills. The coal of





Base from topographic maps of the United States Geological Survey.

Geology by Chas. Butts, assisted by D.D. Condit and W.A. Nelson. Surveyed in 1912 in cooperation with the State of Virginia.

LEGEND

(In Kentucky the rocks above the Lee formation are probably equivalent to the Norton, Gladeville, and lower part of the Wise.)

Cw — **Wise formation**
Sandstone and shale with many coal beds

Cg — **Gladeville sandstone**

Cno — **Norton formation**
Sandstone and shale with many coal beds, most of which are thin in this quadrangle

Cle — **Lee formation**
Mostly coarse thick-bedded sandstone. Includes shale strata with thin coal beds. Sandstone conglomeratic in upper and lower parts

Cpng — **Undifferentiated Mississippian formations**
Include Pennington shale, Cpn (red and green shale and sandstone, 800 feet thick), at top; Newman limestone, Cn (300 feet thick), in middle; and upper part of Grainger shale, Cgr (green clay shale and brown and red sandstone, 400 to 500 feet thick), at bottom

Dgc — **Undifferentiated Devonian formations, including perhaps some Mississippian beds at the top**
Include lower part of Grainger shale and the Chattanooga shale of this region
Soft fissile shale, predominantly black but containing pale-brown layers and dark layers with very thin gray and yellow bands

136 — Coal outcrop; line broken where outcrop is concealed. Number refers to measured section of bed

Shipping mine

Local mine

Prospect

Bore hole

Syncline

Anticline

Road and house

Triangulation station

NAMES OF COAL BEDS IN VIRGINIA

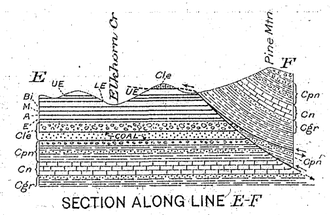
HS	High Splint
P	Pardee
Ph	Phillips
L Sp	Low Splint
T	Taggart
US	Upper Standiford
LS	Lower Standiford
UB	Upper Bolling
LB	Lower Bolling
C	Clintwood
B	Blair
G	Glamorgan
Y	Yellow Creek
Ed	Edwards
U Bn	Upper Banner
L Bn	Lower Banner
K	Kennedy
Sl	So-called Imboden
J	Jawbone

NAMES OF COAL BEDS IN KENTUCKY

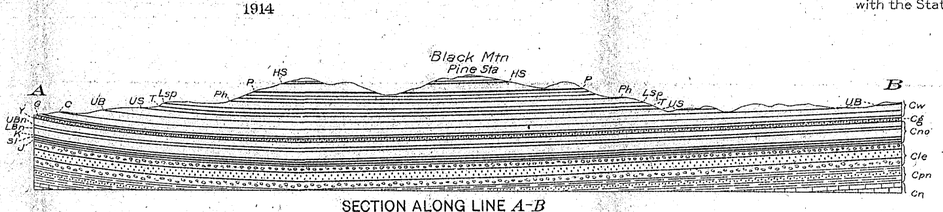
H	Hyden (Fire clay)
UE	Upper Elkhorn
LE	Lower Elkhorn
Bi	Bingham
M	Millard
A	Auxier
E	Elswick

NAMES OF COAL MINES IN KENTUCKY

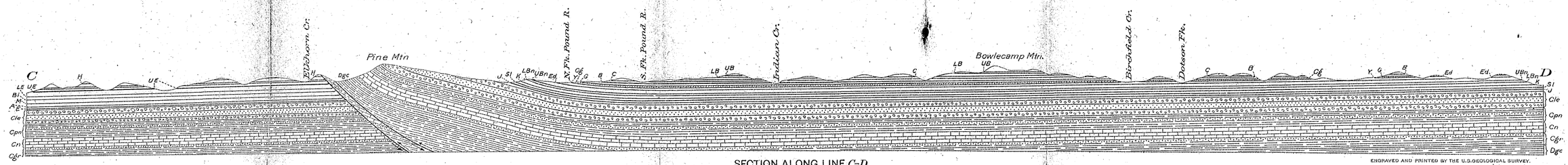
No. 1	Consolidation	No. 201
No. 2	"	" 202
No. 3	"	" 203
No. 4	"	" 204
No. 5	"	" 205
No. 6	"	" 206
No. 7	"	" 207
No. 11	"	" 211
No. 13	"	" 213
No. 14	"	" 214
No. 15	"	" 215



SECTION ALONG LINE *E-F*



SECTION ALONG LINE *A-B*



SECTION ALONG LINE *C-D*
The dip continues to the northwest corner of the quadrangle the same as shown in the section

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY.

GEOLOGIC MAP AND SECTIONS OF THE POUND QUADRANGLE, KENTUCKY AND VIRGINIA

the region is all bituminous, has the same range of composition, and is suitable for the same uses as the coal of the Appalachian field south of the Pocahontas region, except that of Lookout Mountain in Georgia and Alabama. The part of the quadrangle that lies in Virginia is as yet without adequate railroad facilities, but the area in Kentucky has recently been provided with railroads and 14 large mines have been put into operation.

The rocks lie generally nearly flat and all coal beds that outcrop can be exploited by drift mines. The beds generally have a strong roof and stable floor. There is no reason to expect trouble from gas or water. Timber and water for mining uses are abundant. Mining conditions, therefore, seem highly favorable and the region should with development become one of the principal coal-producing centers of the central Appalachian coal field.

THE COAL RESOURCES OF A PART OF NORTHEASTERN MISSOURI.[1]

By F. C. GREENE.

INTRODUCTION.

The district here considered is situated near the eastern border of the western interior coal field which lies in the Mississippi Valley.

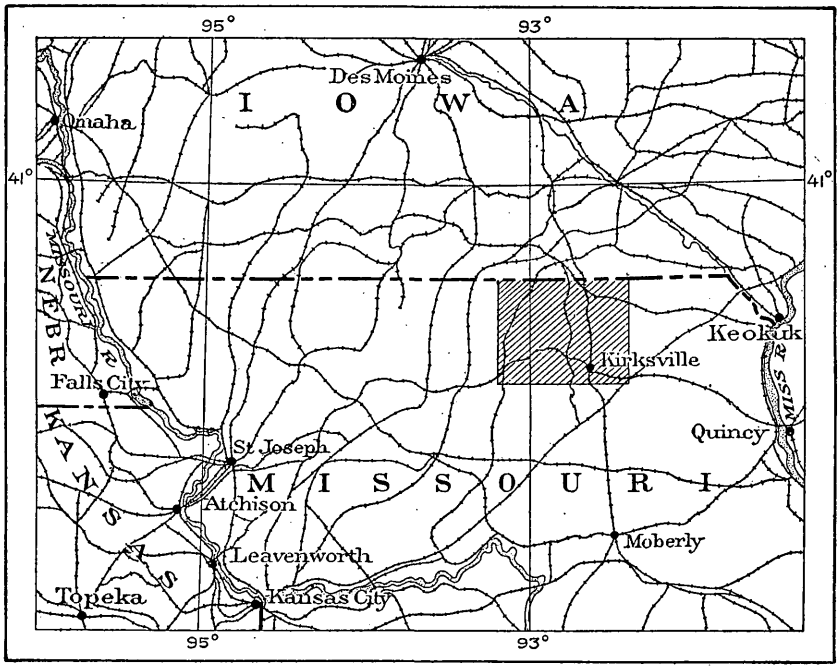


FIGURE 7.—Index map showing location of part of coal field of northeastern Missouri.

(See fig. 7.) The four counties in the northeastern part of Missouri in which the district is situated contain an estimated total original tonnage of nearly 10,000,000,000 short tons of bituminous coal in beds 2 to 6 feet thick and mostly less than 350 feet below the surface. Six lines of railroad cross or touch the area and furnish good shipping facilities.

[1] The field work for this report was done in cooperation with the Missouri Bureau of Geology and Mines, by which this paper is contributed.

The coal is of the bituminous grade, but can not be considered a coking coal. Most of the beds are of uniform thickness and character over large areas. Some of the beds outcrop at the surface and most of the remainder can be reached by shafts not over 200 or 300 feet deep.

This district, which borders the Iowa State line, includes the Novinger coal field, in which the Bevier is the chief producing coal bed, and the Mendota coal field, in which the production comes from other beds. Geographically the two fields are not sharply divided, and in fact to some extent overlap. For this reason and because the district is separated from the other Missouri coal fields by areas in which little or no mining is being done, it will here be described as a unit rather than as two separate fields.

A reconnaissance survey of the region was made in 1910 and 1911 by Henry Hinds and the writer, and in 1912 the outcrops of the coal beds were mapped by the writer, assisted by Maurice Albertson. This paper is based on this field work.

The stratigraphy of the general region is given in the reports of the Missouri and Iowa geological surveys [1] and in more detail in a later report by Hinds.[2] The geologic section of Putnam County given by Hinds is substantially the same as that used in this paper. Several correlations suggested by Hinds can now be made with certainty.

GEOGRAPHY AND TOPOGRAPHY.

Northeastern Missouri is a dissected plain. It is traversed in a north-south direction by the Grand Divide, east of which the drainage is southeast to the Mississippi and west of which it is in general south to Missouri River. The upland surface ranges in altitude from 900 feet along the eastern margin of the area to nearly 1,100 feet near the western edge. Chariton River, the largest stream in this part of the State, occupies a valley 1 to 3 miles wide and about 200 feet below the upland on the east.[3]

The Des Moines branch of the Wabash Railroad follows the Grand Divide across the area, the Iowa & St. Louis Railway extends through the Chariton Valley, and the Keokuk, Laclede & Carrollton branch of the Chicago, Burlington & Quincy Railroad traverses the western edge of the area. These three north-south lines are intersected by the Quincy, Omaha & Kansas City Railroad and the Keokuk & Western Railroad.

[1] See especially Missouri Geol. Survey Rept. for 1873–74, pp. 222–302, 1874, and Iowa Geol. Survey, vol. 5, pp. 360–438, 1896, and vol. 19, pp. 254–284, 1909.

[2] Hinds, Henry, The coal deposits of Missouri: Missouri Bur. Geology and Mines, vol. 11, 2d ser., 1912. Matter published in that report is used here without further acknowledgment.

[3] The topography of part of the area is shown on the Edina, Queen City, and Green City sheets of the United States Geological Survey.

GEOLOGY.

STRATIGRAPHY.

FORMATIONS PRESENT.

The geologic formations at or near the surface in this district are presented in the following table:

Geologic formations in northeastern Missouri.

System.	Series.	Group.	Formation.	Thickness.	Description.
				Feet.	
Quaternary.	Recent.				Alluvium.
	Pleistocene.			10-300	Glacial drift; bowlder clay, sand, pebbles, and bowlders.
	—Unconformity—				
Carboniferous.	Pennsylvanian.	Missouri.	Kansas City formation.	45+	Limestone and shale.
		Des Moines.	Pleasanton formation.	100-150	Shale and sandstone containing thin coal beds.
			Henrietta formation.	30-50	Limestone and shale.
			Cherokee shale.	200-410	Shale and sandstone with coal and some limestone.
	—Unconformity—				
	Mississippian.			(a)	Limestone with some shale and sandstone.

a Not exposed.

Only the upper 125 feet of the Cherokee shale is exposed, the remainder being known from drill records. The Mississippian is nowhere exposed in the area here considered, but along the east border in places it possibly lies immediately below the glacial drift.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

The entire area with the exception of parts of the deeper valleys is covered by an irregular thickness of glacial clay, sand, bowlders, and gravel, which in places is overlain by 1 or 2 feet of gray loess. The glacial materials were spread over the country by a sheet of ice during Pleistocene time. These materials filled up the old valleys and covered the old hills, leaving the surface a nearly level plain. The present cycle of erosion has destroyed much of the plain, though remnants of it have been left along the Grand Divide and in the other high parts of the area.

At most places the upper 30 or 40 feet of the drift consists of yellow clay and the lower part of an irregular thickness of blue clay, with sand or gravel at the base. A line drawn from a point near Kirksville northwest to Lemons approximately separates the area covered by thick drift from that in which the drift is thin. Southwest of that line sandstone and limestone outcrop nearly to the ridge tops, although a few channels filled with thick drift are probably present. Northeast of that line the drift under the uplands is 150 to 300 feet thick, owing apparently to the existence of a preglacial lowland. In certain parts of the area the preglacial channels are especially numerous and seriously interfere with the mining of the higher coal beds; in places the coal gives way to drift. The thickness of the drift on or near the upland is shown in the following drill records:

Depth of drift in a part of northeastern Missouri as shown by drill records.

	Feet.
Four and one-half miles northwest of Connelsville (sec. 19, T. 64 N., R. 16 W.)	110
Green Top	300
One-fourth mile southwest of Green Top (sec. 27, T. 64 N., R. 16 W.)	201
Three miles west of Harris (sec. 30, T. 64 N., R. 22 W.)	215
Howland	164
Kirksville	170
Six miles north of Kirksville (sec. 9, T. 63 N., R. 15 W.)	175
One-half mile west of Kirksville (sec. 8, T. 62 N., R. 15 W.)	140
One and one-half miles northwest of Kirksville (sec. 5, T. 62 N., R. 15 W.)	190
Lancaster	240
Six and one-half miles northeast of Lancaster (sec. 14, T. 67 N., R. 14 W.)	199
Lucerne	185
Memphis and vicinity	67–234
Omaha	115
Queen City	295
Two and one-half miles west of Queen City (sec. 19, T. 65 N., R. 15 W.)	165±
Unionville	220
One mile south of Unionville (sec. 3, T. 65 N., R. 19 W.)	116
Two and one-half miles northwest of Worthington (sec. 19, T. 65 N., R. 16 W.)	95+

In valleys the drift is commonly thinner than shown in the records given.

The great thickness of drift not only impairs the accuracy with which the outcrop of any particular coal bed may be traced, but in the eastern part of the area it completely obscures the boundary of the Pennsylvanian series.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

Thickness and character.—Except for the surficial Pleistocene material all the rocks that outcrop belong to the Pennsylvanian series. An aggregate of about 350 feet of Pennsylvanian rocks is exposed and, as shown by drilling in the northern part of the area, these rocks are underlain by a maximum of about 275 feet more of the same series, which rests unconformably upon strata of Mississippian age. The following table shows the depths at which the Mississippian has been reached, or, in other words, the thickness of the overlying Pennsylvanian and the glacial drift:

Depth to Mississippian rocks in northeastern Missouri as shown by drill records.

	Feet.
Connelsville, on hillside	258
5 miles northwest of Hurdland, on upland	130
Kirksville, on upland	244–450(?)
Memphis, various situations	150–287
Mendota, in valley	296–332
Moulton, Iowa, on upland	463
Sedan, Iowa, on alluvial plain of Chariton River	377
Unionville, on upland	545

Most of the variation in these depths is due to the differences in the altitude of the surface, but some of it is due to the variation in the thickness of the Pennsylvanian itself, the contact of which with the Mississippian is rather irregular because of an unconformity.

The Pennsylvanian series is divided into the Kansas City formation, Pleasanton formation, Henrietta formation, and Cherokee shale. The coal beds, however, are confined chiefly to the Cherokee shale. The following is a generalized section of the Pennsylvanian series of the region:

Generalized section of Pennsylvanian series in northeastern Missouri.

	Ft.	in.
Kansas City formation:		
Bethany Falls limestone member:		
Limestone, in nodules	3	
Limestone, gray; heavy bedded above, thin bedded below; has a few shale partings	12	4
Ladore shale member:		
Shale, blue	1	10
Shale, black, "slaty"	1	6
Limestone, gray		4
Shale, drab	5	
Sandstone, yellow; even and thick bedded	4	9
Shale, light drab; sandy	10	4
Hertha limestone member:		
Limestone, gray; in two beds at Milan, but to the east contains several shale partings	5	

	Ft.	in.
Pleasanton formation:		
Shale, variable; lower part is commonly black and "slaty" and bears large spherical concretions	15	
Coal (Ovid), very irregular, ranges from a film to 2 feet in thickness		3
Clay and shale	5	
Sandstone, blue when fresh, yellow or brown when weathered; in places calcareous; cross-bedded at top and locally contains 1 to 20 feet of conglomerate and coarse sandstone at base; unconformable on underlying beds; thickness of sandstone irregular, 15 to 88 feet, averaging about	50	
Shale, drab; thickness, 5 to 55 feet where present; replaced by the preceding sandstone in some areas; average probably	20	
Limestone, dark and shaly to blue and siliceous; interbedded with fossiliferous shale	2	
Shale, generally red at base; blue, drab, and red above; argillaceous, or in places sandy, and locally containing one or two thin coal beds accompanied by black "slaty" shale; average	20	
Henrietta formation:		
Limestone (Pawnee limestone member), gray, massive to nodular; apparently lacking in places but generally present and average thickness about	3	
Shale, red and green near top; about 10 feet thick and calcareous in southern part of area; contains a layer of sandstone in upper part and is 22 feet thick in northern part; average	15	
Limestone, in several thin layers with shale partings; locally called the "water rock"	2	
Shale, variable, drab to dark; argillaceous, calcareous, or bituminous	10	
Limestone, gray; even bedded ("10-inch cap rock")	1	
Shale, gray, blue, or green	2	
Limestone, blue; argillaceous; weathers to a buff earthy material; the "cap rock"	2	
Cherokee shale:		
Shale, black, "slaty"	1	2
Coal (Lexington) with two or three clay partings; absent in many places	3	3
Clay, 2 to 7 feet, average	3	
Limestone, blue to drab; upper surface uneven; in places conglomeratic; 2 to 6 feet, average	3	
Shale and sandstone, whitish at top	23	
Limestone, dark, impure; 2 to 12 inches		3
Shale, dark and soft at top, black and "slaty" below ("slate vein")	5	6
Shale, dark; calcareous, with abundant shells		6
Coal (Summit)		1
Clay, shaly at base; 5 to 10 feet, average	7	
Limestone, blue, weathers buff; nodular on top	2	
Shale, clayey	3	

	Ft.	in.
Cherokee shale—Continued.		
Limestone, blue, even bedded, weathers to buff-colored blocks; absent in much of area	1	
Shale, light at top, black and "slaty" below; generally absent but in places 6 feet thick; average		6
Coal (Mulky), in one place 21 inches thick; generally absent		1
Shale, sandstone, and clay, 36 to 55 feet; clay at top, dark shale or sandstone at base; average	47	
Coal (Bevier); replaced by sandstone at a few places near Kirksville; north and west of Connelsville and Novinger the thickness is irregular, as the lower clay parting thickens to 20 feet and locally contains sandstone; total coal content of bed commonly about	3	
Clay, locally containing calcareous nodules at base; 1 to 7 feet; average	3	6
Limestone, generally in two beds separated by shale	4	
Shale, clayey and sandy (lowest stratum that outcrops); contains locally a 12-inch coal bed near middle; 40 to 60 feet; average	50	
Coal (Lower Ardmore)	2	
Shale, sandstone, and several irregular coal beds; lower portion absent in southern part of area	160	
Coal (Cainesville?) Upper and lower benches thin where parting thickens; absent in southern part of area; average	6	
Shale, sandstone, and clay; absent in southern part of area	40	
Limestone (Mississippian).		
	560	2

Kansas City formation.—The Kansas City is the highest indurated formation exposed and contains the thickest limestone beds in the area. In this locality the formation is only 45 feet thick, as all but the three lower members have been removed by preglacial erosion. It outcrops in a few small areas, the largest being in the vicinity of Milan, where there are good exposures of both the Hertha and Bethany Falls limestone members; the Bethany Falls is quarried for rough stone.

Pleasanton formation.—Beneath the Kansas City lies 100 to 150 feet of shale and sandstone belonging to the Pleasanton formation. The sandstone is most conspicuously developed southwest of a line extending from Millard to Pennville. It is massive and forms overhanging cliffs and caves along Spring Creek in Sullivan County and in the southern part of Adair County. In northern Putnam County the Pleasanton is represented by a few feet of variegated shale lying between the top of the Henrietta formation and the glacial drift. In the vicinity of Mapleton and Worthington the conglomerate which generally occurs near the middle of the formation rests on beds belonging to the Cherokee shale, indicating the erosion of 100 feet of strata.

Henrietta formation.—Below the Pleasanton lies the limestone and shale of the Henrietta, 30 to 50 feet thick. This formation outcrops throughout the area, wherever erosion has reached its horizon, except along the Chariton River drainage between Novinger and a point about 3 miles south of the Iowa-Missouri State line. In this area and directly east of it the Henrietta formation and probably much of the Cherokee shale have been removed by preglacial erosion. The Henrietta, though not coal bearing, is important as a guide to the depth of the coal beds of the underlying Cherokee.

Cherokee shale.—The Cherokee, which is the chief coal-bearing formation of the area and of the State, lies low with respect to drainage and, therefore, only a comparatively small portion of it is exposed. The upper part outcrops in several localities and contains some of the most persistent strata in Missouri which, like those of the Henrietta formation, furnish important clues to the depth of the underlying coal beds. The lower beds are apparently more irregular. The formation was deposited in an epoch of transgressing seas, so that beds reported in deep drillings in northern Putnam County and in Appanoose County, Iowa, disappear to the south. This is shown in the following drill records:

Log of core drill from boring at Sedan, Iowa.[a]

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Quaternary:				
Soil and drift	74		74	
Cherokee shale:				
Coal (upper bench of Bevier)	2	5	76	5
Fire clay	2		78	5
"Soapstone" shale	21		99	5
Coal (lower bench of Bevier)		5	99	10
Fire clay	3		102	10
Shale, dark, with limestones	16		118	10
"Slate," black	10		128	10
Shale, clayey, white	29		157	10
Coal (Lower Ardmore)	1	10	159	8
Shale, black	3		162	8
"Soapstone" shale	30		192	8
Coal	1	10	194	6
Sandstone	7		201	6
Shale, blue	5		206	6
Coal		9	207	3
Shale, gray	9		216	3
Shale, sandy	16		232	3
Shale, black	4		236	3
Coal		7	236	10
Shale, clayey, blue	2		238	10
Cherokee shale—Continued.				
Coal	2	3	241	1
Shale, blue	5		246	1
"Conglomerate"	1		247	1
Coal	2	10	249	11
"Soapstone" shale	7		256	11
Shale, gray	4		260	11
Shale, blue	2		262	11
Coal	1	3	264	2
Shale, gray	5		269	2
Shale, blue	20		289	2
Sandstone	14		303	2
Shale, blue	18		321	2
(Cainesville coal?) Coal	2	10	324	
(Cainesville coal?) Fire clay		8	324	8
(Cainesville coal?) Coal	2	1	326	9
Shale, blue	9		335	9
Coal	2	4	338	1
Fire clay	7		345	1
Shale, gray	13		358	1
Shale, blue	2		360	1
"Soapstone" shale, white	17		377	1
Limestone (probably Mississippian)	5		382	1

[a] Iowa Geol. Survey, vol. 19, pp. 266–267, 1909.

Log of core drill near Star shaft, Kirksville, Mo.

	Thickness.		Depth.	
Quaternary:	*Ft.*	*in.*	*Ft.*	*in.*
Soil, black	1		1	
Clay, yellow	10		11	
Sand	8		19	
Clay, blue, mixed with sand	51		70	
Cherokee shale:				
Limestone, broken	2		72	
Shale, sandy	30		102	
Shale, black, "slaty" (Summit coal horizon)	5		107	
Shale, calcareous	6		113	
Limestone	2		115	
Shale, dark	2	6	117	6
Shale, light	7	6	125	
Sandstone	37	10	162	10
Bevier coal: Coal	1	3	164	1
Bevier coal: Shale		1	164	2
Bevier coal: Coal	1		165	2
Cherokee shale—Contd.				
Clay	3	4	168	6
Shale, light	2		170	6
Limestone		9	171	3
Shale, blue	1	2	172	5
Limestone		7	173	
Shale, sandy	32		205	
Shale, light	9	10	214	10
Coal (Lower Ardmore)	2		216	10
Clay	2		218	10
Shale, calcareous	25	2	244	
Sandstone	8		252	
Shale, calcareous	10		262	
Limestone	2		264	
Shale, calcareous	10		274	
Limestone (probably Mississippian)	2		276	

MISSISSIPPIAN SERIES.

The Pennsylvanian series throughout northeastern Missouri rests on beds of Mississippian age that contain no coal in this State. These beds outcrop nowhere in the area described in this report but have been found in a number of drillings. The Mississippian rocks consist chiefly of limestone, though at a number of places in Putnam and Adair counties the uppermost beds are thin, alternating layers of limestone, shale, and sandstone that are distinguished with difficulty from the Cherokee shale. Drilling for coal should therefore be carried sufficiently deep to insure reaching the thick and easily recognized limestone that forms the lower and major portion of the Mississippian.

STRUCTURE.

The strata in the area lie nearly horizontal but dip gently to the southwest. The general dip is interrupted by a series of low folds whose axes trend northwest and southeast. The most pronounced fold is the arch that causes the Bevier coal to outcrop near Connelsville.

THE COAL BEDS.

DISTRIBUTION AND STRATIGRAPHIC RELATIONS.

The principal coal beds of the area are the Ovid, Lexington, Mulky, Bevier, Lower Ardmore, and Cainesville (?). Of these, all except the Mulky and Cainesville (?) are utilized, though only two beds, the Lexington and Bevier, are mined for shipment. Coal underlies most of the region shown in Plate XII (p. 234), but there are probably many small barren areas near the eastern margin of the district.

Ovid coal bed.—The Ovid, the highest coal bed in the area, is now mined only for local use. It is probable that for a long time it will

not be used in any other way, owing to its small areal extent and thinness and to the absence of "mining clay" in many places. It has been found thick enough to mine 2 or 3 miles north of Milan (secs. 32 and 27, T. 63 N., R. 20 W.), where it is 14 to 30 inches thick but contains clay partings (Pl. XII, sections 1 and 2). It is mined by drifts about 6 miles north of Green City (sec. 18, T. 64 N., R. 11 W.) where it ranges from 20 to 30 inches (Pl. XII, sections 3 and 4). It is overlain by black laminated ("slaty") shale and rests directly on firm sandstone. It was formerly mined about 2 miles southeast of Youngstown and will probably be found in other small areas in southwestern Adair County. No samples of the Ovid coal were collected in this area for analysis.

Lexington coal bed.—Though important as a source of fuel for local consumption, the Lexington coal of the Mendota district furnished in 1911 but 1 per cent of the State's production. The bed is remarkably uniform over its entire area (Pl. XII, sections 5 to 11) but contains many "slips" (true faults of small throw) and "faults." The "faults" are places in which the coal is lacking, either because it was never deposited there or because of removal by preglacial erosion due to the relatively high position of the bed with regard to drainage. The presence of these abrupt channels detracts greatly from the commercial value of the bed. The Lexington bed outcrops in many places on Spring, Shuteye, Blackbird, and Shoal creeks. The following shows the average section in eastern Putnam County, near the center of the field:

Average section of Lexington coal bed in eastern Putnam County.

	Ft.	in.
Limestone (cap rock)	3	
Clay (clod)	1	2
Shale, black, laminated (slate)		11
Coal (upper bench)	1	9
Clay (mud band)		2
Coal (lower bench)	1	
Clay		1
Coal (Dutchman)		3
Clay	4	6
Limestone (bottom rock)	4	

West of Unionville and north of Milan the "Dutchman" bench disappears. The coal has been mined near Powerville and also in the SW. ¼ SW. ¼ sec. 27, T. 64 N., R. 19 W. It is reported in drillings near Princeton but is irregular in thickness at this place. South of T. 63 N. the Lexington coal is generally absent, though the limestones associated with it are persistent. On Missouri River the coal bed is present and is being mined. Chariton River marks the general eastern boundary of the Lexington bed, but in the northwestern corner of Schuyler County it outcrops in T. 67 N. and is

said to have been traced to Guinn station by drillings. To the north, in Appanoose County, Iowa, the Lexington, or Centerville (Mystic) coal as this bed is there known, is mined extensively.

Mulky coal bed.—The Mulky coal bed has been found of workable thickness at only one place in the area (Pl. XII, section 12), but it may occur at others. The following section was measured on the south side of Shoal Creek near old Glendale post office (NW. ¼ NW. ¼ sec. 35, T. 66 N., R. 17 W.):

Section of Mulky coal bed near old Glendale post office.

	Ft.	in.
Limestone, gray, weathers deep buff	1	5
Shale, banded gray, blue, and black	6	
Coal; contains white partings that weather red	1	9
Shale, gray, streaked with black, soft	1	8

At other places in the Chariton Valley the Mulky coal occurs as a thin bed below its limestone cap rock and roof shale, or as a black streak a few feet below the horizon of the Summit coal bed.

Bevier coal bed.—The coal so extensively mined in the Novinger district and sold under the name "Novinger" is correlated with that in the Bevier field, and in the interests of uniformity the name Bevier, which has priority, is here used. The Bevier bed is 90 to 100 feet below the Lexington. In 1911 the mines operating on the Bevier bed in this locality yielded approximately 10 per cent of the State's production. At Novinger and Connelsville the bed is of uniform thickness (Pl. XII, sections 13 and 14), but at Kirksville and Youngstown (Pl. XII, sections 15 and 16), sandstone replaces the upper bench or the whole bed. The following is the average section in the vicinity of Novinger:

Average section of Bevier coal bed near Novinger.

	Ft.	in.
Coal	2	1
Clay		¼
Coal		4
Clay		1
Coal	1	
	3	6¼

At Danforth, Stahl (Pl. XII, section 17), Duey, and Milan (Pl. XII, section 22) the lower clay parting is irregular. It is 9 feet thick at Stahl, 14 feet thick at Duey, and ranges from a thin film to 27 inches at Milan. North of Connelsville and Hazel Creek in Putnam (Pl. XII, sections 18 and 20), and Schuyler (Pl. XII, section 21) counties, the lower clay parting is as much as 20 feet thick and contains sandstone. The Bevier coal outcrops on Chariton River near Connelsville, at Slate Ford near Worthington, and on the lower courses of Shuteye, Wildcat, and Shoal creeks. Drillings at Prince-

ton and Trenton, Mo., show the two benches of the coal to be irregular and to include more or less clay and shale between them. Drillings near Pure Air and Yarrow, in southwestern Adair County, show nearly or quite the normal thickness of the coal and the clay parting and it is probable that future development will be toward this locality. Drillings along the Wabash Railroad indicate the absence of the Bevier bed under the Grand Divide, north of Kirksville. However, a boring for water in the SW. ¼ SE. ¼ sec. 19, T. 65 N., R. 15 W., is reported to have encountered 56 inches of coal (probably in part shale) at a depth of 245 feet, an altitude which corresponds closely with that of the Bevier coal at the old Rawson shaft about 2 miles distant (SW. ¼ SE. ¼ sec. 12, T. 65 N., R. 16 W.). The reported coal may therefore be the Bevier, but this is the easternmost locality at which there is any evidence of it in the northern part of the area. At all outcrops and as reported in all reliable drill records in northern Putnam and Schuyler counties and in Appanoose County, Iowa, the Bevier bed is split by a clay, shale, or sandstone parting, but both benches are, as a rule, over 14 inches thick.

The material overlying the Bevier bed is variable. At Novinger, Connelsville, and near Hazel Creek it is a light or dark shale which, does not, however, approach a "slaty" shale like that over the Lexington bed. Near Kirksville and east of Youngstown the roof is a massive sandstone whose base is characterized by "rolls," which in places cut down into the coal, thus rendering mining difficult. The coal is underlain by clay and that in turn by limestone.

Lower Ardmore coal bed.—About 50 feet below the Bevier lies the Lower Ardmore coal, a bed that does not outcrop in the area but is well known in drillings. At present it is mined only by the Star Coal Co., near Kirksville (Pl. XII, section 23). It is reported in drillings to range from 14 to 36 inches in thickness, but is usually close to the average of 24 inches.

The western boundary of the Lower Ardmore bed is not known, but the bed has been found at Princeton and is probably the one mined at Trenton. It extends south to Linn and Macon counties, but little is known of it between those counties and the Novinger district. Drillings at Green Top, Queen City, and Lancaster indicate that it is replaced by glacial drift under the Grand Divide. To the north, in Appanoose County, Iowa, it appears to be persistent but is slightly thinner.

Lower beds.—In Davis County, Iowa, 6½ miles northeast of Lancaster (SE. ¼ sec. 14, T. 67 N., R. 14 W.), a 38-inch coal bed with a 4 to 6 inch clay parting was mined, and the same bed is reported to have been found one-half mile south of the Missouri line. The thick coal bed at Sedan, Iowa, is shown in the drill log given on page 230.

MAP SHOWING COAL RESOURCES OF A PART OF NORTHEASTERN MISSOURI, WITH SECTIONS OF THE COAL.

By F. C. Greene.

Scale 1 : 187,500

0 1 2 3 4 5 10 Miles

LEGEND

Area probably underlain by both the Lexington and Bevier coal beds

Area probably underlain by the Bevier coal bed

Area in which the Lexington and Bevier coal beds are probably absent

Coal outcrops (Numbers refer to measured sections)

Coal outcrop concealed by glacial drift; location inferred

Shaft

Drift

Local mine

Drill hole

Note - Entire area may be underlain by still lower coal beds

LEGEND

Coal

Carbonaceous shale

Shale

Sandstone

It is possible that deep drilling may show the presence of this or other thick coal beds in northeastern Putnam and in northern Schuyler counties. At Mendota no thick coal was found at the Cainesville horizon, but between Mendota and Princeton a wide stretch of territory has not been explored. The existence of thick coal below the Lower Ardmore coal bed near Connelsville, Kirksville, and Novinger or for some distance to the south is thought to be improbable.

QUALITY OF THE COAL.

PHYSICAL CHARACTER.

The coal of this district, like that of the surrounding region, is bituminous. It is capable of forming a low-grade coke, but can not be properly considered a coking coal. The average quality of the coal of the district is slightly lower than that of the coal of southwestern Missouri, but compares very favorably with that of the nearby districts in Iowa and Illinois.

In physical properties the coal of the different beds is similar, varying but slightly. White scale (gypsum and calcite) is usually present but is probably more abundant in the Lexington than in the lower beds. The "sulphur" (iron sulphide) concretions are easily detected and may be thrown out by the miner. The luster of the Lexington coal is commonly brighter than that of the lower beds, and the coal is also distinguished by the fact that the larger lumps come from the mine in a roughly cubical shape that has given rise to the name "block coal," which is often used in Iowa. It is this property that gives it good shipping quality and causes it to be favored as a domestic fuel. One of the beds, the Bevier, is somewhat dirty at the top and bottom, but is hard and is an excellent steam coal.

CHEMICAL ANALYSES.

Analyses of samples of the three principal coal beds of the district are given herewith. The Lexington and Bevier beds are represented by four and six analyses, respectively, but the Lower Ardmore bed by only one. Conclusions must be made with this fact in mind.

Analyses of coal samples from northeastern Missouri.

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

Adair County.

Laboratory No.	Locality.	Collector.	Name of bed.	No. on Pl. XII.	Air-drying loss.	Form of analysis.[a]	Proximate.				Ultimate.					Heating value.	
							Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
10088[b]	1½ miles south of Connelsville	J. M. Webb	Bevier	13	11.4	A	16.1	32.1	39.1	12.65	3.31	5.70	55.76	1.00	21.58	5,685	10,240
						B	5.3	36.2	44.2	14.28	3.74	5.00	62.93	1.13	12.92	6,420	11,550
						C	.....	38.3	46.6	15.07	3.94	4.66	66,44	1.19	8.70	6,775	12,190
						D	.....	45.1	54.9	.....	4.64	5.49	78.23	1.40	10.24	7,980	14,360
10106[c]	½ mile west of Kirksville	do	do	15	11.1	A	14.6	32.0	39.5	13.91	3.69	5.56	56.12	.93	19.79	5,700	10,260
						B	3.9	36.1	44.4	15.65	4.15	4.87	63.13	1.05	11.15	6,410	11,540
						C	.....	37.5	46.2	16.29	4.32	4.61	65.71	1.09	7.98	6,675	12,010
						D	.....	44.8	55.2	.....	5.16	5.51	78.50	1.30	9.53	7,975	14,350
10442[c]	do	do	do	15	9.8	A	14.4	32.3	40.2	13.14	5.29	5.56	56.43	1.00	18.58	5,720	10,300
						B	5.1	35.8	44.5	14.57	5.86	4.95	62.56	1.11	10.95	6,345	11,420
						C	.....	37.7	46.9	15.35	6.18	4.63	65.93	1.17	6.74	6,685	12,030
						D	.....	44.6	55.4	.....	7.30	5.47	77.88	1.38	7.97	7,895	14,210
10090[b]	2½ miles southwest of Novinger	V. H. Hughes	do	13	9.5	A	15.1	32.7	41.9	10.26	3.52	5.68	58.41	.98	21.15	5,950	10,710
						B	6.2	36.1	46.4	11.34	3.89	5.11	64.54	1.08	14.04	6,575	11,840
						C	.....	38.5	49.4	12.09	4.15	4.71	68.82	1.15	9.08	7,010	12,620
						D	.....	43.8	56.2	.....	4.72	5.36	78.28	1.31	10.33	7,975	14,360
10089[b]	2½ miles north of Novinger	do	do	13	10.4	A	15.7	33.5	38.9	11.89	3.02	5.69	57.72	.99	20.69	5,785	10,410
						B	6.0	37.3	43.4	13.27	3.37	5.06	64.43	1.10	12.77	6,455	11,620
						C	.....	39.7	46.2	14.11	3.58	4.68	68.50	1.17	7.96	6,865	12,350
						D	.....	46.2	53.8	.....	4.17	5.45	79.77	1.36	9.25	7,990	14,380
10081[b]	1 mile northwest of Stahl	J. M. Webb	Lexington	5	9.5	A	15.4	34.8	38.8	10.99	3.57	5.88	57.09	.95	21.52	5,810	10,460
						B	6.5	38.5	42.9	12.14	3.95	5.33	63.08	1.05	14.45	6,420	11,560
						C	.....	41.1	45.9	12.98	4.22	4.93	67.45	1.12	9.30	6,865	12,360
						D	.....	47.3	52.7	.....	4.85	5.67	77.51	1.29	10.68	7,890	14,200
14799	½ mile west of Kirksville	M. Albertson	Lower Ardmore	23	11.0	A	16.0	38.1	37.2	8.69	4.12	5.90	59.09	.94	21.26	6,000	10,800
						B	5.6	42.9	41.7	9.76	4.63	5.26	66.39	1.06	12.90	6,740	12,130
						C	.....	45.4	44.3	10.34	4.90	4.90	70.33	1.12	8.41	7,140	12,850
						D	.....	50.6	49.4	.....	5.46	5.46	78.44	1.25	9.39	7,965	14,330

[a] A, Analyses of the coal as received; B, air-dried coal; C, moisture-free coal; D, moisture and ash free coal. [b] Composite of three samples. [c] Composite of two samples.

Putnam County.

Laboratory No.	Locality.	Collector.	Name of bed.	No. on Pl. XII.	Air-drying loss.	Form of analysis.[a]	Proximate.				Ultimate.					Heating value.	
							Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
11401[b]	1 mile southeast of Mendota	J. M. Webb (?)	Lexington	7	15.2	A	18.5	32.6	39.0	9.90	4.09	5.76	55.71	0.91	23.63	5,580	10,040
						B	3.8	38.5	46.0	11.67	4.82	4.80	65.69	1.07	11.95	6,580	11,840
						C	.....	40.0	47.9	12.14	5.02	4.55	68.31	1.12	8.86	6,840	12,310
						D	.....	45.5	54.5	.....	5.71	5.18	77.75	1.27	10.09	7,785	14,010
14880	2½ miles northeast of Unionville	M. Albertson	do	8	12.8	A	16.5	34.4	37.3	11.8	3.39	.....	.....	.....	.....	5,600	10,080
						B	4.3	39.4	42.8	13.5	3.89	.....	.....	.....	.....	6,420	11,560
						C	.....	41.2	44.7	14.1	4.03	.....	.....	.....	.....	6,705	12,070
						D	.....	47.9	52.1	.....	4.73	.....	.....	.....	.....	7,810	14,050
14881	do	do	do	8	12.8	A	16.5	34.8	37.4	11.3	2.88	.....	.....	.....	.....	5,565	10,010
						B	4.3	39.8	42.9	13.0	3.30	.....	.....	.....	.....	6,380	11,430
						C	.....	41.6	44.8	13.6	3.45	.....	.....	.....	.....	6,665	11,990
						D	.....	48.2	51.8	.....	3.99	.....	.....	.....	.....	7,710	13,880

Sullivan County.

10143[b]	1 mile south of Milan	J. M. Webb	Bevier	22	8.4	A	13.1	32.3	37.5	17.12	5.93	5.40	53.38	0.92	17.25	5,500	9,900
						B	5.1	35.2	41.0	18.69	6.47	4.88	58.28	1.00	10.68	6,000	10,800
						C	.....	37.1	43.2	19.70	6.82	4.53	61.44	1.06	6.45	6,330	11,390
						D	.....	46.2	53.8	.....	8.49	5.64	76.51	1.32	8.04	7,880	14,180

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

[b] Composite of three samples.

All the samples were selected from freshly cleaned faces of coal in active workings of the mines in accordance with the regulations prescribed by the Bureau of Mines. The analyses were made by this bureau or by the technologic branch of the United States Geological Survey before it was organized as the Bureau of Mines.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis probably represents the coal in its most stable condition and approaching most closely its condition as it reaches the market. Analysis C represents the theoretical condition of the coal after all its moisture has been eliminated. Analysis D represents the coal after all moisture and ash have been theoretically removed. Forms C and D, which are obtained from the others by recalculation, represent theoretical substances that do not exist. In the proximate analysis the coal is broken up into certain conventional constituents, representing approximately those found in the process of coking. In other words, the proximate analysis shows what portion of the sample passes away in coking (the moisture and volatile matter) and what part remains (the fixed carbon and ash). The ultimate analysis shows the chemical elements of the coal. For general comparisons, however, the heating value of the sample in the air-dried condition presents a more succinct means than the amounts of the various constituents determined by the proximate or ultimate analyses.

COMPARISON OF ANALYSES OF THE DIFFERENT BEDS.

The samples as received from the mine show the Lexington coal to contain on the average the most moisture and the Bevier the least, but in the air-dried condition the Lexington contains the least and the Lower Ardmore the most moisture. On an air-dried basis the Bevier bed ranks highest and the Lower Ardmore lowest as regards the amount of fixed carbon in the average sample. According to these analyses, the Lower Ardmore contains the least ash and the Bevier contains the most. The amount of sulphur in the average of the Bevier samples and in the one sample of the Lower Ardmore is practically the same, and is more than in the Lexington. In the number of British thermal units, the Lower Ardmore seems to rank highest, but the Lexington and Bevier appear to be close seconds.

The following table of average analyses shows in concise form the statements of the foregoing paragraph:

Average analyses of coal beds of a part of northeastern Missouri.

Name of bed.	Condition of samples.	Moisture.	Fixed carbon.	Ash.	Sulphur.	British thermal units.
Lexington	Air dried	4.71	43.66	12.57	3.99	11,605
	As received	16.71	38.15	11.00	3.48	10,148
Bevier	Air dried	5.27	43.97	14.63	4.56	11,451
	As received	14.84	39.52	13.16	4.16	10,300
Lower Ardmore	Air dried	5.60	41.77	9.76	4.63	12,132
	As received	15.98	37.18	8.69	4.12	10,798

QUANTITY.

As little is known of the coal resources in many places in the district, only an approximate estimate of the total original tonnage can be made. The following estimate for the four counties in the district, made on the basis of 1,800 tons of coal to the acre-foot, includes only beds 14 inches or more in thickness and is very conservative. Of the total original tonnage of 9,865,000,000 tons, less than one-fifth of 1 per cent has been mined.

Estimated original tonnage of coal.

County.	Coal beds.	Short tons.
Adair	Lexington, Bevier, and Lower Ardmore	2,260,000,000
Putnam	Lexington, Bevier, Lower Ardmore, and lower beds	4,295,000,000
Schuyler	do	340,000,000
Sullivan	Ovid, Lexington, Bevier, and Lower Ardmore	2,970,000,000
		9,865,000,000

DEVELOPMENT.

At present three districts in the area have shipping mines. These districts are, in productive rank, the Novinger-Connelsville, the Coal City, and the Mendota-Unionville. Besides the shipping mines a large number of local mines, chiefly drifts and slopes, operate during the threshing season and the colder months of the year and sell to a wagon trade. Few of these mines penetrate more than 100 feet from the outcrop and are abandoned in the spring, as it is easier to open a new mine than to clean out the old entries when work is resumed in the fall.

HISTORY.

The date of the first mining probably coincides with the settlement of the country. At the Snake Den mine, in northwestern Schuyler County, operations have been in progress more or less continuously for about 50 years. The first shipping mines were those at Mendota,

which have been operated for a quarter of a century or more. The drift mines at Stahl and one of the shafts at Danforth were producing in 1890. The first shaft at Milan was sunk in 1890 and the Blackbird Block Coal Co., after purchasing the mine of Castello & Sunderland, at Blackbird, Putnam County, began operations in September of the same year. The Emporia shaft was sunk in 1894 in the same district. Stroup Bros. began in that year to sink a shaft 1 mile west of Novinger in hope of reaching the bed worked at Danforth. The attempt was successful, and as a result the O. K. Coal Co. was organized and began producing in October, 1894. About the same time the camp at Duey was started and work in both the Lexington and Bevier beds was begun but proved a failure. Before 1897 prospecting at Stahl showed a lower bed and in 1897 a shaft was sunk to it but was soon abandoned.

Although mining began at Novinger in 1894 it was six or seven years before that district began to attract much attention. The Rombauer Coal Co. bought the O. K. property in 1898 and in 1901 began to sink shaft No. 2. In the same year the Kansas City Midland Coal Co. commenced business at Novinger, the Manufacturers Coal & Coke Co. opened a number of mines near Ninevah, changing the name of that village to Connelsville, and C. B. Havens bought the Danforth property. In 1901 also the Iowa & St. Louis Railroad was built, and the district surrounding Novinger was rapidly transformed from a wilderness to a thriving mining community. The next year the Manufacturers Coal & Coke Co. opened a slope in northwestern Schuyler County and the Bevier bed was reached at Kirksville. In 1903 the Great Northern Fuel Co. entered the Novinger field and the next year the second Milan shaft was sunk. Two years later a second shaft was sunk at Kirksville, and in 1912 the Lower Ardmore bed was opened at that place. At present the Danforth, Duey, Stahl, and Milan mines have nearly or quite ceased operations, so far as shipping is concerned, as they are unable to compete with other mines because of the parting in the coal bed.

EQUIPMENT.

The coal is mined by stripping, drifts, and slopes or shafts, though most of the larger mines have shafts. The 236-foot shaft of the Star Coal Co. at Kirksville is the deepest. Most of the larger mines are well equipped with top works and one mine has an electric hoist. The other large mines have steam hoists. The common type of horse gin or handpower hoist is used at the smaller shaft mines. The hauling is done with mules or burros in all mines of any size, though the Consolidated Stahl Coal Co., which formerly operated a drift at Stahl, used motor haulage to advantage.

The mines at Novinger, Connelsville, Milan, Mendota, and Coal City are connected with the main lines of the railroads by spurs, one being under construction at the shaft near Unionville when the field work was done. The mines in eastern Putnam County would undoubtedly be greatly benefited by spurs that could be easily built up Shoal and Blackbird creeks.

MINING METHODS.

Lexington coal bed.—In most of the area under discussion, the Lexington coal is mined by the room-and-pillar system, owing to the presence of "slips" and preglacial channels ("faults") and to the tendency of the underclay to "heave." The limestone cap rock about 2 feet above the coal forms a good roof, however, and would probably permit long-wall work where there are no "slips" and "faults" and where the underclay is thin.

Bevier coal bed.—At present the room-and-pillar method is usually followed in mining the Bevier coal bed, but the long-wall method has been introduced with good results. The hydraulic cartridge is being used in connection with long-wall work and in the opinion of operators in the Novinger field is a success in reducing the amount of slack coal. By the room-and-pillar method approximately two-thirds of the coal is recovered.

Lower Ardmore coal bed.—As the Lower Ardmore coal bed has just been opened, nothing is known of the conditions under which it may best be mined, but it is the intention to use the long-wall system if on trial it proves to be successful. Although not equal in importance at the present time to the Bevier coal, it will probably become a valuable bed when the Bevier is exhausted, and should prove of value at present in the localities in which the Bevier is absent or irregular in thickness.

PRODUCTION.

The production and value of the coal mined in the parts of the four counties lying in the region under discussion for 1910 and 1911 are shown in the following table:

Production and value of coal mined in a part of northeastern Missouri, 1910–11.

County.	Production (short tons).		Value.	
	1910	1911	1910	1911
Adair	250,230	352,486	$412,621	$553,848
Putnam	60,645	21,259	119,896	37,442
Schuyler	1,943	21,950	3,936	40,675
Sullivan	7,200	1,000	21,600	2,750
	320,018	396,695	558,053	634,715

FUTURE OF THE DISTRICT.

Under present conditions the future outlook for the district is not particularly bright, chiefly because of its location, which limits the market. On the south lies the Bevier field and on the north the Iowa field, so that the output in this district is largely used locally or in near-by sections of northern Missouri by railroads and for domestic fuel. Direct communication by rail with northwestern Missouri and eastern Nebraska would furnish a new outlet and would undoubtedly be a great advantage. Manufacturing in the district has been commenced by the location of a shoe factory at Kirksville, and other enterprises might be started at this and other near-by points to the mutual advantage of manufacturer and mine operator.