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BROKEN ARROW COAL AND ASSOCIATED STRATA

Western Rogers, Wagoner, and Southeastern Tulsa Counties,
Oklahoma

by

MALCOLM C. OAKES

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ABSTRACT

The stratigraphy from the upper part of the Chelsea sandstone to the base of the Fort Scott limestone was studied recently in connection with an investigation of the Broken Arrow coal in the area between Broken Arrow and Bushyhead. Bushyhead is situated near the center of T. 23 N., R. 17 E., on the St. Louis-San Francisco Railway, about four miles beyond the northern limit of the area covered by the accompanying map.

The upper part of the Chelsea sandstone consists generally of two phases; a lower, coarse-grained, cross-bedded, tree-bearing sandstone; and an upper grass-covered zone of silty shale and thin-bedded, silty to shaly sandstone. Based on somewhat uncertain determinations of dip, the interval from the top of the Chelsea to the base of the Broken Arrow coal is of the order of 50 to 80 feet. It contains clay shale and silty shale, a few silty sandstone lenses, and several thin coals. Silty to sandy limestone was observed a few feet below the Broken Arrow coal from sec. 21, T. 19 N., R. 15 E. to sec. 24, T. 21 N., R. 15 E., and the log of a well in sec. 7, T. 18 N., R. 15 E. records limestone at this horizon.

The Broken Arrow coal is present throughout the area and ranges in thickness from about 24 inches in the vicinity of Broken Arrow to about 14 inches north of Bushyhead. The interval from the Broken Arrow coal to the base of the Verdigris (Ardmore) limestone ranges in thickness from 16 feet in the vicinity of Broken Arrow to 70 feet north of Bushyhead. The striking similarity of the beds occupying this interval in Oklahoma and the interval between the Croweburg coal and Ardmore limestone in Kansas, together with the fairly definite Verdigris-Ardmore correlation, are good reasons for correlating the Broken Arrow and Croweburg coals. The Verdigris (Ardmore) limestone is dark and massive, 2 to 5 feet thick, and remarkably uniform.

The interval upward from the Verdigris (Ardmore) to the Fort Scott limestone is about 140 feet thick in the vicinity of Broken Arrow but thins to 30 feet or less in T. 22 N. It is somewhat thicker across T. 23 N. A limestone generally 2 to 3 feet thick crops out about 50 feet below the Fort Scott in T. 18 N., Rs. 14 and 15 E. where it has been mistaken for both the Fort Scott and Verdigris limestones. It could be mistaken easily for the Verdigris in subsurface studies. It occupies about the same stratigraphic position as the Breezy Hill limestone of Kansas.

INTRODUCTION

Early in 1941, the Oklahoma Geological Survey and the United States Bureau of Mines began investigating coals in Oklahoma, with special reference to coking properties and other chemical characteristics. Early in 1941, the Bureau of Mines obtained samples of the Henryetta coal, Okmulgee County, and, in the Central Experiment Station, Pittsburgh, Pennsylvania, subjected this coal, in blends with a low-volatile Hartshorne coal from western Arkansas, to coking tests by the Bureau of Mines—America Gas Association methods.

For the fiscal year beginning July 1, 1941, the Oklahoma Geological Survey received funds for financial participation in such investigations, and the McAlester coal was tested in blends with low-volatile coal from northern Le Flore County, Oklahoma. In both instances, satisfactory metallurgical coke was produced. Subsequent tests in the testing laboratory of a manufacturer of by-product coke ovens further demonstrated that Oklahoma coals are satisfactory for this purpose, and Oklahoma coal is now being supplied to coke ovens at new blast furnaces in Texas.

During the fiscal year beginning July 1, 1942, a smaller appropriation was available to the Oklahoma Geological Survey for cooperation with the Bureau of Mines, and it was deemed advisable to obtain and analyze samples from as many mines in as many different coal beds and producing districts, as possible. Included in this program were a number of mines in the coal-producing area between the vicinity of Broken Arrow, southeastern Tulsa-western Wagoner Counties, and Bushyhead, northeastern Rogers County. This is the principal strip-mining district of Oklahoma, and several years ago it accounted for more tonnage than any other mining district in the state. At the present time, coal from this district is contributing substantially to the war effort, introducing the possibility of increased activity, and perhaps new development.

Analyses of coal from various localities in the district showed such widely divergent characteristics, that some question arose as to correlation of the beds from which the samples came, so it was deemed advisable to undertake a stratigraphic investigation with

the view of determining the true correlations of the exposures sampled. Field work was begun April 13, 1943, and continued, with interruptions, to June 18, 1943.

The stratigraphic limits of the investigation were the upper part of the Chelsea sandstone, below, and the base of the Fort Scott limestone, above. The final conclusions reached are that all samples represented by the analyses were from the Broken Arrow coal, and that discrepancies indicated by the analyses are due to lateral variations in the coal. The investigation produced more detailed knowledge of the stratigraphy of the upper Cherokee than has been available heretofore, and the pertinent observations and deductions made in the course of the work are reported in this circular.

The writer wishes to express his appreciation to Mr. R. F. Barrow, of the Seneca Coal and Coke Co., and Messrs. E. L. and D. F. McNabb, of the McNabb Coal Company, to Mr. Frank J. Podpechan of the Rogers County Coal Co. for consultation and cooperation, and to Mr. J. B. Ross, of Foyil, Oklahoma for information as to the character of coal seams found in drilling for oil and gas. Thanks are due to Robert H. Dott and J. O. Beach for assistance in preparation of the manuscript and to Neal T. Dilday for preparation of the map and sections.

Previous investigations. This area, in common with other parts of northeastern Oklahoma, was visited in the course of several early geological expeditions; but the earliest investigation which will be mentioned here is that reported by Gould, Ohern, and Hutchison¹ in 1910. Ohern mapped equivalent strata in the Vinita quadrangle, to the north, during the period 1908 to 1911. A little later Carl D. Smith mapped the Claremore Quadrangle which includes most of the area considered here. Neither the work of Ohern nor that of Smith was published, but the original maps were used in compiling the Geologic Map of Oklahoma² in 1926. The writer has had access to the unpublished report of Ohern and to a photostatic copy

¹ Gould, Charles N., Ohern, D. W., and Hutchison, L. L., "Proposed Groups of Pennsylvanian Rocks of Eastern Oklahoma," *The State University of Oklahoma Research Bull.* 3, 1910.

² Miser, Hugh D., "Geologic Map of Oklahoma", *U. S. Geological Survey*, 1926.

of Smith's original map. Both contributed substantially to this investigation, as did a manuscript reconnaissance map by S. W. Lowman, made in 1933, which was kindly loaned to Oklahoma Geological Survey, and for which acknowledgement is gratefully made.

Manuscript for a general report on coal in Oklahoma, prepared by C. W. Shannon and others in 1915, was revised by C. L. Cooper and published as Oklahoma Geological Survey Bulletin No. 4, in 1926³. A section entitled "Northeastern Oklahoma" contains brief descriptions and a generalized map of coal beds of the area. It seems that there was some confusion as to correlations of the coals and reference was not made to the Broken Arrow bed, nor is the bed shown on the map in the area between Arkansas and Verdigris Rivers. However, from Verdigris River to the north limit of the present investigation the trace of the outcrop of the bed called "Fort Scott coal" corresponds in general with the Broken Arrow coal as mapped in the course of the present work. Oklahoma Geological Survey Bull. 19, pt. 2, "Petroleum and Natural Gas in Oklahoma", 1917, and Bull. 40 Vol. 3, "Oil and Gas in Oklahoma", 1930, include brief discussions of the geology of Tulsa, Wagoner, and Rogers Counties.

A few analyses of samples of what the writer identifies as Broken Arrow coal (generally referred to as "Fort Scott" or "unnamed") from mines in Rogers and Wagoner Counties, are given in U. S. Bureau of Mines Technical paper 411, published in 1928, and in Oklahoma Geological Survey Bulletin 51, published in 1929. These analyses are reprinted in this circular together with recent unpublished analyses of the U. S. Bureau of Mines in the Table of Analyses and discussed in the section on analyses.

Methods of Present Investigation. Through cooperation of the U. S. Bureau of Mines, aerial photographs for the area from Arkansas River to the north side of T. 22 N., were available. They were used in the field as a stereoscopic base map, sketching being done on the stereoscopic image.

The area has many good roads which afford convenient access to outcrops by automobile. Sketching as well as checking of ear-

³ Shannon, C. W., and others, revised and edited by Cooper, C. L., "Coal in Oklahoma", *Okla. Geol. Survey Bull.* 4, 1926.

lier maps was done from these roads wherever possible. However, escarpments generally capped by persistent key limestone beds extend locally great distances beyond the outcrops of these limestones, the extensions being capped by local sandstone lenses somewhat lower in the section. For this reason mapping from the stereoscopic image was not uniformly trustworthy and considerable work had to be done afoot between the roads.

Stratigraphic sections were measured and described wherever opportunity afforded. Natural exposures of coal are rare, but strip pits are numerous in the area and even the oldest of these are clearly indicated on the stereoscopic image. All these pits were visited and in and above many of them sections were measured from the coal up to the Verdigris limestone. When plotted and correlated, the measured sections disclosed the relationship of the Broken Arrow coal to the Verdigris limestone throughout the area and to certain local sandstone lenses. Bearing these relations in mind, the outcrop of the coal was drawn on the stereoscopic image as accurately as could be between strip pits or other exposures. Finally the data were assembled from the photographs to the map.

The problem, as originally undertaken, did not extend beyond T. 22 N. Later it was considered advisable to include the coal exposures in the strip pits in sec. 10, T. 23 N., R. 17 E., north of Bushyhead, but aerial photographs were not available, and no mapping was done. However, sections were measured and the correlations worked out in the field.

STRATIGRAPHY

The rocks included in this investigation comprise the upper 140 to 240 feet of the Cherokee in the upper part of the Des Moines series of Pennsylvanian age. The stratigraphic section studied extends from the upper part of the Chelsea sandstone, upward to the base of the Fort Scott limestone, which marks the top of the Cherokee.

Chelsea sandstone. This unit was named by D. W. Ohern in an unpublished report from exposures in the Vinita quadrangle, east and southeast of the town of Chelsea. Only the upper part was studied in detail.

In general, the upper part of the formation consists of two phases; a lower, massive, tree-bearing sandstone and an upper grass-covered zone of thin-bedded, silty sandstone and silty shale. At most places north of Verdigris River the lower 10 to 20 feet of the grassy zone is silty shale and the upper 10 feet, more or less, is thin-bedded, silty sandstone. However, immediately south of Verdigris River this grass-covered zone contains two bands of silty shale and two of silty sandstone.

These stratigraphic relationships are not as clearly discernible everywhere in the field as could be desired. It seems that there is both lateral and vertical gradation, so that no single phase occupies exactly the same stratigraphic position throughout the area. The top of the massive tree-bearing sandstone probably would be taken as the top of the Chelsea sandstone in casual, reconnaissance mapping, and has been so mapped in this area by some geologists, but it is not a clear-cut formational boundary. For instance, at the NE cor. sec. 27, T. 19 N., R. 15 E., this tree-bearing sandstone rises in the section to a point considerably higher stratigraphically than elsewhere, and this higher portion grades laterally into, and inter-fingers with shale both northward and southward. Similar local accentuation of sandstone deposition is common in the Pennsylvanian formations of northeast Oklahoma.

The Chelsea sandstone probably is equivalent to some of the sandstones of the Senora formation.

Interval from the top of the Chelsea sandstone to the base of the Broken Arrow coal. According to field measurements, this interval is 50 to 80 feet thick, but the accuracy of these figures is in some doubt, owing to difficulty in determining dips. It contains clay-shale and silty shale; a few thin, silty sandstone lenses; several thin coals of local occurrence, none of which is known to be of economic importance; and at least one lenticular limestone.

The most conspicuous sandstone lens lies a few feet below the Broken Arrow coal, and extends from the south side of the area into sec. 10, T. 19 N., R. 15 E.

Coal seams encountered in wells drilled in the area have been reported by several drillers. Surface exposures of coal have been reported by local residents, but the only exposure seen by the writer is that on the east side of the road immediately north of W $\frac{1}{4}$ cor. sec. 2, T. 19 N., R. 15 E. where the coal is only 0.2 foot thick. Norman D. Newell, in unpublished notes, mentions an exposure of coal 2.0 feet thick in this same locality, a good example of the erratic nature of these seams.

Limestone occurs a few feet below the Broken Arrow coal and is commonly separated from the coal by a thin bed of shale. Exposures were found near the W $\frac{1}{4}$ cor. sec. 21, T. 19 N., R. 15 E. and northward to the NE cor. sec. 24, T. 21 N., R. 15 E. They generally consist of one or more beds of silty to sandy, fossiliferous, dark colored limestone, 1 foot or less thick, separated from each other and from the overlying Broken Arrow coal by shale. The maximum thickness of this limestone-and-shale section is about 10 feet. The log of L. L. Boyd, G. T. Hanks, et al, Heckman No. 1, center NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 7, T. 18 N., R. 15 E. records limestone at this horizon though the Broken Arrow coal is not recorded.

Broken Arrow coal. The Broken Arrow coal is present throughout the area (from south of Broken Arrow to north of Bushyhead) and probably extends farther, both northward and southward. It reaches its maximum thickness of a little more than 24 inches in the vicinity of Broken Arrow and its minimum of about 14 inches between Sequoya and Bushyhead, in T. 23 N., R. 17 E. The

Broken Arrow coal is here correlated with the Croweburg coal of Kansas.

Interval from top of Broken Arrow coal to base of Verdigris limestone. This interval ranges from 16 feet thick in the vicinity of Broken Arrow to 70 feet thick north of Bushyhead. South of Verdigris River the entire interval is well exposed in strip pits and includes a lower dark shale containing spheroidal calcareous concretions in its upper part; and an upper black fissile shale containing phosphatic nodules. North of Verdigris River the interval is so thick that all of it is not exposed in most strip pits, but judging from material found on weathered slopes it probably has the same general characteristics as south of the river. Most of the northward thickening seems to be in the lower division which contains some silty sandstone lenses north of Verdigris River. Describing what is presumably the same interval in Kansas, Pierce and Courtier wrote:

"The Croweburg coal is overlain by 3 to 8 feet of shale, the upper half light gray and the lower half somewhat darker in color. Above this unit is 2½ to 5 feet, averaging 3 feet, of fissile black shale, containing black siliceous limestone concretions, many of which are 18 inches in diameter, and some 3 feet in diameter were noted. Small phosphate nodules, about three-fourths of an inch in diameter, are common in the black shale. . . . The large concretions have the shape of flattened spheres, whereas the small ones may be round, flattened, or several may be grouped together like peanut brittle. The succession of strata just described—that is, a coal overlain by gray shale, and then a black shale with concretions—furnishes an excellent means of identifying the Croweburg coal, for none of the other coals in the Cherokee shale have a similar succession of strata associated with them."⁴

The sequence and lithology of the beds between the Broken Arrow coal and Verdigris limestone in Oklahoma are strikingly similar to that of the beds between the Croweburg coal and Ardmore limestone in Kansas, and this together with the fact that the Verdigris-Ardmore correlation is fairly well established, makes the correlation of the Broken Arrow coal with the Croweburg seem fairly certain.

⁴Pierce, W. G., and Courtier, W. H., "Geology and Coal Resources of the Southeastern Kansas Coal Field" *Kansas Geol. Survey Bull.* 24, p. 75, 1937.

Verdigris limestone. The Verdigris limestone is remarkably uniform in thickness and character across the area. Exposures generally consist of 2 to 2.5 feet of dark, massive, fossiliferous limestone; but fresher exposures in strip pits are about 5 feet thick and include more shaly, less resistant beds at the top and bottom. Norman D. Newell in his unpublished notes describes the Verdigris as containing chert, at least locally. Where the Verdigris limestone is covered by rubble in the hills north of Verdigris River, its approximate position is marked by a band of polygonal chert fragments, which probably originated from a 4-inch bed of chert mentioned by Ohern⁵ as occurring 10 feet above the Verdigris limestone in this part of the area.

Strata above the Verdigris limestone. The interval between the Verdigris limestone and the Fort Scott limestone is about 140 feet thick in the vicinity of Broken Arrow, but thins to 30 feet, or less, about the middle of T. 22 N. It is somewhat more than 30 feet thick across T. 23 N. A generalized section above the Verdigris limestone in T. 18 N. follows:

Bed	Feet
6 Limestone, Fort Scott	
5 Shale and sandstone, both silty, about (Contains the Prue (Squirrel) sand of subsurface terminology.)	40
4 Limestone, unnamed but occupies about the same horizon as the Breezy Hill limestone of Kansas, dark, silty, fossiliferous, about (This limestone has been mistaken in surface outcrops by some geologists for both Fort Scott and Verdigris and could be mistaken easily for the Verdigris in subsurface studies.)	2 to 5
3 Sandstone, medium-grained to silty (Possibly this is part of the Prue sand of the subsurface in some areas to the west.)	10 to 20
2 Shale, silty to sandy, about	70
1 Limestone, Verdigris	

The limestone, No. 4 of the foregoing table, was not observed north of T. 18 N. It may be studied in the field conveniently at the following places: In the road and immediately east of a house on the south side of the road at the top of the hill about a fourth of a mile west of the NE cor. sec. 18, T. 18 N., R. 15 E. In the ditch on the north side of the railroad and immediately west of

⁵Ohern, D. W., "The Stratigraphy of the Older Pennsylvanian Rocks of Northeastern Oklahoma," *The State University of Oklahoma Research Bull.* 4, p. 17, 1910.

the stream along the east side of the NE $\frac{1}{4}$ sec. 13, T. 18 N., R. 14 E. In a draw at about the center of the SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 13, T. 18 N., R. 14 E. In a ditch on the north side of the road near the top of the hill at the S $\frac{1}{4}$ cor. sec. 24, T. 18 N., R. 14 E. On the east side of the road and immediately south of a house, also on the east side of the road, about a quarter of a mile south of the NW cor. sec. 25, T. 18 N., R. 14 E. The following is a generalized section of the strata above the Verdigris limestone north of T. 18 N:

Bed	Feet
5 Limestone, Fort Scott	
4 Shale, clay to sandy, in part black and fissile.....	5 to 10
(Contains the Fort Scott (Mulky) coal which is mined at numerous places for local use but in this area is generally too thin to be of commercial importance.)	
3 Sandstone and silty shale	10 to 20
(The Prue (Squirrel) sand of the subsurface)	
2 Shale, clay to silty	10 to 60

Fort Scott limestone. No description of the Fort Scott limestone will be attempted. It overlies the Cherokee shale directly and only the contact was mapped.

COAL

Below Broken Arrow Coal. Numerous "shows" of coal have been reported by well drillers in the interval between the Chelsea sandstone, below, and the Broken Arrow coal, above. Also residents have reported several surface outcrops, some of which have been worked for local use. These outcrops seem to be similar to the one seen by the writer on the east side of the road an eighth of a mile north of the W $\frac{1}{4}$ cor. sec. 2, T. 19 N., R. 15 E. where the coal is 0.2 feet thick. Norman D. Newell, in unpublished notes, reports a coal in this same locality, probably the same seam, as 2.0 feet thick, and drillers describe the coals of this interval as extremely lenticular and seldom more than 0.5 feet thick.

Broken Arrow coal. Present information indicates that this coal is continuous from the vicinity of Broken Arrow at least as far north as the strip pits in sec. 10, T. 23 N., R. 17 E., north of Bushyhead, and that it is probably the same as the Croweburg coal of Kansas. The Broken Arrow coal has a reported maximum thickness of 27 inches in the vicinity of Broken Arrow where it is generally 18 to 24 inches thick, but farther north it is thinner, being only 14 inches thick at some places between Sequoya and Bushyhead, in T. 23 N., R. 17 E.

South of Verdigris River the Broken Arrow coal has been stripped extensively and that part of the area is now producing an important quantity of relatively hard, black, bituminous coal which has long been prized as domestic and steam plant fuel. Operators report that this coal has good keeping qualities, which permits stockpiling for seasonal and emergency use.

From Verdigris River to the vicinity of Sequoya, middle of T. 22 N., the few small strip pits have been abandoned for several years, and no fresh exposure of coal was seen. Information from operators and residents in the area indicates that the coal here, though thick enough to be worked and of good fuel value, has poor keeping qualities. It is said to be soft and breaks down to fine slack soon after mining. Though the coal generally is thinner from Sequoya northward, than south of Verdigris River, operators say that it has the same good qualities and the pits are supplying

important quantities of coal to war industries and to the civilian market.

Fort Scott coal crops out a few feet below the base of the Fort Scott limestone as far south as the north part of T. 19 N. It is a hard, black, bituminous coal of good quality but, in this area, it is generally much less than 1 foot thick and is worked for local use only. Because of its position, normally 1 to 3 feet below the base of the Fort Scott limestone, this coal is considered to be equivalent to the Fort Scott (Mulky) coal of Kansas and Missouri.

MEASURED SECTIONS OF BROKEN ARROW COAL

Although analyses of Broken Arrow coal show considerable variation, the fresh coal, as seen in those parts of the area where it is actively mined, is of rather uniform appearance. Partings of any sort are uncommon and thickness is its most conspicuous variable. Therefore the description of the coal by townships is limited to the following tabulation of measured sections. An asterisk (*) indicates that an analysis of a sample from the locality is given under the same number in the table of analyses and that the coal section was taken from the publication cited. Name of coal bed in parenthesis, thus: (Broken Arrow), is the writer's correlation. All others are from the writer's field notes. Most of these measured sections are shown graphically on Plate II.

T. 18 N., R. 15 E.

1. **Broken Arrow, Seneca Coal and Coke Co. Strip Pit*. Sec. 5, T. 18 N., R. 15 E.

Source: U. S. Bur. of Mines Tech. paper. No. 411, p. 49.

Analyses: A24773 to A24775. Bituminous coal, Broken Arrow district, from Seneca Coal and Coke Company mine, north strip pit, sec. 5, T. 18 N., R. 15 E. On the Missouri-Kansas-Texas Railroad. Coal bed unnamed (Broken Arrow); dip $1\frac{1}{2}^{\circ}$; thickness of bed 22 inches; cover at points sampled, 25 feet. The bed was measured and sampled at two points by W. W. Fleming, Aug. 26, 1926, as described below:

Section	A		B	
Laboratory No.	A24773		A24774	
Immediate roof, soft shale	Ft.	in.	Ft.	in.
Coal		6		6
Dirt band (bony) not included in sample		1		1
Coal	1	3	1	2
Pyrite streak				
Thickness of bed	1	10	1	9
Thickness of sample	1	9	1	8

Section A (sample A24773) was cut at south end of strip pit and section B (sample A24774) at 100 feet from south end of strip pit. The ultimate analysis of the composite sample made by combining face samples A24773 and A24774 is given under laboratory No. A24775.

System of mining, strip pit; coal shot from the solid; it was screened through round-hole screens, and three sizes shipped. At time of sampling the daily output was 500 tons, and life of the mine was estimated as 15 years. (The locality was visited by M. C. Oakes in June 1943. This particular pit was inactive but the same company continues to operate in the area with power shovels and 20 ton semi-trailer trucks.)

2. *Broken Arrow, Seneca Coal and Coke Co. Strip Pit* (abandoned). NW cor. sec. 9, T. 18 N., R. 15 E.

Source: Measured by the writer, June 18, 1943, as described below:

Shale not measured	Ft.
Coal, about	1.8
Shale, sandy, silty	14.0

3. **Broken Arrow, Seneca Coal and Coke Co., Seneca No. 2 Strip Pit*. Sec. 19, T. 18 N., R. 15 E.

Source: U. S. Bur. Mines unpublished data.

Analyses: B-85413 to B-85418. Bituminous coal, Tulsa district. From Seneca Coal and Coke Co., No. 2 Strip Pit, $2\frac{1}{2}$ miles southeast of Broken Arrow, sec. 19, T. 18 N., R. 15 E., on Missouri-Kansas-Texas Railroad. Coal bed: Broken Arrow; dip 2° ; thickness of bed $23\frac{1}{2}$ inches to 27 inches; cover at the points sampled 28 to 37 feet. The bed was measured and sampled at five places by C. P. Haller, September 9, 1942, as described below:

Section Laboratory No.	A B-85413		B B-85414		C B-85415		D B-85416		E B-85417	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Immediate roof, slate										
Bony coal	2	3	2	0	1	11½	2	1½	1	11½
Coal										
No parting bands in bed; floor, clay, hard, rough										
Thickness of bed	2	3	2	0	2	0½	2	1½	1	11½
Thickness in sample	2	3	2	0	1	11½	2	1½	1	11½

Section A (sample B-85413) was cut 260 feet north and 550 feet west of NE cor. SW¼ sec. 19; section B (sample B-85414) 50 feet south and 1050 feet west of NE cor. SW¼ sec. 19; section C (sample B-85415) 300 feet south and 1300 feet west of NE cor. SW¼ sec. 19; section D (sample B-85416) 665 feet south and 1575 feet west of the NE cor. SW¼ sec. 19; section E (sample B-85417) 625 feet north and 650 feet east of the SW cor. SW¼ sec. 19. The ultimate analysis of a composite sample made by combining face samples Nos. B-85414 to B-85417 inclusive is given under laboratory No. B-85418.

System of mining, stripping; explosives, black powder; the coal was prepared in 6 sizes and picked on a belt. Daily output at time of sampling was 1,000 tons, all from advance workings. Estimated life of mine 10 years.

4. *Broken Arrow, Seneca Coal and Coke Co. Strip Pit.* ⅛ mile east of the SW cor. sec. 19, T. 18 N., R. 15 E.

Source: Measured by the writer, June 18, 1943, as described below:

Shale in pit above the coal, not measured.	Ft.
Coal	1.8
Covered, shale, about	10.0

5. *Broken Arrow, Seneca Coal and Coke Co. Strip Pit* (abandoned). Vicinity of the NW cor. sec. 30, T. 18 N., R. 15 E.

Source: Measured by the writer, May 7, 1943, as described below:

Shale, dark	Ft.
Coal, about	10.0
Shale, black, hard, bottom of pit, not measured.	1.8

T. 19 N., R. 15 E.

6. *Catoosa, Seneca Coal and Coke Co. Strip Pit.* ⅛ mile east of the NW cor. sec. 21, T. 19 N., R. 15 E.

Source: Measured by the writer, June 18, 1943, as described below:

Shale above coal, not measured.	Ft.
Coal	1.8
Shale, silty, about	5.0

7. *Catoosa, Outcrop Section.* Vicinity W¼ cor. sec. 21, T. 19 N., R. 15 E.

Source: Measured by the writer, June 16, 1943, as described below:

Shale, not measured	Ft.
Coal	1.8
Covered, shale	3.2
Limy siltstone, fossiliferous	2.9
Limy siltstone	2.8
Limestone, gray, weathers red, silty to sandy, fossiliferous	1.2
Sandstone, silty, base not exposed	4.0

8. **Catoosa, Seneca Coal and Coke Co. No. 4 Strip Pit, Sec. 29, T. 19 N., R. 15 E.*

Source: U. S. Bureau Mines unpublished data.

Analyses: B-85920 to B-85926 inclusive. From Seneca Coal and Coke Co's. No. 4 Strip pit 2½ miles southeast of Catoosa, sec. 29, T. 19 N., R. 15 E., on the St. Louis-San Francisco Railway. Coal bed: Cherokee (Broken Arrow); dip 2°; thickness of bed 19 inches to 21 inches; cover at the points sampled 25 feet. The bed was measured and sampled at six points by C. P. Haller, September 10, 1942, as described below:

Section Laboratory No.	A B-85920		B B-85921		C B-85922	
	Ft.	in.	Ft.	in.	Ft.	in.
Roof, slate						
Coal	1	5½	1	9¼	1	6
Clay		½				¾
Coal		3				2½
Floor, clay, hard, smooth						
Total thickness of bed	1	8½	1	9¼	1	9
Thickness in sample	1	8	1	9¼	1	8½

Section Laboratory No.	D B-85923		E B-85924		F B-85925	
	Ft.	in.	Ft.	in.	Ft.	in.
Roof, slate						
Coal	1	8	1	7	1	7
Clay						
Coal						
Floor, clay, hard, smooth						
Total thickness of bed	1	8	1	7	1	7
Thickness in sample	1	8	1	7	1	7

Section A, (sample B-85920) was cut 5160 feet north and 660 feet west of SE cor. sec. 29; Section B, (sample B-85921), 4540 feet north and 620 feet west of SE cor. sec. 29; Section C (sample B-85922), 3660 feet north and 790 feet west of SE cor. sec. 29; Section D (sample B-85923), 2240 feet north and 485 feet west of SE cor. sec. 29; Section E (sample B-85924), 1220 feet north and 360 feet west of SE cor. sec. 29; Section F (sample B-85925), 700 feet north and 400 feet west of SE cor. sec. 29. The ultimate analysis of a composite sample made by combining face samples Nos. B-85920 to B-85925 inclusive is given under laboratory No. B-85926.

System of mining, stripping; explosives, black powder and dynamite for roof. This coal was prepared in 6 sizes and picked on a belt. Daily output at time of sampling 1800 tons, all from advanced workings. Estimated life of mine 6 years.

9. *Catoosa, Seneca Coal and Coke Co. Strip Pit.* 0.1 mile west of SE cor. sec. 29, T. 19 N., R. 15 E.

Source: Measured by the writer, April 19, 1943, as described below:

	Ft.
Dark clay shale	11.0
Coal	1.4
Shale dark, bottom of pit, not measured.	

10. **Catoosa, McNabb Coal Company Strip Pit, Secs. 21 and 28, T. 20 N., R. 15 E. Rogers Co.*

Source: U. S. Bur. Mines unpublished data.

Analyses: B-84164 to B-84168. High volatile bituminous coal, Tulsa district, from McNabb Coal Co. strip pit mine; 2 pits average distance 1 mile east of Catoosa, secs. 21 and 28, T. 20 N., R. 15 E.

Sold to domestic trade and hauled to shipping point at Catoosa, on St. Louis-San Francisco Railway. Coal bed: unnamed (Broken Arrow); dip 1°; thickness of bed 15½ to 21¼ inches; cover at points sampled 18 to 36 feet. The bed was measured and sampled at four points by C. P. Haller, August 27, 1942, as described below:

Section Laboratory No.	A B-84164		B B-84165		C B-84166		D B-84167	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Immediate roof slate	1	9¼	1	3½	1	9	1	8¼
Coal								
No parting bands in bed.								
Floor, clay, fairly hard, smooth								
Thickness of bed	1	9¼	1	3½	1	9	1	8¼
Thickness in sample	1	9¼	1	3½	1	9	1	8¼

Section A (sample B-84164) was cut 440 feet south and 300 feet west of NW cor. SE¼ SE¼ sec. 28; Section B (sample B-84165), 330 feet south and 460 feet east of NW cor. SE¼ SE¼ sec. 28; Section C (sample B-84166), 400 feet south and 450 feet west of NW cor. SE¼ SE¼ sec. 28; Section D (sample B-84167), 50 feet north and 50 feet west from 10 acre corner on ¼ sec. line, sec. 21. The ultimate analysis of a composite sample made by combining face samples B-84164 to B-84166 inclusive is given under laboratory No. B-84168.

System of mining, stripping; explosive, black powder and dynamite used for roof; this coal was prepared in 4 sizes and picked on a belt. Daily output at time of sampling 400 tons, all from advance workings. Estimated life of mine 10 years.

11. *Catoosa, McNabb Coal Co. Strip Pit.* About ⅛ mile north of the SE cor. sec. 28, T. 20 N., R. 15 E.

Source: Measured by the writer, May 6, 1943, as described below:

	Ft.
Shale, dark	17.0
Coal	1.4
Covered, shale, about	1.0
Limestone, dark, gnarly, fossiliferous	1.0
Covered, shale	1.5
Limestone, fossiliferous, weathers gray to red	1.0

12. *Catoosa, McNabb Coal Co. Strip Pit (abandoned)*. 200 feet south of the N $\frac{1}{4}$ cor. sec. 34, T. 20 N., R. 15 E.

Source: Measured by the writer, May 6, 1943, as described below:

	Ft.
Shale, dark, weathers gray	26.0
Coal, about	1.4
Shale, dark, silty, about	1.8
Limestone, gray to black, gnarly, and knotty in appearance, silty, includes a network of coaly stringers, fossiliferous.....	1.0

T. 22 N., R. 16 E.

13. *Sequoia, Rogers County Coal Co. Strip Pit NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 10, T. 22 N., R. 16 E.*

Source: Measured by the writer, April 20, 1943, as described below:

	Ft.
Shale	23.0
Coal	1.4
Shale, bottom of pit, not measured..	

14. **Sequoia, Rogers County Coal Co. Strip Pit*. Secs. 14 and 23, T. 22 N., R. 16 E.

Source: U. S. Bur. Mines unpublished data.

Analyses: B-84595 to B-84598. Bituminous coal, Tulsa district, from Rogers County Coal Co. strip pit 6 miles northeast of Claremore, secs. 14 and 23, T. 22 N., R. 16 E. near St. Louis-San Francisco Railway. Coal bed: unnamed (Broken Arrow); dip 1°; thickness of bed 17 $\frac{1}{2}$ inches to 22 $\frac{1}{2}$ inches; cover at points sampled 12 to 25 feet. The bed was measured and sampled at three points by C. P. Haller, August 28, 1942, as described below:

Section Laboratory No.	A B-84595		B B-84596		C B-84597	
	Ft.	in.	Ft.	in.	Ft.	in.
Roof, slate						
Coal	1	5 $\frac{1}{2}$	1	8	1	10 $\frac{1}{2}$
No parting bands in bed						
Floor, clay, soft, smooth						
Thickness of bed	1	5 $\frac{1}{2}$	1	8	1	10 $\frac{1}{2}$
Thickness of sample	1	5 $\frac{1}{2}$	1	8	1	10 $\frac{1}{2}$

Section A (sample B-84595) was cut 800 feet north of the SE cor. SW $\frac{1}{4}$ sec. 14; section B (sample B-84596), 650 feet north and 250 feet west of SE cor. SW $\frac{1}{4}$ sec. 14; sample C (sample B-84597), 700 feet south and 400 feet west of SE cor. SW $\frac{1}{4}$ sec. 14. The ultimate analysis of a composite sample made by combining face samples Nos. B-84595 to B-84597 inclusive is given under laboratory No. B-84598.

System of mining, stripping; explosives, dynamite used for roof. The coal was prepared in 7 sizes and was picked on a belt. Daily output at time of sampling was 400 tons, all from advance workings. Estimated life of mine, 10 years.

15. *Bushyhead, Outcrop Section*, 0.3 mile north of the SW cor. sec. 4, T. 23 N., R. 17 E.

Source: Measured by the writer, April 13, 1943.

Covered, probably shale	50.0
Coal, poorly exposed in east bank of north-south road.....	1.5
Covered, probably shale, not measured.	

T. 23 N., R. 18 E.

16. **Bushyhead Coal Co. Mine* sec. 10, T. 23 N., R. 18 E.

Source: Oklahoma Geological Survey Bull. 51, p. 101.

Analyses: 177. Bituminous coal, northeastern Oklahoma district, from Bushyhead Coal Co. No. 1 strip pit, a wagon mine, 1 $\frac{1}{2}$ miles north of Bushyhead. Coal bed: Fort Scott (Broken Arrow); thickness 1 foot 6 inches; cover at point sampled, 24 feet. Sampled at three places in pit. The bed was measured and sampled by J. E. Moose and W. R. Rutherford, July 10, 1928, as described below:

Section	A		B		C	
	Ft.	in.	Ft.	in.	Ft.	in.
Roof, slate and clay						
Bony coal		2		1		0
Coal	1	3	1	6	1	6
Floor, clay						
Thickness of bed	1	3	1	6	1	6
Thickness of sample	1	3	1	6	1	6

System of mining, stripping with steam shovel. Coal shot with black powder and loaded into trucks which haul it to St. Louis-

San Francisco Railway. Average daily output, 125 tons, all from advance workings. (Visited by M. C. Oakes, May 13, 1943. Pit has been abandoned for several years.)

ANALYSES OF BROKEN ARROW COAL BY TOWNSHIPS

Following are analyses of Broken Arrow coal arranged by townships. (Page 26) As indicated individually, some are previously published analyses by the U. S. Bureau of Mines, some are recent unpublished analyses by the same agency, and others are from an earlier publication of the Oklahoma Geological Survey. In the preceding measured sections and descriptions of Broken Arrow coal by townships, those marked by an asterisk (*) were sampled and the analyses are included under corresponding numbers in the following table.

The following generalizations are based on a study of the analyses of airdried samples:

The volatile matter tends to decrease slightly northward, from 38.1 percent in the vicinity of Broken Arrow to 33.8 percent in the vicinity of Sequoya and is 34.3 percent north of Bushyhead.

The fixed carbon increases northward from 50.8 percent in the vicinity of Broken Arrow to 61.6 percent near Sequoya, and is 59.2 percent north of Bushyhead.

The percentage of ash is erratic but tends to decrease northward. The maximum is 9.4 percent southeast of Broken Arrow, the minimum is 4.5 percent in the vicinity of Catoosa. Except in one locality, the ash of all samples had a softening point above 2,000° F.

The sulphur content is also erratic. The maximum is 3.6 percent in T. 18 N., the minimum is 0.4 percent in the vicinity of Catoosa and near Sequoyah it is about 0.9 percent.

The figures for B.t.u. increase as the impurities decrease. The minimum is 13,290 in T. 18 N., near Broken Arrow, and the maximum 14,170 in T. 22 N. near Sequoya. It is about 13,970 near Catoosa and 13,720 in T. 23 N., north of Bushyhead.

BROKEN ARROW COAL

ANALYSES OF BROKEN ARROW COAL

	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS						SOFTENING TEMP. ¹ OF ASH			Air Dry Loss	
	Moisture	Volatile Matter	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	Ash	B. t. u.	Start °F.	Down °F.		Fluid °F.
Lab. B-85418 ^a Composite of B-85413 to B-85417 inc. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	1.8 8.4	38.9 36.3 39.6 43.4	50.7 47.3 51.7 56.6	8.6 8.0 8.7	5.4 5.8 5.3 5.8	72.8 67.8 74.1 81.2	1.6 1.5 1.6 1.8	8.2 13.8 6.9 7.5	3.4 3.1 3.4 3.7	8.6 8.0 8.7	13220 12320 13450 14740				6.8
8. WAGONER COUNTY															
Lab. B-85920 ^a Catoosa, 2½ mi. SE of: 5160' N., 660' W. of SE cor. sec. 29, T. 19 N., R. 15 E.; Seneca Coal and Coke Co., Seneca No. 4 strip pit. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	2.7 8.0	35.2 33.2 36.1 38.6	55.8 52.8 57.4 61.4	6.3 6.0 6.5						1.3 1.3 1.4 1.5	13330 12610 13710 14650	2010	2050	2150	5.4
Lab. B-85921 ^a Same: 4540' N. 620' W. of SE cor. sec. 29. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	2.8 6.8	35.1 33.6 36.1 38.5	56.0 53.7 57.6 61.5	6.1 5.9 6.3						1.8 1.7 1.9 2.0	13480 12910 13860 14790	2000	2060	2260	4.2

COAL ANALYSES

Lab. B-85922 ^a Same: 3660' N. 790' W. of SE cor. sec. 29. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	3.1 7.3	35.3 33.7 36.4 40.1	52.7 50.5 54.5 59.9	8.9 8.5 9.1							12640 12090 13040 14350	2360	2470	2550	4.4
Lab. B-85923 ^a Same: 2240' N., 485' W. of SE cor. sec. 29. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	2.6 6.9	36.0 34.5 37.0 39.5	55.4 52.9 56.8 60.5	6.0 5.7 6.2							13480 12880 13840 14760	2070	2140	2460	4.4
Lab. B-85924 ^a Same: 1220' N., 360' W. of SE cor. sec. 29. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	3.2 6.5	35.4 34.2 36.6 38.8	55.9 54.0 57.7 61.2	5.5 5.3 5.7							13470 13020 13920 14760	2040	2110	2240	3.3
Lab. B-85925 ^a Same: 700' N., 400' W. of SE cor. sec. 29. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	3.1 7.4	35.0 33.5 36.1 38.7	55.5 53.0 57.3 61.3	6.4 6.1 6.6							13310 12720 13740 14700	2010	2070	2150	4.4

ANALYSES OF BROKEN ARROW COAL

	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS						SOFTENING TEMP. ¹ OF ASH			Air Dry Loss	
	Moisture	Volatile Matter	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur	Ash	B. t. u.	Start °F.	Down °F.		Fluid °F.
Lab. B-85926 ³ Composite of B-85920 to B-85925 inc. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	2.7 7.0	35.2 33.6 36.2 38.8	55.6 53.2 57.1 61.2	6.5 6.2 6.7	5.4 5.6 5.2 5.6	75.2 71.9 77.3 82.8	1.8 1.8 1.9 2.0	9.8 13.3 7.6 8.2	1.3 1.2 1.3 1.4	6.5 6.2 6.7	13330 12750 13710 14690				4.4
10. ROGERS COUNTY Lab. B-84164 ⁸ Catoosa, 1 mile east of; 440' S., 300' W of NW cor. of SE $\frac{1}{4}$ of SE $\frac{1}{4}$ sec. 28, T. 20 N., R. 15 E.; McNabb Coal Co. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	4.5 6.9	32.7 31.9 34.2 36.3	57.3 55.8 60.0 63.7	5.5 5.4 5.8					.5 .5 .5 .6		13290 12950 13910 14760	2120 2160	2160 2260		2.5
Lab. B-84165 ³ Same: 330' S., 460' E. of NW cor. of SE $\frac{1}{4}$ of SE $\frac{1}{4}$ sec. 28. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	4.0 6.6	33.8 32.9 35.2 37.5	56.4 54.9 58.8 62.5	5.8 5.6 6.0					.4 .4 .4 .5		13300 12940 13850 14740	2180 2210 2550			2.7

Lab. B-84166 ³ Same: 400' S., 450' W. of NW cor. of SE $\frac{1}{4}$ of SE $\frac{1}{4}$ sec. 28. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	5.1 7.1	32.3 31.6 34.0 36.1	57.0 55.9 60.2 63.9	5.6 5.4 5.8							13130 12850 13840 14700	2150 2180	2180 2280		2.1
Lab. B-84167 ³ Same: 50' N., 50' W. from 10 acre cor. on $\frac{1}{4}$ sec. line, sec. 21. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	4.4 7.1	32.7 31.7 34.2 35.8	58.6 57.0 61.3 64.2	4.3 4.2 4.5	5.6 5.8 5.4 5.6	76.8 74.6 80.3 84.1	1.9 1.8 2.0 2.0	10.9 13.1 7.3 7.7	.5 .5 .5 .6	4.3 4.2 4.5	13550 13160 14170 14840	2290 2470	2470 2710		2.8
Lab. B-84168 ³ Composite of samples B-84164, B-84165, and B-84166. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	4.6 6.9	32.6 31.8 34.1 36.3	57.2 55.8 60.0 63.7	5.6 5.5 5.9	5.4 5.6 5.2 5.5	75.1 73.3 78.7 83.6	1.9 1.9 2.0 2.1	11.5 13.3 7.7 8.3	.5 .4 .5 .5	5.6 5.5 5.9	13270 12940 13910 14770				2.5
14. ROGERS COUNTY Lab. B-84595 ⁸ Claremore, 6 miles NE of; 800' N. from SE cor. of SW $\frac{1}{4}$ sec. 14, T. 22 N., R. 16 E.; Rogers County Coal Co. Coal (air dried) Coal (as received) Coal (moisture free) Coal (moisture and ash free)	6.2 9.1	32.6 31.6 34.7 36.6	56.5 54.8 60.3 63.4	4.7 4.5 5.0					.7 .7 .7 .8		13280 12870 14160 14900	2200 2260 2470			3.1

ANALYSES OF BROKEN ARROW COAL

	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					B. t. u.	SOFTENING TEMP. ¹ OF ASH			Air Dry Loss
	Moisture	Volatile Matter	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulphur		Ash	Start °F.	Fluid °F.	
Lab. B-84596 ³														
Same as above, 650' N., 250' W. of SE cor. of SW ¹ / ₄ , sec. 14.														
Coal (air dried)	5.6	31.9	58.1	4.4					.8	13400	2150	2230	2550	4.0
Coal (as received)	9.4	30.6	55.8	4.2					.7	12860				
Coal (moisture free)		33.8	61.6	4.6					.8	14200				
Coal (moisture and ash free)		35.4	64.6						.9	14890				
Lab. B-84597 ³														
Same as above, 700' S., 400' W. of NE cor. of NW ¹ / ₄ , sec. 23.														
Coal (air dried)	5.6	32.3	56.8	5.3					1.1	13240	2050	2220	2450	2.8
Coal (as received)	8.3	31.4	55.2	5.1					1.1	12860				
Coal (moisture free)		34.2	60.2	5.6					1.2	14030				
Coal (moisture and ash free)		36.2	63.8						1.2	14860				
Lab. B-84598 ³														
Composite of samples Nos. B-84595 to B-84597, inclusive.														
Coal (air dried)	5.6	32.5	57.1	4.8	5.6	75.1	1.8	11.8	.9	4.8	13350			
Coal (as received)	8.7	31.4	55.2	4.7	5.7	72.6	1.7	14.5	.8	4.7	12910			
Coal (moisture free)		34.4	60.5	5.1	5.2	79.6	1.9	7.3	.9	5.1	14150			
Coal (moisture and ash free)		36.3	63.7		5.5	83.9	2.0	7.6	1.0		14910			3.3

COAL ANALYSES

16. ROGERS COUNTY														
Lab. No. 177 ⁴														
Bushyhead, 1½ miles north of; Bushyhead Coal Co. No. 1 strip pit, composite of: Face near middle of pit. Face, south end of pit.														
Coal (as received)	8.2	31.5	54.3	6.0										
Coal (moisture free)		34.3	59.2	6.5										
														3.9

¹ For some of the analyses given here, only one figure was reported as "softening temperature." In this table that figure has been arbitrarily placed in the middle column under the heading "Down," and is the temperature at which the cone of coal ash fused to a spherical lump in a slightly reducing atmosphere.

² Analyses taken from: Analyses of Oklahoma Coals; U. S. Bureau of Mines Technical Paper 411.

³ Unpublished analyses of the U. S. Bureau of Mines, made in cooperation with the Oklahoma Geological Survey.

⁴ Moose, Joe E., and Searle, V. C., A chemical study of Oklahoma coals; Oklahoma Geological Survey Bull. 51.

APPENDIX A

MEASURED STRATIGRAPHIC SECTIONS

1. SECS. 23 AND 24 T. 18 N., R. 14 E. FROM A BAROMETRIC PROFILE EXTENDING FROM THE STRIP PIT ABOUT 0.1 MILE EAST OF THE SE COR. SEC. 24, TO OUTCROP OF FORT SCOTT LIMESTONE ABOUT 0.2 MILE WEST OF THE S $\frac{1}{4}$ COR. SEC. 23.	
9 FORT SCOTT limestone, not measured.	
8 Covered, shale and sandstone, about.....	50.0
7 Limestone, about	3.0
6 Sandstone, fine-grained to silty, about	17.0
5 Covered, probably shale, about	66.0
4 VERDIGRIS limestone, dark, weathers yellow, fossiliferous.....	2.5
3 Shale, upper 5.7 feet black fissile and contains phosphatic nodules.	
Lower 10 feet dark, total.....	15.7
2 BROKEN ARROW coal, about	1.8
1 Shale, black, not measured.	
2. SEC. 7, T. 18 N., R. 15 E. MEASURED IN A DRAW 200 FEET SOUTH OF THE CENTER OF THE SECTION.	
Between Broken Arrow coal and Fort Scott limestone.	
4 Covered, silty shale and sandstone.	
3 Limestone, fossiliferous, weathers brown to red	2.0
2 Siltstone, limy	2.0
1 Covered, shale, probably silty	
3. SEC. 7, T. 18 N., R. 15 E. MEASURED FROM AN EXPOSURE OF THE LOWER LIMESTONE IN A DRAW $\frac{1}{4}$ MILE NORTH OF THE CENTER OF THE SECTION SOUTHWESTWARD UP THE HILL TO THE UPPER LIMESTONE.	
4 FORT SCOTT limestone, base only, top eroded.....	2.0
3 Covered	40.0
2 Limestone, weathers brown to red, lower part silty, exposed in bank of draw	4.0
1 Shale, silty.	
4. SECS. 9, 10, AND 11, T. 18 N., R. 15 E. FROM TOP OF SANDSTONE WEST OF N $\frac{1}{4}$ COR. SEC. 11 TO BROKEN ARROW COAL AT THE NW COR. SEC. 9. WEST COMPONENT OF DIP ABOUT 40 FEET PER MILE.	
6 Shale, not measured.	
5 BROKEN ARROW coal, poor exposure	1.8
4 Covered, shale, sandy, silty, clay	14.0
3 Sandstone, fine-grained to silty and shaly, crops out $\frac{1}{4}$ mile east of NW cor. sec. 9 about	10.0
2 Covered, sandy to silty shale and clay shale.....	90.0
1 CHELSEA sandstone, massive, not measured.	
5. SECS. 19, 20, 21, and 22, T. 18 N., R. 15 E. TOP OF THE MASSIVE SANDSTONE AT THE SE COR. SEC. 22 TO BROKEN ARROW COAL IN A STRIP PIT $\frac{1}{2}$ MILE EAST OF THE SW COR. SEC. 19, WESTWARD COMPONENT OF DIP RANGES FROM 40 to 60 FEET PER MILE.	
8 Shale in pit above coal, not measured.	
7 BROKEN ARROW coal	1.8
6 Covered, shale, probably about	10.0
5 Sandstone, thin bedded, silty, about	10.0
4 Covered, probably shale, clay to silty, about.....	60.0

3 CHELSEA sandstone, silty, about	10.0
2 Covered, probably silty shale, about	20.0
1 Sandstone massive, not tree-bearing in this vicinity, not measured.	
6. SEC. 30, T. 18 N., R. 15 E. MEASURED IN AN ABANDONED BUT FRESH STRIP PIT NEAR THE NW COR. SEC. 30.	
6 Shale, weathers yellow	10.0
5 VERDIGRIS limestone, dark, weathers yellow, fossiliferous.....	2.5
4 Shale, black, fissile, contains phosphatic nodules	5.7
3 Shale, dark	10.0
2 BROKEN ARROW coal, about	1.8
1 Shale, black, bottom of pit.	
7. SEC. 2, T. 19 N., R. 15 E. EXPOSURE IN SMALL STREAM ON EAST SIDE OF ROAD $\frac{1}{2}$ MILE NORTH OF W $\frac{1}{4}$ COR.	
4 Shale, not measured	
3 Coal, about	0.2
2 Shale, about	1.3
1 CHELSEA sandstone, not measured.	
8. SECS. 2 AND 3 T. 19 N., R. 15 E. MEASURED FROM TOP OF THE MASSIVE TREE-BEARING SANDSTONE AT THE NE COR. SEC. 2 TO THE VERDIGRIS LIMESTONE IMMEDIATELY EAST OF THE NW COR. SEC. 3. ALONG STATE HIGHWAY 33.	
5 Shale, not measured.	
4 VERDIGRIS limestone, dark fossiliferous, massive	3.0
3 Mostly covered shale, clay and silty, contains some sandstone, includes Broken Arrow coal	100.0
2 CHELSEA shale and sandstone, silty, not tree-bearing about.....	20.0
1 Sandstone, massive, tree-bearing, not measured.	
9. SEC. 7, T. 19 N., R. 15 E. MEASURED IN NORTH BANK OF CREEK $\frac{1}{4}$ MILE EAST OF NW COR. SEC. 7.	
4 LABETTE shale, covered.	
3 FORT SCOTT limestone, dark weathers gray, fossiliferous	6.0
2 Shale, black, fissile, with phosphatic nodules	4.0
1 Limestone, top only exposed.	
9A. SEC. 7, T. 19 N., R. 15 E. LOG OF A WATER WELL, NEAR SW COR. OF SEC., SUPPLIED BY LUTHER WHITE.	
11 Soil	7.0
FORT SCOTT limestone	
10 Limestone, upper Ft. Scott	9.0
9 Black slate (fissile shale with phosphatic nodules)	6.0
8 Limestone, lower Ft. Scott	6.0
CHEROKEE shale.	
7 Shale, white	2.0
6 Coal	0.5
5 Shale, gray	4.5
4 Sand, fine-grained, micaceous, gray, no water	20.0
3 Shale, gray, sandy	20.0
2 Shale, gray	33.0
1 Limestone, gray, salt water	5.0
10. SEC. 7, T. 19 N., R. 15 E. MEASURED FROM BRIDGE SOUTH OF NE COR. SEC. 7, WESTWARD UP WINDING ROAD TO TOP OF HILL.	
13 FORT SCOTT limestone, weathers gray, top eroded	2.0
12 Covered, black fissile shale with phosphatic nodules	3.0
11 Limestone, dark, weathers light gray, fossiliferous, poorly exposed, about	3.0

10	Covered, evidence of coal near top, about	2.5
9	Sandstone, weathers brown, massive, silty	2.0
8	Shale, dark, silty	4.0
7	Sandstone, weathers brown, fine-grained, massive	1.0
6	Shale, silty, dark	8.0
5	Sandstone, massive, fine-grained	1.0
4	Covered, silty shale	5.0
3	Sandstone, massive, fine-grained weathers brown	9.0
2	Shale, dark, silty	2.0
1	Covered	3.0
Floor of bridge.		

11. SEC. 21, T. 19 N., R. 15 E. LIMESTONE CROPS OUT IN WEST ROAD DITCH SOUTH OF DRAW NEAR W $\frac{1}{4}$ COR. AND SECTION EXTENDS ABOUT 200 FEET SOUTHWARD UP HILL TO EXPOSURE OF COAL IN EAST ROAD BANK.

7	Shale, not measured.	
6	BROKEN ARROW coal	1.8
5	Covered, shale	3.2
4	Siltstone, limy, fossiliferous	2.9
3	Siltstone, limy	2.8
2	Limestone, gray, weathers red, silty to sandy, fossiliferous	1.2
1	Sandstone, silty, base not exposed	4.0

12. SECS. 21, 22, AND 23, T. 19 N., R. 15 E. ESTIMATED FROM BAROMETRIC ELEVATIONS AND OTHER OBSERVATIONS ALONG THE ROAD FROM OUTCROP OF MASSIVE SANDSTONE NEAR NE COR. SEC. 23 TO THE COAL IN STRIP PIT $\frac{1}{8}$ MILE EAST OF NW COR. SEC. 21.

7	Shale above coal, not measured.	
6	BROKEN ARROW coal	1.8
5	Shale, silty, about	5.0
4	Sandstone, silty, about	10.0
3	Covered, shale, silty, about	65.0
2	CHELSEA, partly covered, silty shale and silty sandstone, about	10.0
1	Sandstone, massive, not measured.	

13. SEC. 29, T. 19 N., R. 15 E. MEASURED IN AN ABANDONED BUT FRESH STRIP PIT, IN THE NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$.

6	VERDIGRIS limestone, weathers yellow, fossiliferous	4.0
5	Shale, black fissile with phosphatic nodules	4.0
4	Shale, dark, contains black spheroidal concretions	12.0
3	Hard streak (sideritic shale?) contains pyrite	0.1
2	Shale, black	5.0
1	BROKEN ARROW coal, top exposed in a fresh but abandoned pit, base not exposed.	

14. SEC. 29, T. 19 N., R. 15 E. MEASURED IN PIT 0.1 MILE WEST AND 150 FEET NORTH OF SE COR. THIS IS FRESH EXPOSURE AND SHOWS DETAILS OF THE VERDIGRIS LIMESTONE NOT SEEN IN MOST SURFACE EXPOSURES OR IN STRIP PITS NEAR THE OUTCROP WHERE, IN GENERAL, ONLY THE MIDDLE PORTION REMAINS.

9	Shale weathered to clay	0.3
8	VERDIGRIS limestone, dark, fossiliferous	0.05
7	Shale seam	1.5
6	Limestone, dark, fossiliferous	0.1
5	Shale seam	2.0
4	Limestone, dark, fossiliferous	0.2
3	Clay seam	0.5
2	Limestone, dark, fossiliferous	
1	Shale, black, fissile to blocky.	

15. 150 FEET SOUTH OF NO. 14, SEC. 29, T. 19 N., R. 15 E. MEASURED IN THE STRIP PIT 0.1 MILE WEST OF SE COR. OF SECTION.

8	Shale, weathered	10.0
7	VERDIGRIS limestone, dark, weathers yellow, massive, fossiliferous	2.0
6	Shale, gray, weathers yellow, about	2.5
5	Shale, black fissile	5.7
4	Shale, dark, contains discoidal concretions	5.7
3	Shale, clay, dark	11.0
2	BROKEN ARROW coal	1.4
1	Shale, dark, bottom of pit.	

16. SEC. 3, T. 20 N., R. 15 E. FROM OUTCROP OF THE VERDIGRIS LIMESTONE $\frac{1}{2}$ MILE WEST OF THE SE COR., TO THE OUTLIER OF FORT SCOTT LIMESTONE $\frac{1}{4}$ MILE EAST OF THE SW COR.

4	FORT SCOTT limestone, an outlier of the basal part.	
3	Covered, shale with silty sandstone in upper part	60.0
2	VERDIGRIS limestone, dark, fossiliferous, about	3.0
1	Covered, shale not measured.	

17. SEC. 21, T. 20 N., R. 15 E. MEASURED IN THE SW $\frac{1}{4}$ SW $\frac{1}{4}$.

3	VERDIGRIS limestone, dark, fossiliferous, top not well exposed	3.0
2	Shale, black, fissile with phosphatic nodules	4.0
1	Shale, dark clay to silty	23.0
Water level in an abandoned strip pit.		

18. SEC. 27, T. 20 N., R. 15 E. MEASURED IN AN OLD STRIP PIT NEAR THE S $\frac{1}{4}$ COR.

2	VERDIGRIS limestone, weathers yellow, base only exposed.	
1	Covered, probably shale	20.0
Water level in old strip pit.		

19. SEC. 28, T. 20 N., R. 15 E. MEASURED IN ROAD AND IN WALL OF FRESH STRIP PIT ABOUT $\frac{1}{8}$ MILE NORTH OF SE COR.

16	Soil cover	
15	VERDIGRIS limestone, dark, fossiliferous, weathers yellow, about ..	2.5
14	Shale, gray	1.5
13	Shale, black fissile with phosphatic nodules	4.0
12	Shale, dark with discoidal concretions (sideritic?)	6.0
11	Shale, dark	17.0
10	BROKEN ARROW coal, about	1.4
9	Covered, probably about	1.0
8	Limestone, dark, gnarly, fossiliferous	1.0
7	Covered, shale	1.5
6	Limestone, fossiliferous, weathers gray to red	1.0
5	Covered, probably silty shale	6.0
4	Sandstone, gray, silty	2.0
3	Shale, sandy to silty	2.0
2	Sandstone, gray, silty	2.0
1	Shale, not measured.	
1 to 9 inclusive measured in the north-south road, 10 to 16 inclusive measured in the strip pit.		

20. SEC. 34, T. 20 N., R. 15 E. MEASURED IN AN OLD STRIP PIT 200 FEET SOUTH OF THE N $\frac{1}{4}$ COR.

7	VERDIGRIS limestone, base only exposed.	
6	Covered, shale	6.0
5	Shale, dark, weathers gray	26.0
4	BROKEN ARROW coal, about	1.4
3	Shale, dark, silty, about	1.0

- 2 Limestone, gray to black, (gnarly, knotty in appearance) silty, includes network of coaly stringers, fossiliferous, about 1.0
Also crops out in the road 200 feet north where it is underlain by about 2.5 feet of shale followed by 3 feet of sandstone and then by shale.
- 1 Covered, about 1.0
- Water level in old pit

21. SEC. 1, T. 21 N., R. 15 E. MEASURED UP THE ESCARPMENT WEST OF THE N $\frac{1}{4}$ COR.

- 13 FORT SCOTT limestone, gray, fossiliferous, top eroded 4.0
9 Shale, black fissile with phosphatic nodules 4.0
8 Limestone, massive, gray, weathers yellowish-brown, fossiliferous 7.0
7 Shale 1.0
6 FORT SCOTT (MULKY) coal 1.2
5 Shale, silty to sandy, weathers brown 3.0
4 Limestone, dark-brown, fossiliferous 0.8
3 Shale, silty, weathers dark to brown 12.0
2 Sandstone, fine-grained to silty 11.0
1 Covered by talus slope 8.0

22. SEC. 2, T. 21 N., R. 15 E. MEASURED UP A CONSPICUOUS HILL ALONG AN EAST-WEST ROAD, $\frac{1}{4}$ MILE EAST OF NW COR.

- 4 FORT SCOTT limestone, basal part 2.0
3 Coal and shale, weathered, about 2.6
2 Shale, silty to sandy, partly covered, about 30.0
1 VERDIGRIS limestone, exposed about 250 feet south of road, about 2.0
Succeeded downward by shale.

23. SEC. 26, T. 21 N., R. 15 E. MEASURED FROM A DRAW IMMEDIATELY NORTH OF THE SE COR. TO THE BASE OF THE FORT SCOTT AT THAT CORNER.

- 7 FORT SCOTT limestone, massive and white, top eroded and covered 6.0
6 Covered, probably shale containing a thin coal 5.0
5 Sandstone, massive to thin-bedded and cross-bedded, fine-grained to silty, weathers brown, about 6.0
4 Shale, silty 8.0
3 Covered, nearby exposures are shale 23.0
2 VERDIGRIS limestone, dark, weathers brown, fossiliferous, two or more massive beds, shatters in weathering, about 9.0
1 Covered, probably black fissile shale with phosphatic nodules, about 4.0

24. SEC. 34, T. 21 N., R. 15 E. SE $\frac{1}{4}$ NW $\frac{1}{4}$. ABOUT 400 FEET NORTH OF A FARM HOUSE ON THE EAST SIDE OF A BIG DRAW.

- 3 FORT SCOTT limestone, base of the Fort Scott. 60.0
2 Covered, shale and sandstone 60.0
1 VERDIGRIS limestone, top only exposed.

25. SEC. 35, T. 21 N., R. 15 E. IN BANK OF AND UP THE HILL FROM AN OLD STRIP PIT NEAR THE N $\frac{1}{4}$ COR.

- 3 VERDIGRIS limestone, dark, weathers yellow, fossiliferous, base only, top eroded. 28.0
2 Covered, probably shale and sandstone 17.0
1 Shale, gray, silty, contains sideritic streaks 0.1 foot thick and 2 to 3 feet apart

Water level in old strip pit.

26. SEC. 35, T. 21 N., R. 15 E. IN BANK OF OLD STRIP PIT, IN SE $\frac{1}{4}$ NW $\frac{1}{4}$.

- 3 VERDIGRIS limestone, dark, weathers yellow, fossiliferous, base only, top eroded.

- 2 Covered, probably shale 20.0
1 Shale with sideritic silty streaks 0.1 foot thick and 3 to 4 feet apart 23.0

Water level in old strip pit.

27. SECS. 3, 4, AND 5, T. 21 N., R. 16 E. FROM TOP OF THE MASSIVE TREE-BEARING SANDSTONE NEAR THE N $\frac{1}{4}$ COR. SEC. 3, WESTWARD TO OUTCROP OF THE VERDIGRIS LIMESTONE IN THE EAST-FACING ESCARPMENT 0.2 MILE EAST OF THE NW COR. SEC. 5. MEAN DIP OF THE VERDIGRIS LIMESTONE IN AREA FARTHER WEST IS 40 FEET PER MILE.

- 6 Shale, not measured.
5 VERDIGRIS limestone, dark, fossiliferous, about 3.0
4 Covered, clay shale and silty shale, contains Broken Arrow coal about 55 feet below top, about 100.0
3 CHELSEA sandstone, thin-bedded, not tree-bearing 10.0
2 Covered, shale, silty, about 5.0
1 Sandstone, massive tree-bearing, top exposed, not measured.

28. SEC. 1, T. 22 N., R. 16 E. ALONG ROAD. 0.1 MILE EAST OF N $\frac{1}{4}$ COR.

- 12 LABETTE shale, covered, soil 6.0
11 FORT SCOTT limestone, gray, fossiliferous, lenticular beds 6.0
10 Covered in part, seems to be black fissile shale with phosphatic nodules, about 3.0
9 Limestone, gray, fossiliferous, thin-bedded to massive 6.0
8 Shale, weathers buff 1.5
7 Coal, badly weathered, about 1.0
6 Sandstone, fine-grained, some silty shale 22.0
5 Sandstone, brown, silty 2.0
4 Shale, gray 9.0
3 VERDIGRIS limestone, dark, weathers yellow, fossiliferous 3.0
2 Shale, black fissile with phosphatic nodules 1.0
1 Covered, gray shale.

29. SEC. 10, T. 22 N., R. 16 E. IN AND ABOVE STRIP PIT, IN NW $\frac{1}{4}$ SE $\frac{1}{4}$.

- 5 VERDIGRIS limestone, base, poorly exposed, weathers yellow fossiliferous.
4 Covered, shale 25.0
3 Shale, in bank of pit 23.0
2 BROKEN ARROW coal 1.4
1 Shale, bottom of pit.

30. SEC. 12, T. 22 N., R. 16 E. FROM ABANDONED STRIP PIT $\frac{1}{4}$ MILE WEST OF THE S $\frac{1}{4}$ COR., SOUTHWESTWARD UP HILL.

- 3 VERDIGRIS limestone, base only exposed.
2 Covered, probably silty shale 35.0
1 Shale, silty, exposed in wall of pit 15.0

Water level in abandoned strip pit.

31. SEC. 19, T. 22 N., R. 16 E. BEGINS UNDER BRIDGE AT CENTER OF SECTION AND EXTENDS WESTWARD TO TOP OF HILL.

- 9 FORT SCOTT limestone, dark, weathers gray, fossiliferous, top probably eroded, about 4.0
8 Covered, probably black fissile shale with phosphatic nodules 6.0
7 Limestone, dark, weathers buff, fossiliferous, about 3.0
6 Covered, probably shale 2.0
5 Coal, weathered, about 0.4
4 Covered, probably shale 7.0

BROKEN ARROW COAL

3	Shale, dark, much weathered	18.0
2	Covered by alluvium	5.0
1	VERDIGRIS limestone, top only is exposed in stream bed for ¼ mile.	
32. SEC. 18, T. 22 N., R. 17 E. AND SECS. 13 AND 14, T. 22 N., R. 16 E. FROM MASSIVE TREE-BEARING SANDSTONE IMMEDIATELY EAST OF SW COR. SEC. 18, T. 22 N., R. 17 E. TO TOP OF HILL NORTH SIDE OF ROAD IN SEC. 14, T. 22 N., R. 16 E.		
11	FORT SCOTT limestone, poorly exposed, top eroded, caps hill, not measured.	
10	Covered, probably shale and sandstone	30.0
9	VERDIGRIS limestone, dark, weathers buff, poorly exposed in road	3.0
8	Covered	40.0
7	Sandstone and silty shale exposed in strip pit	8.0
6	Shale, dark, exposed in strip pit	12.0
5	BROKEN ARROW coal, exposed in strip pit	1.5
4	Shale, clay shale to silty shale, mostly covered	50.0
3	CHELSEA sandstone, silty, not tree-bearing, mostly covered about	10.0
2	Covered, silty shale, about	15.0
1	Sandstone, massive, tree-bearing, not measured.	
33. SEC. 4, T. 23 N., R. 17 E. MEASURED ON HILL IN THE SE¼ OF SECTION.		
4	FORT SCOTT limestone, caps top of hill, base only present.	
3	Covered, wooded, seems to be mostly sandstone	40.0
2	VERDIGRIS limestone, poorly exposed, about	5.0
1	Covered, shale, not measured.	
34. SEC. 4, T. 23 N., R. 17 E. ABOUT 0.3 MILE NORTH OF THE SW COR. BEGINNING IN ROAD NEAR TOP OF SPUR AND EXTENDING UP HILL NORTHEASTWARD.		
6	VERDIGRIS, Top of ridge covered by limestone fragments which are dark, weather yellow to buff, and probably represent a limestone bed at about this horizon.	
5	Covered, probably silty shale, about	15.0
4	Sandstone, buff, thin-bedded, silty, flaggy, makes bench, about	5.0
3	Covered, probably shale	50.0
2	BROKEN ARROW coal, poorly exposed in east bank of north-south road	1.5
1	Covered	15.0 or more
35. SEC. 10, T. 23 N., R. 17 E. NEAR W¼ COR. FROM WATER'S EDGE IN AN ABANDONED STRIP PIT NORTHWARD TO TOP OF RIDGE.		
4	Covered, wooded, probably thin sandstone beds and silty shale, to top of hill	15.0
3	Covered, probably shale	25.0
2	VERDIGRIS limestone, weathers yellow, fossiliferous, makes bench, not well exposed, about	2.0
1	Covered, probably shale	55.0

Water level in an abandoned strip pit.





