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GEOLOGY AND FUEL RESOURCES
OF THE
SOUTHERN PART OF THE OKLAHOMA COAL FIELD

PART 3. THE QUINTON-SCIPIO DISTRICT
PITTSBURG, HASKELL, AND LATIMER COUNTIES

BY
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JAMES STEELE WILLIAMS

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NOTE

The Geological Survey, in 1930, 1931, 1933, and 1934, conducted an investigation of the geology and coal resources of the portion of the southeastern Oklahoma coal field extending northeastward from Coalgate to McAlester and thence eastward through Wilburton and Howe to the Oklahoma-Arkansas State line. The geologists have prepared separate reports on the areas for which they were responsible. However, as these areas are adjacent and form a real unit both geographically and geologically, the four reports are issued as parts of a single bulletin covering this portion of the southeastern Oklahoma coal field. No edition of the consolidated volume will be published, but the four parts can be bound together if desired.

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GEOLOGY AND FUEL RESOURCES OF THE SOUTHERN PART OF THE OKLAHOMA COAL FIELD

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ABSTRACT

The Quinton-Scipio district includes about 450 square miles, mostly in Pittsburg County but partly in Haskell and Latimer Counties, Okla. The stratified rocks exposed at the surface in the district are the McAlester, Savanna, Boggy, Thurman, Stuart, and Senora formations, of Pennsylvanian age, and consist of alternating beds of shale and sandstone with some coal beds and a few beds of limestone less than 1 foot thick. The total thickness of these formations exposed in the district is between 3,000 and 3,300 feet. There are probably unconformities at the base of the Savanna sandstone and at the base of the Thurman sandstone. Overlying the Pennsylvanian formations in parts of the district are unconsolidated sand, gravel, and clay, which in part belong to the Gerty sand, a deposit in an abandoned Quaternary (?) river channel. Other unconsolidated deposits include sand on stream terraces and Recent alluvium.

The southeastern part of the district is crossed by the Enterprise, Kinta, Burning Springs, Flowery Mound, and Lake McAlester anticlines, which trend east-northeastward, roughly parallel to the northern front of the Ouachita Mountains, which lie to the south. Broad shallow synclines lie between these anticlines. The Lilypad Creek anticline trends slightly east of north across the western part of the district.

Coal has been mined intermittently in the district since 1902, but only a small amount for local use is now produced. There are several coal beds in the lower part of the Boggy shale, but only the Secor coal, which lies 450 to 500 feet above the base of that formation, has been mined on a commercial scale. This bed is from 2 to 3 feet thick and is a bituminous coal of good quality.

Nearly 200 wells have been drilled in the district in the search for oil and gas, and gas has been produced from fields on the Kinta anticline since 1915. Many of the wells have penetrated the McAlester shale, which is 800 feet thick in the northern part of the district and more than 2,000 feet thick at one locality in the southern part. Many of the wells also have penetrated the underlying Hartshorne sandstone and the upper part of the Atoka formation. The Hartshorne sandstone is thin in the northern part of the district but averages more than 250 feet thick on parts of the Kinta anticline. The Atoka formation and the underlying Morrow formation, also of Pennsylvanian age, have been penetrated by only two wells, both in the northern part of the district, one of which has been drilled through the older Paleozoic rocks to limestone of Ordovician age. The Pennsylvanian

formations thin over the anticlines, suggesting recurrent movement on them during the deposition of the rocks. The interval between the base of the McAlester shale and the top of the Morrow formation is estimated to thin at a rate of 130 feet to the mile in a direction N. 50° W. across the district.

Structure contours on the Upper Hartshorne coal, near the base of the McAlester shale, show that it has been folded into anticlines and synclines, the axes of which coincide approximately with those in the surface rocks, although the dips of the anticlinal flanks are steeper than in the surface rocks. The northwestward thinning of the lower Pennsylvanian rocks may result in the upward disappearance or reduction in size of these anticlines in the basal Pennsylvanian or pre-Pennsylvanian rocks and a westward shift of their crests.

The Quinton, Carney, and Blocker-Featherston fields, on the Kinta anticline, together yielded from the Hartshorne sandstone more than 60 billion cubic feet of dry high-methane gas to January 1934, and contain more than 60 billion feet in reserve. Marketable quantities of gas have also been developed in secs. 26 and 32, T. 9 N., R. 16 E., and in sec. 5, T. 8 N., R. 16 E., from beds in the Boggy, McAlester, and Hartshorne formations. The oil or gas possibilities of the underlying rocks have not been adequately tested.

INTRODUCTION

As one of the projects made possible by an allotment of funds from the Public Works Administration and carried out under the supervision of the Geological Survey, the Quinton-Scipio district, in southeastern Oklahoma (see fig. 8), was mapped geologically in the spring and early summer of 1934. The area is of economic importance because of existing gas fields, reserves of coal, and the presence of structure in the surface rocks which suggests the possibility that additional supplies of gas or oil may be developed. Geologically the project was of additional value because of the need of determining by detailed mapping the relations of the rocks of Carboniferous age exposed at the surface. These rocks dip generally northwestward, and farther north and west large amounts of oil and gas have been obtained from them.

The rocks in much of this region consist almost exclusively of alternating sandstones and shales of rather uniform lithologic aspect. The sandstones are lenticular. Although the rocks are chiefly of types which suggest deposition in a shallow-water environment, it has long been known that the sediments were laid down in a geosynclinal trough, the long-continuing subsidence of which permitted the accumulation of many thousands of feet of sediments along the axial portion. The thickness of these sedimentary rocks diminishes toward the northwest, and the rocks include lesser proportions of sandstone and relatively greater proportions of the finer-grained rocks, such as shale and limestone. For various reasons the paleontologic knowledge of the beds has not yet reached the stage of development at which the fossils contained in them are completely reliable guides to correlation. There has long been need of systematic, detailed areal mapping of large areas in Oklahoma underlain by Carboniferous rocks and extending from the region of the Ouachita Mountains into the oil-producing areas farther north in eastern Oklahoma. Mapping of this type has previously been done in the McAlester district,[1] the Muskogee-Porum district,[2] and the Howe-Wilburton district.[3] This report represents an additional area of such mapping, extending northward from latitude 35°, the north boundary of the McAlester district, to the Canadian River, and eastward from R. 13 E. to R. 18 E. The area includes about 450 square miles lying very largely in northern Pittsburg County but including, in the northeast corner, 18 square miles of Haskell County, and, in the southeastern part, 6 square miles in Latimer County. (See fig. 8.)

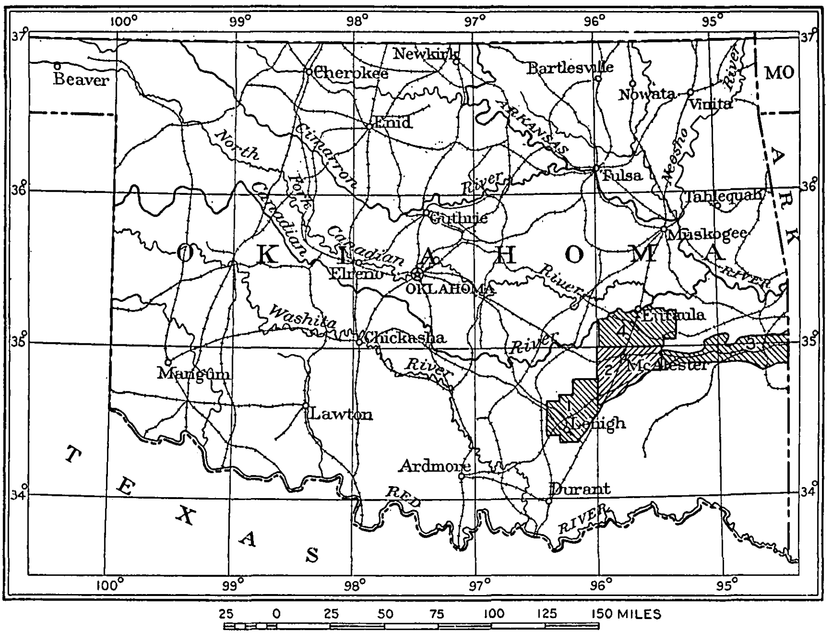


FIGURE 8.—Outline map of Oklahoma showing location of Quinton-Scipio and other districts. 1, Lehigh district; 2, McAlester district; 3, Howe-Wilburton district; 4, Quinton-Scipio district.

FIELD WORK

Mapping was begun in the later part of March 1934 and continued until the end of July by a party under the supervision of C. H. Dane. Carl Anderson, H. E. Rothrock, and James Steele Williams served as geologists, and Walton Christian, Raymond Hart, and L. M. Wilshire as instrument men. Robert Roth was also with the party for a few days as instrument man. During most of August 1934 H. E. Rothrock

[1] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 1, The McAlester district: Geol. Survey Bull. 874-A, 1937.

[2] Wilson, C. W., Jr., Geology of the Muskogee-Porum district, Muskogee and McIntosh Counties, Okla.: Oklahoma Geol. Survey Bull. 57, 1937.

[3] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 4, The Howe-Wilburton district: Geol. Survey Bull. 874-D (in preparation).

obtained many of the subsurface data included in this report, and during part of February 1935 he obtained additional subsurface data and checked some of the previous surface mapping.

Mapping was done by stadia traverse on a scale of 2 inches to 1 mile. The area lies in the southern part of the Canadian quadrangle and the southwestern part of the Sans Bois quadrangle, mapped on a scale of 1:125,000 by the Geological Survey. The region has been surveyed by the General Land Office, and the topographic maps give altitudes to the nearest foot at all township corners. Some of the benchmarks are still in place, and the location of some now missing can be closely determined, so that a very good control is afforded for checking altitudes. Some check altitudes were also obtained through the courtesy of the Missouri-Kansas-Texas Railroad and the Fort Smith & Western Railway. The township plats of the General Land Office are accurate and were plotted directly on the plane-table sheets, thus affording a good horizontal control for the stadia traverse. Because of the nature of the terrane and the locally thick woodland, it was necessary, in some places, to take long shots with the rod held in tree tops, in order to obtain altitudes on key beds that could not have been otherwise obtained except at prohibitive cost of time. The mapped locations of such points may be considerably in error, but, because of the generally low angles on such shots, the altitudes obtained are sufficiently accurate for the purpose for which they were needed.

The compilation of the field data and the preparation of the report represent office work of all three authors. For the subsurface data presented Mr. Rothrock is almost wholly responsible. Mr. Williams has contributed the section on the invertebrate paleontology of the Carboniferous formations.

ACKNOWLEDGMENTS

T. A. Hendricks, of the Geological Survey, spent a few days with the party at the beginning of the field season, acquainting them with the nature and distribution of the Carboniferous and Quaternary (?) formations of the adjoining McAlester district. W. W. Fleming, of the McAlester office of the conservation branch of the Geological Survey, placed the facilities of his office at the disposal of the writers. Information concerning the mining of coal in the district was contributed by many residents of the district, but special thanks are due to Mr. Charles Glenn, of Quinton, and Mr. Robert Lee, of Blocker.

The collection of drilling records was aided by the cordial cooperation of the oil and gas operators of the district, and the collection of data on the production of gas was greatly aided by the cooperation of the Corporation Commission of the State of Oklahoma. Special thanks are due to the management and personnel of the Utilities

Production Corporation and the Oklahoma Natural Gas Co. for information concerning the gas fields in the vicinity of Quinton. The Laughlin-Simmons Co., of Tulsa, and the McAlester Engineering Co., of McAlester, generously furnished a considerable number of altitudes of wells which otherwise could not have been obtained. The authors are grateful to Messrs. L. P. Coblentz and E. I. Streich, of Quinton, for personal observations and historical information regarding the Quinton fields. Helpful data were furnished by Messrs. James O. Lewis and Harry F. Wright, of Tulsa, and constructive criticism of the methods of computing gas reserves of the fields of the district was given by Mr. Eugene A. Stephenson, of Rolla, Mo.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Most of the Quinton-Scipio area is hilly. The land forms have been produced by the action of erosion on alternating beds of more resistant sandstone and less resistant shale, although the major streams pursue courses that are indifferent to the attitude and distribution of the beds. The hills represent residual masses consisting of or capped by more resistant rock that has not yielded readily to erosion. Some of them are broadly flat-topped and isolated; but more typically, where their capping bed of resistant sandstone dips gently, they have a steep frontal escarpment and a top that slopes gently downward toward the base of the escarpment produced by the next overlying sandstone bed.

The maximum relief in the area is more than 900 feet. The easternmost point on the Canadian River along the north margin of the area lies at an altitude of less than 550 feet above sea level. The highest point is the top of Panther Mountain, in sec. 24, T. 7 N., R. 18 E., which is slightly higher than 1,470 feet. Two points along the east line of T. 8 N., R. 18 E., have altitudes of 1,250 feet, and in the southwestern part of that township the hills reach an altitude of nearly 1,100 feet. In the western two-thirds of the area mapped the relief does not much exceed 400 feet.

The Quinton-Scipio district is drained by numerous streams. The Canadian River, which forms the northern boundary of the district, heads far to the west, in the southern Rocky Mountains in New Mexico, and about 30 miles to the northeast of the eastern end shown on the map it empties into the Arkansas River. In the northwestern part of the area the Canadian receives the tributary flow of Choctaw and Scipio Creeks, but only one other stream of importance enters it from the south. This is Gaines Creek, which flows from south to north across the central part of the area, receiving as tributaries from the west Coal Creek and Rock Creek and from the east Ash Creek and Mathuldy Creek. T. 8 N., Rs. 17 and 18 E., is drained by Longtown Creek and its tributaries. Longtown Creek flows from east to west in its upper course but turns northward and thence eastward and northeastward in the northwestern part of T. 8 N., R. 17 E., and eventually empties into the Canadian River. The southeastern part of the area is drained eastward by Sans Bois Creek, which joins the Arkansas River. Lake McAlester, in the southern part of T. 7 N., R. 14 E., and northern part of T. 6 N., R. 14 E., is a large and attractive body of water, with a deeply indented shore line, formed by the damming of Bull Creek, a tributary of Coal Creek.

The larger streams of the area flow in all seasons, although the flow is only slight in the dry summer months. During wet seasons these streams frequently overflow their banks and spread widely over their alluvial plains. The alluvial plain of Gaines Creek at places is more than 2 miles wide, although it enters the Canadian River through a narrow defile. The Canadian River itself flows in a wide alluvial plain, but the lateral swinging of the meandering stream has locally cut away most or all of the alluvium on the south side of the river. At 25 to 80 feet above the level of the alluvium of the Canadian River there are extensive gently sloping terrace surfaces, notably west and south of Indianola and west of Canadian. The extent and distribution of these terrace surfaces are not directly related to the present drainage—in fact, much of their area is now drained southward away from the river. Similar nearly level terrace surfaces of smaller extent occur in the valleys of Scipio, Gaines, and Longtown Creeks.

The larger streams of the district follow courses that are not directly related to the shape, distribution, and inclination of the bedrock; they flow in winding or meandering channels that cross the present ridges. The smaller streams follow courses developed on the gentle back slopes away from the ridge escarpments or run along the foot of the escarpments or between parallel ridges. These smaller streams generally flow only in wet seasons or after storms.

CLIMATE AND VEGETATION

The district has hot, dry summers and short, mild winters. The average annual rainfall is somewhat more than 40 inches. Rain is general and abundant during spring and early summer, but local during July and August, when there is drought in occasional years. The uplands of the district are timbered, chiefly with red and white oaks, blackjack, elms, hickories, and hackberries. Many of the valley and lowland areas have been cleared but originally were timbered with water and willow oaks, hickories, willows, and cottonwoods. There are some areas of natural prairie.

CULTURE

The rural farming population of the district is rather evenly distributed over the entire area, although locally concentrated in such places as afford the best farm land. The largest town is Quinton, which had a population of 1,804 according to the 1930 census. A smelter in Quinton, which used gas from the nearby Quinton gas field, has not been operating of late years, and coal mining has been of little importance, but the town remains the center of operations of the gas field and the trading center of a considerable area. Indianola, Crowder, and Canadian are the next largest towns in the district, but no one of these has a population of more than 400. The city of McAlester, a few miles south of the district, has a population of about 12,000, and Eufaula, a few miles north of the Canadian River, has a population of somewhat more than 2,000. The district is served by two railroads. The main line of the Missouri-Kansas-Texas Railroad, from Texas to St. Louis and Kansas City, runs somewhat east of north across the central part of the district, connecting McAlester and Eufaula and passing through Crowder and Canadian. The Fort Smith & Western Railway, which connects Fort Smith, Ark., and Guthrie, Okla., runs southwestward from Quinton through Featherston and Blocker and thence northwestward through Crowder and westward through Indianola, crossing the Canadian River a short distance to the west. Oklahoma-United States Highway 69 follows the Missouri-Kansas-Texas Railroad northward across the central part of the district, and Oklahoma State highways connect Crowder with Quinton and places to the east, McAlester with Quinton, Quinton with places to the north, and Quinton with Wilburton, to the south. There are many other graded roads, most of which follow section lines, but many of the upland areas are accessible only by poor roads or trails.

STRATIGRAPHY

GENERAL FEATURES

The rocks exposed at the surface in the Quinton-Scipio district are chiefly of Pennsylvanian age, but there are large areas of Recent alluvium, and some terrace deposits may also be of Quaternary age. The Pennsylvanian rocks have been subdivided into the following formations, listed in order of age, the oldest first: McAlester shale, Savanna sandstone, Boggy shale, Thurman sandstone, Stuart shale, and Senora formation. Each of these formations consists of alternating beds of sandstone and shale. Within this district only the Boggy shale includes beds of coal of commercial value. Some of the shales and sandstones are of continental origin, and others are marine. Thin marine limestones occur at several horizons in the Boggy shale and Savanna sandstone. No marked unconformity in the Pennsylvanian rocks can be recognized, but there may be slight unconformities at the base of the Savanna sandstone and at the base of the Thurman sandstone. Erosional irregularities are present at the base of many of the sandstone beds within the formations, but the individual sandstone beds are notably lenticular, and the irregularities at their bases are of little time significance.

CARBONIFEROUS SYSTEM

PENNSYLVANIAN SERIES

McALESTER SHALE

The topmost part of the McAlester shale crops out in narrow strips bordering the alluvial bottom of Sans Bois Creek in secs. 1, 2, 11, and 12, T. 7 N., R. 18 E. The McAlester shale was named by Taff [4] from the city of McAlester, in the north-central part of the McAlester district. The formation at its type locality has recently been studied, mapped, and described in greater detail.[5] The McAlester shale has not been traced into this district, but there is little doubt that it is correctly identified. The shale lies below the base of the overlying series of sandstone beds which forms the Savanna sandstone. The subsurface data available from the wells drilled in the Quinton gas field also show that the base of the Savanna sandstone lies above the surface in the area of shale outcrop. Small exposures show that the shale is dark, firm, and platy and interbedded with thin fine-grained micaceous sandstones.

SAVANNA SANDSTONE

The Savanna sandstone, which was named by Taff [6] from the town of Savanna, in the McAlester district, crops out in the southeastern part of the Quinton-Scipio district on the crest of the Flowery Mound anticline south of Coal Creek and west of Gaines Creek, on the crest of the Burning Springs anticline south of Elm Creek, and along the crest of the Kinta anticline south of Sans Bois Creek. It is 550 feet thick south of Quinton, the only locality within the district where the underlying McAlester shale is exposed. The nature of the contact is not determinable at that locality, but in the McAlester district, to the south, the Savanna sandstone rests upon the McAlester shale with an irregular contact that is believed to represent an unconformity.[7]

The Savanna sandstone is extremely variable in character from place to place, owing to the lenticularity and lack of continuity of many of the sandstone beds which it contains. On the whole the percentage of sandstone in the formation is greater than that contained in either the underlying or the overlying unit, but probably in most places within the district less than half of the total bulk of the formation is sandstone, most of the remainder consisting of blocky greenish-yellow, drab, or gray clay with small ellipsoidal concretions of siderite, and

[4] Taff, J. A., Geology of the McAlester-Lehigh coal field, Indian Territory: U. S. Geol. Survey 19th Ann. Rept., pt. 3, p. 441, 1899.

[5] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 1, The McAlester district: Geol. Survey Bull. 874-A, pp. 13-16, 1936.

[6] Taff, J. A., op. cit., p. 438.

[7] Hendricks, T. A., op. cit., pp. 16-17.

of sandy micaceous clay, gray or black bedded shale, and carbonaceous shale. There are several coal beds in the Savanna sandstone in the McAlester district,[8] but no minable coal was observed in the formation in the Quinton-Scipio district. A sandstone bed as much as 50 feet thick was seen at one place, but elsewhere the sandstones do not much exceed 20 feet in thickness, and most of them are much thinner. The thicker and more lenticular beds occur chiefly in the upper part of the formation. The thick sandstone beds of the Savanna are massive or strongly cross-bedded, gray, yellow, or white, fine- to coarse-grained or even gritty. The coarser-grained sandstones in places carry numerous grains of white chert, but normally quartz is the chief constituent. The thick sandstones may have erosional irregularities at the base, and on the whole their characteristics are those of stream-channel fillings.

Many of the sandstone beds of the Savanna are only a foot or so in thickness, and these may be massive, platy, or thin-bedded, and several such sandstones may be interbedded with approximately equal thicknesses of bedded micaceous shales. Some of the sandstone beds of this type contain numerous casts of marine or brackish-water fossils, but others contain broken fragments of plant material.

In the shales and sandy shales of the Savanna formation there are at many places irregularly ellipsoidal masses of sandstone, ranging in diameter from a few inches to several feet. These masses in the simplest forms are made up of concentric sheets which are the bedding layers of the sandstone. The bedding is shown by gradual variation in grain size, alternation of fine and coarse layers, and most convincingly by mica flakes and plant fragments that follow the now curving surfaces between concentric sheets. In more complex forms the original bedding is minutely contorted or even destroyed, and the shapes of the masses are irregular. In a few places sandstone beds in the formation consist chiefly of a succession of large masses of this kind. Most of these sandstone lumps and masses probably represent the results of movement during an early stage of compaction of the sediments, when the sandy portion of the sediments had attained a strength and coherence greater than that of the interbedded highly plastic muds and yet was soft enough to deform without extensive fracturing. The ellipsoidal shape of the masses of sandstone may have developed during the rolling of small lenses of more coherent sandstone in a matrix of plastic mud because of some lateral movement in the unconsolidated material.

At several localities in the eastern part of T. 7 N., R. 17 E., the northern part of T. 7 N., R. 18 E., and the southeast corner of T. 8 N., R. 18 E., there are outcrops of thin fossiliferous limestone beds at horizons from 150 to 180 feet below the top of the Savanna sand-

[8] Hendricks, T. A., op. cit., p. 19.

stone. Although tracing of these beds was not accomplished, there is a strong suggestion that the outcrops represent a definite zone of marine limestone beds, although individual beds may not be continuous. Near the center of the south line of sec. 36, T. 8 N., R. 18 E., the following section, which contains the thickest limestone bed observed in the Savanna, is exposed:

Section near south quarter corner of sec. 36, T. 8 N., R. 18 E.

	Ft.	in.
Shale, with light yellow-brown concretions	2+	
Limestone, shaly, exceedingly fossiliferous		10
Coal		2
Clay, light gray	1	6
Shale, dark gray, bedded	3	
Limestone, very fossiliferous	1	6
Sandstone, light tan, medium-grained	7	
Shale, gray, bedded.		

A limestone bed 8 inches thick, sandy in the lower part, overlain by drab shale, and resting on a sandstone bed, was observed at several localities in secs. 9 and 10, T. 6 N., R. 17 E., at a horizon about 300 feet below the top of the Savanna, and thin limestone beds are probably present at other horizons within the formation.

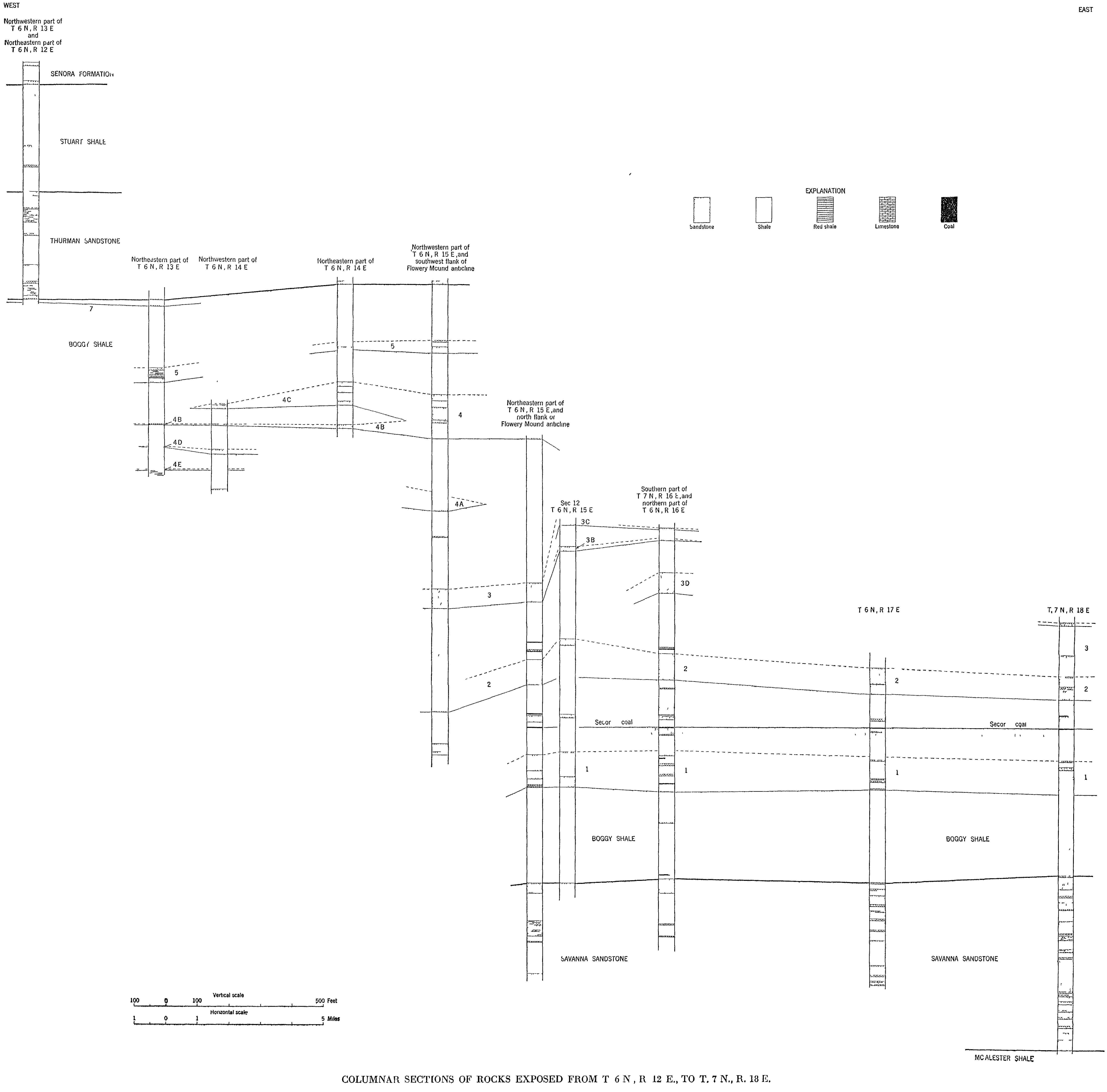
BOGGY SHALE

The Boggy shale crops out over a larger area than any other formation in the Quinton-Scipio district, extending northeastward in a belt ranging from 8 to 15 miles in width. The outcrop is continuous with that of the McAlester district on the south, and that in turn is continuous with the outcrop at the type locality, from which the formation was named by Taff,[9] the branches of Boggy Creek immediately southwest of the McAlester district.

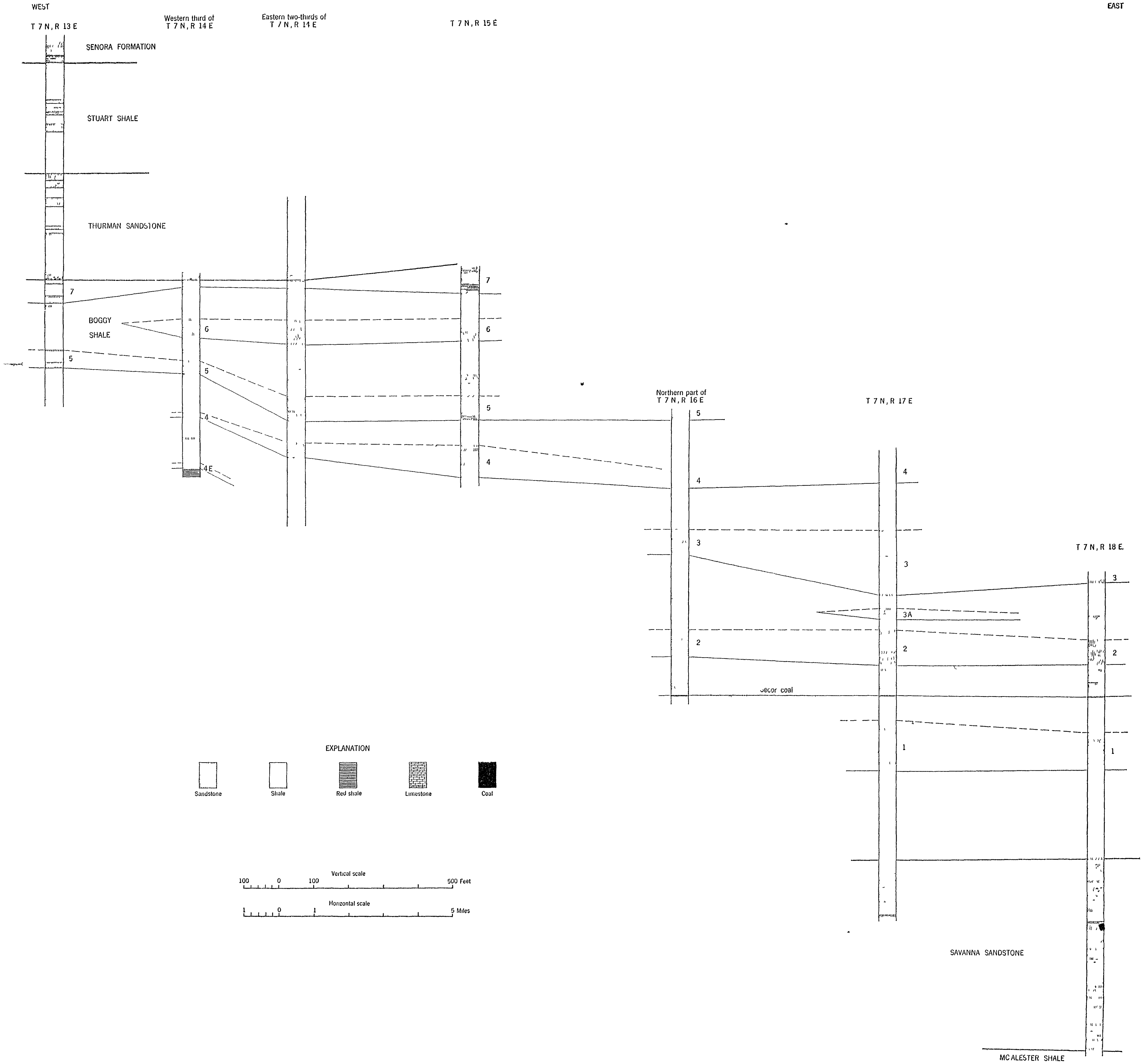
The aggregate thickness of the Boggy shale in the Quinton-Scipio district, as determined by the summation of numerous partial sections, ranges from 1,700 to 1,900 feet. Because the partial sections are widely spaced and because the formation from other evidence is known to change in thickness laterally, the thickness obtained by the method used is only of general value. The partial sections indicate the probability that the formation is thickest in the northern part of T. 6 N., Rs. 15 and 16 E.

The formation is predominantly shale but contains a variable number of sandstone beds or zones in which sandstone is equal to or predominant over shale in thickness. These zones of sandstone are as much as 100 feet thick. Where the dips are relatively steep, as in the southern part of the area of exposure, the thicker sandstone beds and such sandstones as are separated by thick shale intervals make

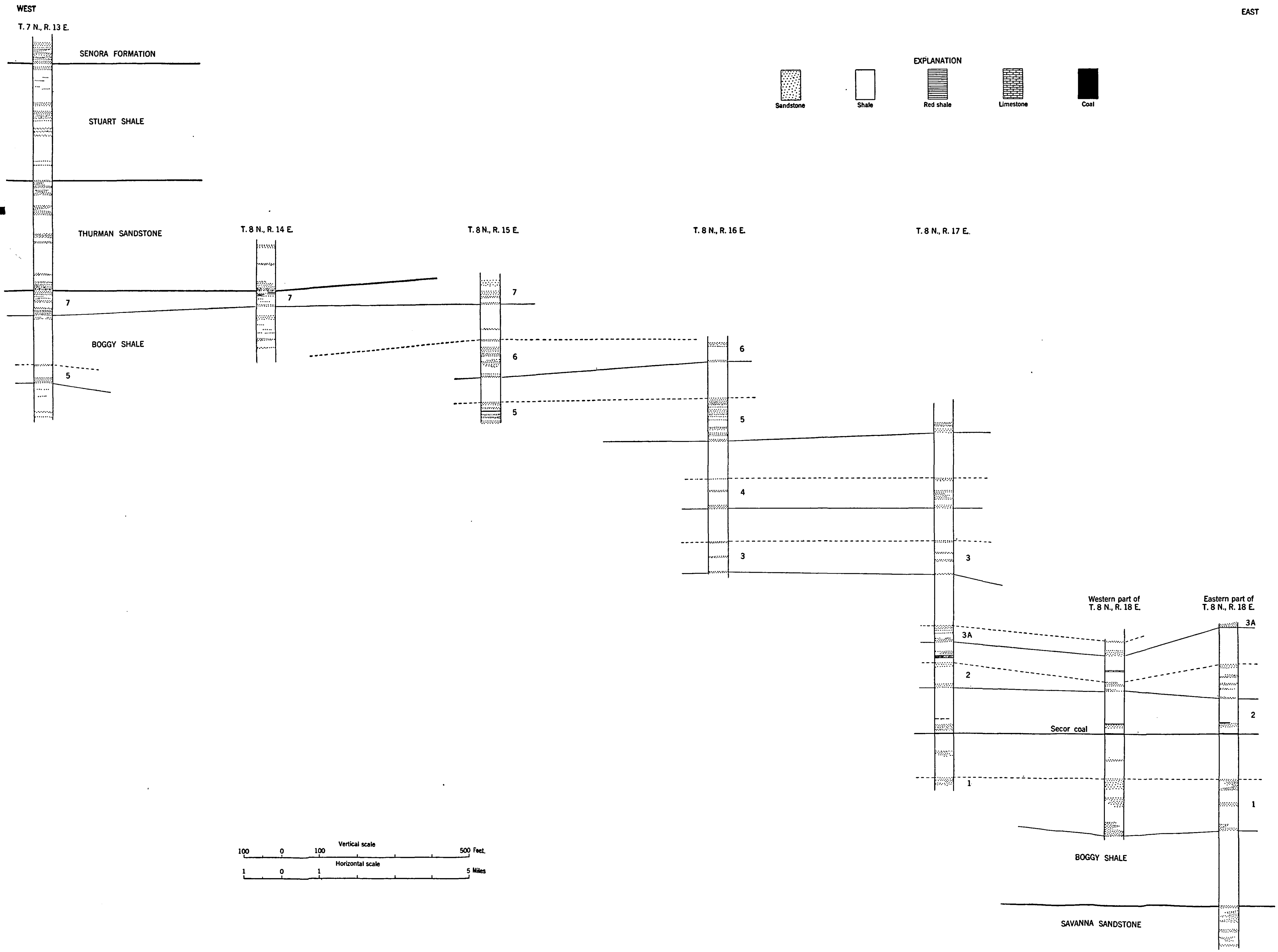
[9] Taff, J. A., Geology of the McAlester-Lehigh coal field, Indian Territory: Geol. Survey 19th Ann. Rept., pt. 3, p. 438, 1899.



COLUMNAR SECTIONS OF ROCKS EXPOSED FROM T 6 N, R 12 E., TO T. 7 N., R. 18 E.



COLUMNAR SECTIONS OF ROCKS EXPOSED FROM T 7 N., R 13 E, TO T. 7 N., R 18 E.



COLUMNAR SECTIONS OF ROCKS EXPOSED FROM T. 7 N., R. 13 E., TO T. 8 N., R. 18 E.

topographic ridges that are traceable with some degree of assurance over most of the district. Where the dips are gentle the degree of exposure is not sufficiently good to permit the tracing of individual beds for more than short distances. Accordingly an attempt has been made to show on the areal map (pl. 12) the extent and persistence of zones within the Boggy in which sandstone makes up the predominant or conspicuous part of the section. The base of these zones has been shown on the map by a solid line; the top by a dashed line. No attempt has been made to differentiate the precisely located contacts from those which are inferred. On the diagrams showing the correlation of the generalized sections of exposed rocks (pls. 14, 15, and 16), the solid correlation lines represent the bases of sandstone zones as they are shown on the areal map and the dashed correlation lines represent the tops of the sandstone zones. The continuity of the sandstone zones thus shown on the areal map and sections is based on the compilation and comparison of a great number of partial sections measured and computed from altitudes on traceable sandstone beds. The columnar sections are much generalized from numerous partial sections. The lines shown on both the areal map and the cross-section diagrams are in many places known to be not the bases or tops of continuous beds of sandstone, but represent merely the approximate position of the bottom or top of indefinite zones in which sandstone makes the conspicuous part of the section. In most places, however, the basal line of a zone represents the approximate location of the basal contact of a traceable bed of sandstone. In addition, it must be remembered that the columnar sections shown on the diagrams are much generalized from a much greater number of local sections and show only to a small degree the true variability of the sandstones. The lenticularity of the individual beds is well established by field observation, and individual lenses may reach 20 feet or more in thickness but do not have great lateral extent. Examples of the fusion of two or more beds to form a single thicker bed are also common. Lateral changes in lithology of the individual beds from thin-bedded and even shaly sandstones to massive and cross-bedded sandstones or to sandstones that exhibit contorted or deformed bedding are the rule rather than the exception.

The Boggy shale is believed to overlie the Savanna sandstone conformably, although no exposures of the contact were observed. Hendricks [10] has reported that a coal bed occurs about 20 feet above the base of the Boggy in the McAlester district. Coal at about this horizon is reported to crop out in the bed of Jones Creek in the NW¼ sec. 7, T. 6 N., R. 17 E., and to have been encountered in a well drilled south of the creek. In the NE¼ sec. 35, T. 9 N., R. 18 E., a short distance northeast of the mapped area, are outcrops of velvety

[10] Hendricks, T. A., op. cit., p. 23.

black pyritic shale with several beds of coal, none of which exceed 6 inches in thickness. These outcrops are believed to represent the coal zone near the base of the Boggy shale, as the top of the Savanna sandstone crops out a short distance below and to the east of them.

The lower 200 to 300 feet of the Boggy shale is predominantly dark-gray to black, evenly bedded shale with only local thin-bedded sandstones. Above this lies a zone of sandstone and shale 100 to 150 feet thick, which contains a workable coal bed at places in the southern part of T. 7 N., R. 16 E., in secs. 1 and 2, T. 6 N., R. 16 E., and in sec. 6, T. 6 N., R. 17 E. This sandstone zone is extensively exposed in the east-central part of T. 8 N., R. 17 E., and the northwestern part of T. 8 N., R. 18 E.

From 50 to 125 feet above this lowest sandstone zone of the Boggy and 450 to 500 feet above the top of the Savanna sandstone is a minable coal bed, the Secor coal (pl. 19, *A*), which crops out extensively in the southeastern third of the Quinton-Scipio district and has been worked on a small scale at a great number of localities, both by stripping and by tunneling operations. At most places the coal, which is normally about 2 feet thick, is underlain by gray clay and overlain by black shale, locally limy, which contains invertebrate fossils. This dark shale grades upward through sandy shales into a bedded sandstone 5 to 10 feet thick (pl. 19, *B*). The base of the sandstone is vague but generally lies 15 to 25 feet above the coal. Resting directly upon the top of the sandstone or at most a few feet above it a thin coal bed has been found at a considerable number of localities. A coal bed 200 feet higher than the Secor coal crops out at several localities in T. 8 N., R. 17 E. In the NW¼ sec. 27 of that township it is reported to be 22 inches thick and to have been dug for local use. Overlying the coal or a few inches above it is a bed of yellow limestone 4 to 6 inches thick, which is very fossiliferous. Coal at this horizon has also been dug in the NW¼ sec. 6, T. 8 N., R. 18 E. At one locality a little farther east in that section and probably 170 feet above the Secor coal, a poorly bedded to massive gray limestone 6 to 8 inches thick, weathering yellow, crops out. This is also very fossiliferous. It is overlain and underlain by black thin-bedded shale.

In the NE¼ sec. 36, T. 7 N., R. 15 E., in the bluff on the east bank of Coal Creek, a coal bed is exposed which is about 240 feet higher than the Secor coal. This coal bed is from 9 to 12 inches thick and is capped by a sandstone bed 6 to 12 inches thick, which in turn is overlain by a limestone bed from 3 to 12 inches thick. At 25 feet higher stratigraphically is another coal bed, 9 inches thick, which is both underlain and overlain by black fissile shale. A thin coal bed overlain by limestone is reported to be present at about this horizon in sec. 7, T. 6 N., R. 16 E.

A more detailed description of the nature, distribution, and mining of the Secor coal is given on pages 196–204.

In Tps. 6 and 7 N., R. 13 E., and in the western part of T. 7 N., R. 14 E., blocky red clays and greenish sandy clays occur at several horizons in the upper part of the Boggy shale, where they are associated with white cross-bedded and irregularly bedded sandstone. Clays of this type are also found in the overlying Thurman sandstone, to the west, and have been described as occurring in the Boggy shale and underlying Savanna sandstone in the western part of the McAlester district.[11]

At certain localities within the outcrop area of the Boggy shale the rocks display abnormally steep and eccentric dips and include unusually great thicknesses of sandstone that are not duplicated along the strike of the beds. For the origin of these features no wholly satisfactory hypothesis has yet been advanced, but in spite of the fact that they may affect areas of as much as 80 acres and present an apparent stratigraphic section of hundreds of feet, they have been ignored in compiling the structure-contour map of the district, because it is believed that they do not represent the results of diastrophic movements but are rather depositional features of some sort—or more probably deformational features formed prior to the consolidation of the beds. To give some idea of the nature of these peculiar features, the area in the vicinity of the Rainbow Girls' Camp, south of Lake McAlester, including portions of secs. 3, 4, 9, and 10, T. 6 N., R. 15 E., will be briefly described.

The regional dip in the vicinity is about 3° SE., as shown on the structure-contour map, and probably normally does not exceed 5° or 6° at individual outcrops. On the road up the hill to the Rainbow Girls' Camp, nearly on the line between secs. 3 and 4, the road ditches expose a thickness of perhaps 25 feet of gray bedded shale and sandy shale, without abnormally steep bedding. In the overlying 10 feet of shale exposed, the dip increases gradually but somewhat erratically from 10° SW. to 25° or 30° S. Exposures immediately above are obscure, but at a level 5 feet higher are encountered shattered masses of sandstone that extend upward into sandstone with contorted bedding of the type previously described as due to movement in the partly consolidated sediments. Above this lie the massive sandstone ledges which form the escarpment rim below the camp. These ledges, 5, 10, 15, or more feet in thickness, dip southward in succession (pl. 18, *B*). Along the steep front of the escarpment the ledges slant diagonally down the slope but appear to terminate abruptly. Beneath the sandstone ledges lie shales that have a gentle southward dip.

On the more gentle southward slope south of the camp many more sandstone ledges crop out along a small creek for a distance of about 1,500 feet southward from the rim. Variable in lithologic details and from 2 to 10 feet thick, these ledges all dip 15°–25° S. The most

[11] Hendricks, T. A., op. cit., pp. 18–19, 23.

southerly sandstone is a very massive one, which does not show enough bedding to determine the dip but appears to have a somewhat wavy under surface. The south face of this sandstone ledge abuts sharply against shale, and there is a suggestion of slickensiding on the sandstone. The shale has a dip of 20° N. at the nearest point to the sandstone at which the dip can be measured. The northward dip diminishes abruptly away from the sandstone, and 50 feet to the south the shale appears to dip southward beneath an overlying thin sandstone bed which also dips southward at about the normal regional angle.

Among numerous other localities at which there are much-disturbed sandstone beds are the NW¼ sec. 12, T. 6 N., R. 14 E.; the SW¼ sec. 19, T. 7 N., R. 15 E., where the sandstones lie within one of the shale intervals; the NE¼ sec. 11, T. 7 N., R. 16 E.; and the SE¼ sec. 34, T. 9 N., R. 16 E.

Peculiar bedding features of another type are well exposed on the dugway of the Crowder-Blocker road in the NE¼ sec. 1, T. 7 N., R. 15 E. These consist of ellipsoidal sandstone masses 10 to 15 feet or more in diameter. Most of them were evidently beds or lenses of sandstone, perhaps as much as 5 feet thick. The beds or lenses are now bowed down at the center and rolled up at the edges, so that on the outside of each individual mass the base of the bed is exposed (pl. 17, *A*). The beds on the sides of the masses stand vertical or are overturned, and at the tops of the masses the beds may be completely inverted. In several masses the central portions are composed of shale. The external surfaces of the sandstone are smoothed and slickensided where they are in contact with the body of shale in which they are embedded, and some of these external surfaces are clearly fault contacts that cut off the bedding of the adjoining shale. The bottoms of the masses of sandstone are close to the underlying sandstone bed, but the bases are not exposed. On the whole it seems most probable that these features are the result of movement in the partly consolidated materials, in which a sandstone bed or lens was able to fold down into the more plastic shale. The under surfaces of some of these folded or rolled sandstones exhibit the small bedding faults that are found on the bottom surfaces of numerous slabs of the Pennsylvanian sandstones where the rocks are essentially horizontal. These faults have probably been correctly regarded as depositional or compactional features, and accordingly the folded masses here described are younger than the faults.

Even if it is admitted that the formation of these folded masses and the peculiar areas of erratic dips previously described is due to movement in materials that had at the time been recently deposited, it may nevertheless be true that the initiating cause of the movement came from deeper-lying structural displacements which were taking place as the general basin of deposition warped intermittently downward to accommodate the influx of sediments. No systematic arrangement or alinement of the features has been discerned, however, and it may be that the cause is to be sought wholly in differential compaction, local depositional overloading, and subsequent sliding of material to less heavily sedimented areas.

THURMAN SANDSTONE

The Thurman sandstone crops out in a strip a few miles wide extending from the southwest corner of the district through the northwestern part of T. 6 N., R. 13 E. (pl. 18, *A*), the central part of T. 7 N., R. 13 E., and the southeastern part of T. 8 N., R. 13 E., thence extending eastward into the southwestern part of T. 8 N., R. 14 E., and covering also a few square miles in the north-central part of T. 7 N., R. 14 E. The capping sandstone of the hills in the extreme southern part of sec. 12, T. 6 N., R. 14 E., and the southwest corner of sec. 31, T. 6 N., R. 15 E., is also regarded as the basal part of the Thurman sandstone. The formation was named by Taff.[12] Although no type locality was given, the former village of Thurman, north of the limits of mapping in the McAlester-Lehigh coal field, in the NE¼ sec. 30, T. 8. N., R. 14 E., probably provided the name of the formation. As the Thurman-Boggy contact is now mapped in the Quinton-Scipio district, the village of Thurman may actually have stood upon the uppermost beds of the Boggy shale. This is of little consequence, for the lithology and limits of the formation as described and mapped by Taff can be readily recognized.

The Thurman sandstone in the Quinton-Scipio district is from 290 to 335 feet thick and consists of alternating beds of sandstone, sandy shale, and shale. A basal bed of chert-pebble conglomerate is rather widespread. This bed or an equivalent coarse-grained sandstone, as mapped in this district, runs into the basal contact as mapped by Taff [13] in the adjoining area to the south. Locally in the Quinton-Scipio district the conglomerate attains a thickness of 10 feet and contains pebbles of white or light-gray weathered chert as much as half an inch thick. Elsewhere it may contain only scattered pebbles or grit-sized grains of chert, and in some places no pebbles are found. In Tps. 6 and 7 N., R. 13 E., although only a minor fraction of the formation as shown in the columnar sections (pls. 14, 15) consists of outcropping sandstone beds that can be traced for distances of half a mile or more, much of the concealed intervals undoubtedly consists of soft or thin-bedded sandstones and sandy shales, and on the whole the sandstone in the formation is believed to equal the shale, if not to predominate over it. The sandstones, like those in the other formations of the district, are variable in texture, type of bedding, and thickness, and lateral changes in lithology are common. Some contain carbon-

[12] Taff, J. A., Geology of the McAlester-Lehigh coal field, Indian Territory: Geol. Survey 19th Ann. Rept., pt. 3, p. 439, 1899.

[13] Taff, J. A., op. cit., pl. 64.

ized plant fragments in abundance; in others marine invertebrate fossils are found. At different horizons throughout the formation greenish sandy clays, reddish clays, and cross-bedded sandstones occur, but bedded dark shales with calcareous concretions, containing an invertebrate fauna, are much more abundant.

The top of the Thurman in the SE¼ sec. 12, T. 6 N., R. 12 E., just west of the area shown on the map (pl. 12), appears to lie at the top of a ledge of sandstone. The top of this sandstone seems quite probably to be the horizon also selected by Taff [14] as the top of the Thurman in the closely adjacent portion of the Coalgate quadrangle. The top of the sandstone is computed to be 290 feet above the base of the Thurman, as compared with the thickness of 250 feet assigned by Taff to the Thurman in the northeastern part of the Coalgate quadrangle, but this difference is doubtless explainable as due to difference in determination of the dip of the beds.

Above this sandstone in the SW¼ sec. 1, T. 6 N., R. 12 E., lie gray shales, but above what is believed to be the same bed in the NW¼ sec. 6, T. 6 N., R. 13 E., the exposures are chiefly of soft sandstone, including some sandy shales. Above these in the southern part of sec. 36, T. 7 N., R. 12 E., lies a cross-bedded buff sandstone believed to be about 15 feet thick. At this locality these soft sandstones and the overlying harder cross-bedded sandstone are included in the Thurman (making the total thickness of the formation 335 feet), but they are not believed to extend southward into the area of the Coalgate quadrangle, where they are represented by shales there included in the lower part of the overlying Stuart shale. The relations between the formations are for this reason believed to be transitional, the lower part of the Stuart shale grading northward into sandstones inseparable from the Thurman sandstone.

Chert-pebble conglomerate at the base of the Thurman has been observed as far east as the SW¼ sec. 10, T. 7 N., R. 14 E. East and north of that point the basal Thurman is not recognizable and the contact as drawn is largely conjectural and based on the observed regional dip of the beds. In the southern part of sec. 3, T. 7 N., R. 14 E., the beds thus included in the Thurman consist largely of bedded gray and dark shale with two thin sandstones 110 and 190 feet above the base of the formation. There is therefore a great diminution northeastward in the amount of sandstone in the Thurman in the Quinton-Scipio district, whereas in the Coalgate quadrangle the sandstone beds in the upper part of the Thurman become finer-grained westward, more shale is included in the formation, thin beds of impure limestone appear, and the basal conglomeratic ledge may be absent. These changes are accompanied by a decrease in thickness of the formation from 250 feet to 80 feet.[15]

[14] Taff, J. A., Geol. Survey Geol. Atlas, Coalgate folio (no. 74), 1901.
[15] Idem, p. 4.

On the south edge of sec. 12, T. 6 N., R. 14 E., several coarse-grained sandstones cap an outlying high hill, which extends southward into the McAlester district.[16] Although no chert pebbles were observed in these sandstones, they have a rather typical coarse-grained texture, and their high position in the stratigraphic section makes it probable that they represent the basal portion of the Thurman sandstone.

The basal conglomeratic bed of the Thurman sandstone in the Quinton-Scipio district rests with a sharp contact and local erosional irregularity on the underlying Boggy shale. Angular discordance has not been detected with assurance, because of the nature of the exposures and the absence of reliable traceable key beds in the uppermost part of the Boggy and because of internal changes in thickness of that formation. Because of the distinctive character of the basal Thurman, which may imply a new source of supply of sediment, and because of the local erosional irregularity at the base, it is believed that the Thurman may rest unconformably on the Boggy shale.

STUART SHALE

The Stuart shale, named by Taff[17] presumably from the town of Stuart, in T. 5 N., R. 11 E., Hughes County, crops out in the Quinton-Scipio district in the northwestern part of T. 7 N., R. 13 E., and the southwestern part of T. 8 N., R. 13 E., where it has a thickness of 315 feet. The outcrops occur in the steep slopes of the hilly escarpment that is surmounted by the succeeding Senora formation. The Stuart consists chiefly of dark laminated shales, which at places carry ferruginous or calcareous nodules and concretionary beds. Some of these beds contain invertebrate fossils. There are some interbedded sandstones throughout the formation, but sandstone beds are thickest and most numerous in the middle portion, in a zone from 80 to 210 feet above the base, although sandstone nowhere occupies all of this interval. The sandstone in this part of the formation is massive, cross-bedded, or evenly bedded. Locally sandstone beds were observed to contain large numbers of pellets and lumps of gray clay in their basal parts. Elsewhere invertebrate fossil remains were observed in the sandstone. The division of the Stuart into a middle sandstone member and upper and lower shale members was also observed by Taff[17] in the Coalgate quadrangle.

SENORA FORMATION

The Senora formation was named by Taff[17] from the old post office of Senora, in southern Okmulgee County.[18] The contact as mapped by Taff in the Coalgate quadrangle was examined in the northeastern

[16] Hendricks, T. A., op. cit., p. 26.
[17] Taff, J. A., Geol. Survey Geol. Atlas, Coalgate folio (no. 74), p. 4, 1901.
[18] Gould, C. N., Index to the stratigraphy of Oklahoma: Oklahoma Geol. Survey Bull. 35, p. 44, 1925.

part of T. 6 N., R. 12 E., and followed northward into the outcrop of the formation in the Quinton-Scipio district, in the northwestern part of T. 7 S., R. 13 E., and the southwestern part of T. 8 N., R. 13 E. Only the basal 70 feet of the Senora formation is exposed. This consists chiefly of sandstone with some shale beds, the base of the formation being placed at a sandstone bed 10 feet thick. The formation, where it is completely exposed elsewhere, has a thickness of as much as 500 feet.[19]

QUATERNARY (?) SYSTEM

GERTY SAND AND TERRACE SANDS

The Gerty sand was named by Taff[20] from the town of Gerty, in Hughes County. The original name of the type locality (Guertie) having been changed to "Gerty" by the United States Geographic Board, the name of the formation has been changed correspondingly.[21] The surface of the Gerty sand forms a narrow, much dissected and discontinuous eastward-sloping plain, about 90 miles long and locally as much as 4 miles wide, extending eastward from Byars, Okla., through the McAlester district[22] and into the Quinton-Scipio district. Exposures of gravel and sand definitely assignable to the Gerty occur in the south-central part of the Quinton-Scipio district along the valley of Gaines Creek. The gravel contains rounded pebbles and cobbles of quartz, quartzite, chert, flint, jasper, and silicified wood, the nearest source of which is in the Cretaceous or older rocks of the Rocky Mountains or the Tertiary deposits of the High Plains. Intermixed with these exotic types of pebbles is a variable proportion of sandstone pebbles of probably local origin. The Gerty sand has been demonstrated to be the deposit left by the Canadian River when that stream flowed across this general region in a course antedating that which it now occupies.[23] Pebbles of siliceous rocks in terrace deposits thus identifiable as Gerty sand have been found in the Quinton-Scipio district as far north as sec. 2, T. 7 N., R. 15 E. The thickness of the Gerty sand is not known but may be as much as 30 feet.

No evidence bearing on the age of the Gerty was found in the Quinton-Scipio district. Pleistocene age for the formation has been suggested on the basis of an elephant tusk found in it in the Stonewall quadrangle.[24]

Deposits consisting chiefly of fine-grained red sand underlie extensive terraces 25 to 80 feet above the level of the alluvium of the Canadian River west and south of Indianola and west of Canadian.

[19] Taff, J. A., op. cit. (Coalgate folio), p. 4.

[20] Taff, J. A., Geology of the McAlester-Lehigh coal field, Indian Territory: Geol. Survey 19th Ann. Rept., pt. 3, p. 439, 1899.

[21] Hendricks, T. A., op. cit., p. 26.

[22] Idem, p. 28.

[23] Idem, pp. 28-33.

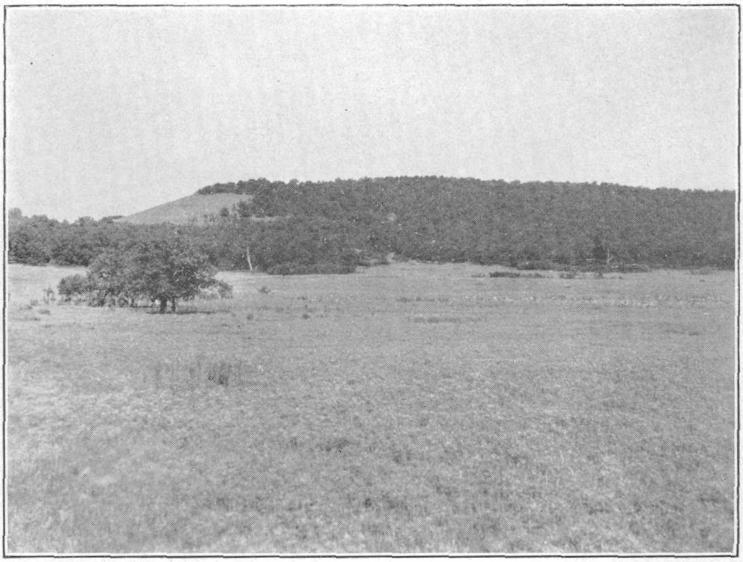
[24] Morgan, G. D., Geology of the Stonewall quadrangle, Oklahoma: Bur. Geology (Norman, Okla.) Bull. 2, p. 145, 1924.

A. ROLLED MASS OF SANDSTONE IN THE BOGGY SHALE.

Along road from Crowder to Blocker in NE ¼ sec. 1, T. 7 N., R. 15 E. Instrument belt in circle shows scale.

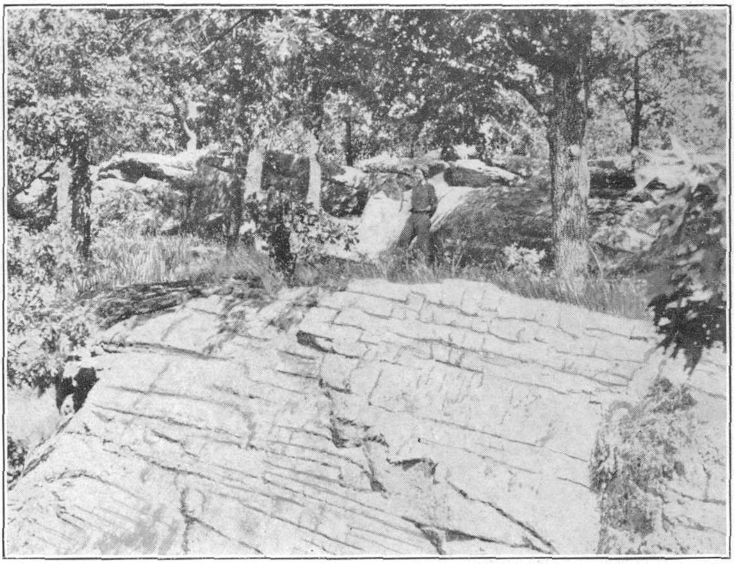
B. CONTORTED BEDS OF SANDSTONE IN THE BOGGY SHALE.

Beds of lower horizon at same locality as those shown in *A*.



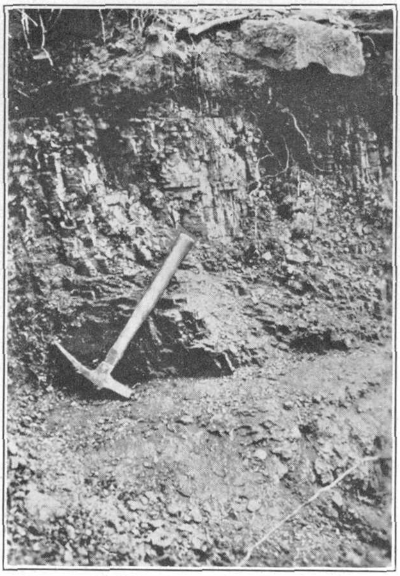
A. RIDGE CAPPED BY THURMAN SANDSTONE.

View looking west in sec. 3, T. 6 N., R. 13 E. Slopes of Boggy shale at left and in foreground.



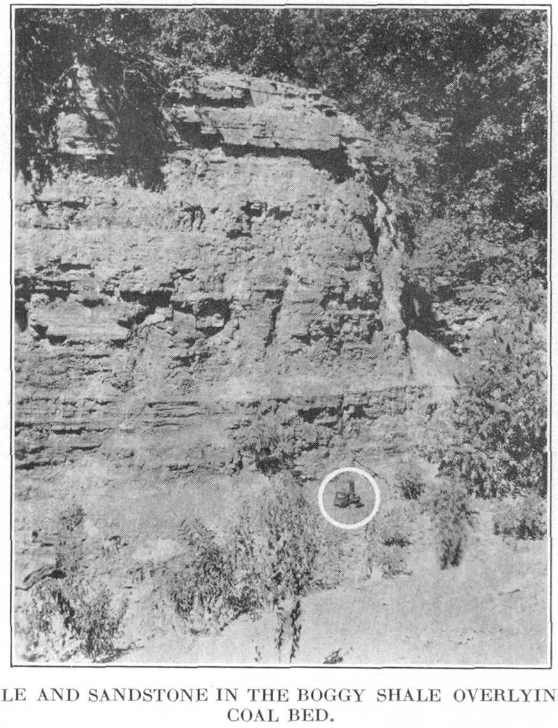
B. SANDSTONE BEDS OF ABNORMAL THICKNESS AND DIP IN THE BOGGY SHALE.

Near Rainbow Girls' camp in southeast corner of sec. 4, T. 6 N., R. 14 E. Beds dip away from the observer at an angle greater than the regional dip.



A. SECOR COAL BED.

Exposed in a small strip pit near center of SE¼ NE¼ sec. 26, T. 8 N., R. 17 E.



B. SANDY SHALE AND SANDSTONE IN THE BOGGY SHALE OVERLYING THE SECOR COAL BED.

Exposed in a small strip pit in SW¼ sec. 23, T. 8 N., R. 18 E. The instrument belt in the circle lies on the coal, which is concealed by wash.

These deposits and similar deposits in and near the valleys of Scipio, Gaines, and Longtown Creeks are shown on plate 12 with the same pattern as the deposits of Gerty sand, although they are of more recent origin. The sand is rather uniformly fine-grained, varies from white to light red, and locally contains some muddy bands. Except for these interbedded clays or silts, however, the bedding is vague. The material, where exposed in road cuts or gullies, stands in steep or vertical banks like loess. Exposures of as much as 15 feet of the sand were seen, but it probably has a thickness of at least 25 feet, the amount by which the northern edge of the terrace surfaces stands above the alluvial bottom of the river. The material probably is chiefly older alluvium and valley wash deposited in part by the Canadian River and in part by tributary streams at a former higher level of the river, but it may in part have been deposited by the wind.

QUATERNARY SYSTEM

RECENT ALLUVIUM

The alluvial bottoms of the larger streams of the area range from less than 100 feet to 2 miles in width. In most places the alluvial fill is a gray sandy silt that ranges in thickness from a few inches on the edges of the flood plains to at least 25 feet in the banks of the streams, many of which have not cut through the alluvium to bedrock.

INVERTEBRATE PALEONTOLOGY OF THE CARBONIFEROUS FORMATIONS

By James Steele Williams

GENERAL FEATURES

Collections of marine invertebrates were obtained from the Savanna sandstone, Boggy shale, Thurman sandstone, and Stuart shale. Only a small thickness of the overlying Senora formation is present in the district, and this crops out in a small and difficultly accessible area. Accordingly, no collections from it were made, although large faunules have been obtained from it in the nearby Stonewall quadrangle.[25] All the collections studied consist of megafossils. A few samples were collected and washed for microfossils, but none yielded faunules of any importance.

The collections suggest very strongly that a relationship exists in the Quinton-Scipio district between the conditions of deposition of certain types of sediments and the composition of the faunules. The limestones, in the main, have the most varied faunules, with brachiopods, bryozoans, crinoids, and corals among the most abundant forms and gastropods and pelecypods among the rare forms. However, some limestones have meager faunas. At least one, a limestone that

[25] Morgan, G. D., Geology of the Stonewall quadrangle, Oklahoma: Oklahoma Bur. Geology Bull. 2, p. 88, 1924.

is partly oolitic, has a faunule that suggests the former existence of a depauperizing influence. Another, a very sandy limestone or limy sandstone, is clearly indicated by its fauna to be of fresh-water origin.

The shales also vary in lithology, and the different lithologic types have in the main different faunules. Most of the black fissile and pyritic shales from which collections were obtained have faunules composed largely of species of *Aviculipecten* that are known to occur in brackish-water sediments. They also have as prominent elements in their faunas Lingulas and individuals of *Crurithyris planoconvexa*. A fresh-water form, *Naiadites? elongata,* occurs in them at one place, and fern pinnules were collected at another place. At a locality where the black shales are conspicuously pyritic small coiled gastropods, suggestive of unfavorable life conditions, were the most abundant forms in a rather meager collection.

The lighter and less fissile clay shales and limy shales, where fossiliferous, yielded marine faunas.

The sandstones have faunas of two types. Many of the sandstones in the younger formations have abundant marine faunas. Other sandstones, especially many of those in the Boggy formation, have yielded only plants and other nonmarine forms. Some sandstones have yielded both plants and marine fossils at slightly different stratigraphic positions, and this suggests that they are in part marine and in part continental.

The stratigraphic value of the collections is enhanced because they were made during the plane-table mapping of the district. On the other hand, many of the collections were made in more or less incidental fashion during the mapping and are consequently of small size. Toward the end of the season a few days were allotted to more intensive collecting, and larger collections were made then from some of the more fossiliferous localities. All the collections were located stratigraphically and geographically through reference to instrument or rod stations.

The identifications of the fossils here reported were made in the winter of 1935–36, and changes in nomenclature made in articles reaching me after March 1, 1936, are not included in this article. A few changes made in articles reaching me before this date are also not included, either because I disagree with them on morphologic or philosophic grounds or because I have some slight misgiving about them and have not yet been able to take the time to satisfy myself about them. Few if any of the species concerned will be less well understood than they are now because of my reluctance to adopt the changes at once.

Despite the fact that the best fossils obtainable from many zones were fragmentary or otherwise poorly preserved, an effort was made, so far as time permitted, to get representative collections from every fossil-bearing zone in the area studied. The approximate relative abundance of the various species was noted in the field. To aid further in obtaining an estimate of the total relative composition of the faunules, identifications were attempted in the laboratory of nearly all the material collected, whether fragmentary or completely preserved. Question marks were, however, added to identifications of specimens that did not show all the characters essential for reasonably certain identification. Only the good material was identified positively. I believe that the attempted identification of all material, even if some of the genera have to be queried, gives a more nearly representative and hence a more reliable and more valuable faunal list for correlation than is obtained when only the material that can be positively identified is used. There is little danger in such a policy if question marks are added to all identifications about which there is a reasonable doubt.

COLLECTIONS FROM THE SAVANNA SANDSTONE

Invertebrate fossil collections were made from five zones in the Savanna sandstone. All the collections came from thin limestones or limy shales, exposed in the southeastern part of the district. The collections from the oldest beds came from a roadside ditch along the Quinton-Wilburton road about 2 miles south and 1 mile east from Quinton. These collections were obtained from a thin calcareous zone that is in a shale and is close to the base of the Savanna formation. Most of the other collections came from a single locality, along a road about 2,700 feet east of the southwest corner of sec. 36, T. 8 N., R. 18 E. This locality is about half a mile south and half a mile east from Quinton.

The lowest fossil zone at this locality is an 18-inch limestone and the weathered limy shale immediately above it. This limestone is about 150 to 180 feet below the top of the Savanna. Two collections were made from this zone. The next higher zone is a very ferruginous and calcareous brown and greenish-gray shale, 2 to 8 inches above the 18-inch limestone, and the zone next above this is a 10-inch tannish-gray, very shaly limestone or limy shale above a 2-inch coal and about 12 feet above the 18-inch limestone. The highest fossiliferous zone in the Savanna is an 8-inch yellow-brown, very ferruginous sandy limestone about 80 to 100 feet below the top. The collection from it was made at Featherston.

All the fossil zones, with one exception, are almost literally masses of shells and shell fragments, mainly of brachiopods. *Marginifera muricatina missouriensis* Girty is the most abundant form. A small variety of *Spirifer opimus* Hall, which I have informally designated variety A, is also very common in most of the collections. *Chonetes* (*Mesolobus*) *mesolobus* (Norwood and Pratten) occurs sparingly. Several other brachiopods are common in one or more collections. Crinoid columnals occur in nearly all collections, and *Prismopora* and *Hustedia* occur in three of the zones. Pelecypods and gastropods are relatively rare.

The collections from the 10-inch shaly limestone above the 2-inch coal differ markedly in general composition from the other collections. They have many macerated shell fragments of many kinds, but the most abundant recognizable forms are branching bryozoans. If recognizable individuals are truly representative, the brachiopods are entirely lacking, but a few pelecypods and a few gastropods are present.

All the zones here described are marine. Plants were obtained near the top of the Savanna at a locality near Quinton. These are in the hands of C. B. Read, of the Geological Survey, for identification. The invertebrate species collected from the various zones of the Savanna are listed by zones and by collection numbers in the subjoined table. Comparisons between the fauna of the Savanna and the faunas of other formations and age determinations and correlations are discussed on pages 182–189.

Fossil invertebrates collected from the Savanna sandstone

[The numbers given in this and succeeding tables are permanent numbers in the Carboniferous invertebrate paleontology records of the U. S. Geological Survey. r, rare; c, common; vc, very common; a, abundant]

	7937, 7941	7936, 7942	7944, 7945	7939, 7940	7943
Spongiae:					
Sponge? borings				r	
Anthozoa:					
Lophophyllum profundum Edwards and Haime	c				
Pelmatozoa:					
Crinoid columnals	c	c	r		c
Hydreionocrinus acanthoporus (Meek and Worthen)	r				
Hydreionocrinus mucrospinus (McChesney)	c				
Bryozoa:					
Tabulipora? sp. undet	r				
Fenestella? sp. undet	r				
Prismopora triangulata White var	r		r		
Prismopora? sp. undet		r			
Other Bryozoa, branching types				a	
Brachiopoda:					
Derbya crassa (Meek and Hayden)	r				
Derbya crassa (Meek and Hayden), young only		r			
Derbya sp. undet., immature	r				
Chonetes (*Mesolobus*) *mesolobus* (Norwood and Pratten) var	?				
"*Productus*" (*Juresania*) *nebrascensis* Owen	c				
"*Productus*" (*Juresania*) sp. undet., young	r				
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten					?
"*Productus*" (*Linoproductus*) sp. undet	r	r			
Marginifera muricatina Dunbar and Condra					?
Marginifera muricatina missouriensis Girty	a	a	a		a
Wellerella? osagensis immatura Dunbar and Condra	r				
Dielasma bovidens (Morton)	r				
Spirifer opimus Hall var. A	c	vc	c		vc
Squamularia perplexa (McChesney)	c				
Squamularia sp. undet., young			r		
Punctospirifer kentuckyensis (Shumard)	c				
Hustedia mormoni (Marcou)	c	r	r		
Hustedia mormoni miseri (Mather)		r	c		
Composita sp. undet		?	r		
Cleiothyridina orbicularis (McChesney)	r				
Pelecypoda:					
Edmondia sp. undet			r		
Myalina sp. undet				r	

Fossil invertebrates collected from the Savanna sandstone—Continued

	7937, 7941	7936, 7942	7944, 7945	7939, 7940	7943
Pelecypoda—Continued.					
Schizodus meekanus Girty		r		r	
Deltopecten? occidentalis (Shumard), very young			r		
Deltopecten? sp. undet	r	?			
Streblopteria tenuilineata Meek and Worthen			r		
Limatulina? sp. undet	r				
Astartella concentrica? Conrad	r				
Gastropoda:					
Euphemites? sp. undet., molds				r	
Bucanopsis? sp. undet., molds				r	
Pharkidonotus? sp. undet	r				

7937, 7941. Thin limy shale near base.
7936, 7942. Thin limestone 150 to 180 feet below top.
7944, 7945. Limy shale above limestone of 7936.
7939, 7940. Shaly limestone 138 to 168 feet below top.
7943. Sandy limestone 80 to 100 feet below top.

COLLECTIONS FROM THE BOGGY SHALE

More collections were obtained from the Boggy shale than from any other formation, but the individual collections are, in the main, smaller than those from either the underlying or overlying formation. The fossils in the Boggy shale collections indicate a variety of ecologic conditions. About half of them suggest normal marine environments; some suggest very quiet waters and possibly waters in which whether owing to brackish waters or to unfavorable bottom conditions and perhaps a reducing environment, normal marine forms could not thrive; other collections are made up definitely of fresh-water forms.

Fossils were obtained from a considerable variety of types of rock. Many collections but relatively few individuals were obtained from black fissile shales, which occur in most places immediately above the Secor coal. At some localities these shales contain pyrite, and at one locality some of the fossils in them are partly preserved in pyrite. The presence and rather good preservation in rocks of this lithologic type of the fine markings on great numbers of thin pelecypod shells, such as those of "*Aviculipecten*" *herzeri* Meek, suggest to me deposition of these black shales in quiet waters. The faunal associations in the black shales at the place where the fossils are preserved in pyrite are such as to indicate unfavorable conditions for marine life. Significant in the collections from the black shales here are common Lingulas, "*Aviculipecten*" *herzeri*, *Aviculipecten* cf. *A. whitei* and *Aviculipecten rectilaterarius*, *Crurithyris planoconvexa*, and many small gastropods. The absence of larger individuals of gastropods suggests a depauperizing influence. I have found both of the last two *Aviculipectens* mentioned above associated with plants either in this district or in other places in the Midcontinent region. *Crurithyris* seems to be a genus that is capable of withstanding conditions unfavorable for many other normally marine genera. The preference of *Lingula* for muddy bottoms and brackish water is well known.

The presence, though doubtfully recognized, of a chonetid and a *Marginifera* in the same beds suggests that more or less normal marine waters were not far distant and may have invaded parts of the Quinton-Scipio district for brief intervals soon after deposition of the Secor coal. This suggestion is strengthened by a small collection from black shales which are in part coaly at another locality (8029). This collection contains pelecypods which I believe are more than likely marine.

At a locality in sec. 10, T. 6 N., R. 15 E., the black shales immediately above the Secor coal have a faunule consisting of *Naiadites elongata*, a fresh- or brackish-water form; *Aviculipecten* cf. *A. whitei;* and fern pinnules. This is certainly a nonmarine faunule. Most of the other collections obtained immediately above the Secor coal suggest brackish or nonmarine waters.

Blue-gray shales 40 to 50 feet or more above the Secor coal contain what I would call a normal marine fauna; but included in the collections from them are two of the *Aviculipectens* mentioned above. If my interpretations are correct, the species of *Aviculipecten* mentioned have a considerable ecologic range.

Most of the limestones or highly calcareous shales of the Boggy have marine faunas, consisting mainly of brachiopods but containing a relatively large number of gastropods and few pelecypods. With one or two exceptions, the fossil-bearing limestones are restricted to the lower half of the Boggy, but none occur below the Secor coal.

Most of the Boggy sandstones have meager faunas, and only a few of them are definitely marine. The only sandstone from which I have studied a collection that I would call undoubtedly marine lies about 350 feet below the top of the Boggy. The collection from it consists largely of *Allerisma terminale.* As plant remains were obtained in other beds in the same sandstone group, I believe that this sandstone is in part marine and in part continental. The invertebrate faunas of all the other Boggy sandstones are either not certainly diagnostic of continental or marine origin or are definitely nonmarine. As plant collections from most of them suggest they were at least in part nonmarine, I am inclined to believe that most of the Boggy sandstones are of nonmarine origin, though a few of them may contain marine sediments. The presence of many individuals of a form which I am tentatively identifying as *Naiadites elongata* Dawson, a fresh-water pelecypod, and the absence of any marine species in a thin brown very limy sandstone or sandy limestone near the top of the Boggy strongly suggest that this sandstone is of continental origin. Because no marine fossils were obtained above a horizon about 350 feet below the top of the Boggy and plants and nonmarine invertebrates were obtained in two or three zones above this horizon, I believe it not unlikely that the upper part of the Boggy in the Quinton-Scipio district is all nonmarine. The absence of marine fossils may be due, however, merely to the lack of exposures of marine beds, because marine fossils have been found in the upper Boggy elsewhere.[26]

Collections were made from eight zones in the Boggy shale. The lowest zone is immediately above the Secor coal, where black shales, in part fissile, were the source of several collections. The zone next above this one is a bluish-gray marine clay shale above a local coal and about 30 to 50 feet above the Secor coal. A few feet above this zone and in the same shale body is a thin nodular bed of tan, very ferruginous and very calcareous shale or ironstone, which is the third fossilferous zone of the Boggy. Above it is a fossiliferous zone estimated to be 200 to 250 feet above the Secor coal. Collections from three widely separated localities are grouped in this one zone, but in all probability they are not from the same bed. Two of them came from limestones known to be above coals. The other came from a nodular brownish-gray fine-grained limestone 3 to 4 inches thick, which is in part oolitic. This limestone contains only macerated shell fragments and small gastropods. The collection from this limestone was obtained at a more southwesterly locality than those from which came the other two collections, which contain normal marine species, and I am inclined to believe that it represents a local limestone that had a different sedimentary environment and perhaps is at a slightly different horizon from that of the limestone which yielded the other two collections.

The fifth fossiliferous zone in the Boggy is a noncalcareous micaceous green siltstone which occurs in a sandstone unit estimated to be from 600 to 800 feet above the Secor coal. The sixth zone is a thin yellow sandstone about 350 feet below the top of the Boggy and about 200 to 400 feet above the fifth zone. It yielded one invertebrate fossil collection consisting entirely of small individuals of *Allerisma terminale* Hall. The seventh zone is a thin brown, very limy sandstone or sandy limestone about 200 feet below the top of the Boggy. One collection was obtained from it, consisting largely of *Naiadites elongata* Dawson. The highest fossil zone in the Boggy is a sandstone within 40 to 60 feet of the top of the formation.

The species collected from the various zones in the Boggy shale are listed by zones and collection numbers in the following table. Comparisons between the fauna of the Boggy and the faunas of other formations in the Quinto-Scipio district, age determinations, and correlations are discussed on pages 182–189.

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[26] Morgan, G. D., op. cit., pp. 81-83. Hendricks, T. A., Geology and coal resources of the McAlester district, Okla.: Geol. Survey Bull. 874-A, pp. 23-24, 1937.

Fossil invertebrates collected from the Boggy shale

	8028	8029	8030	8031	8032, 8035, 8036	8033	8046	8034, 8045	8027	8025, 8026	8040	8043	8044	8037	8039	8038
Anthozoa:																
Lophophyllum profundum Edwards and Haime											c					
Vermes:																
Worm markings																a
Pelmatozoa:																
Crinoid columnals										c						
Brachiopoda:																
Lingula carbonaria Shumard													?			
Lingula? sp. undet					c								r			
Derbya crassa (Meek and Hayden), young only										c						
Chonetes (*Mesolobus*) *mesolobus* (Norwood and Pratten)					?				r	vc						
Chonetes? sp. undet								r								
Marginifera muricatina Dunbar and Condra					r				?	a	vc					
Marginifera sp. undet., young							?	r								
Spirifer sp. undet., fragments											r					
Crurithyris planoconvexa (Shumard)					c											
Crurithyris? sp. undet							?									
Hustedia mormoni (Marcou)											r					
Pelecypoda:																
Clinopistha radiata levis Meek and Worthen								r								
Edmondia sp. undet								?								
Leda? sp. undet		r						r								
Parallelodon cf. *P. obsoletus* (Meek)																
Parallelodon "tenuistriatus" (Meek and Worthen)										r						
Parallelodon sp. undet								r								
Pteria? sp. undet		r						r								
Myalina sp. undet													r			
Naiadites? elongata Dawson	c														a	
"Aviculipecten" herzeri Meek			c		vc			c								
Aviculipecten cf. *A. pellucidus* Meek and Worthen					?											
Aviculipecten rectilaterarius (Cox)				r		r										
Aviculipecten cf. *A. whitei* Meek	r							?								
Aviculipecten whitei Meek var					r											
Deltopecten? occidentalis (Shumard) var		r														
Euchondria? neglecta (Geinitz)			r		r		?									
Limatula? fasciculata Girty					c											
Allerisma terminale Hall														vc		
Pleurophorus? sp. undet							?									
Astartella? concentrica Conrad										r						
Other pelecypods															c	

Gastropoda:																
Bellerophon? sp. undet., internal molds									r				c			
Patellostium sp. undet., molds		r			r											
Euphemites? carbonarius (Cox)					r					r						
Pharkidonotus? percarinatus (Conrad)										c						
Phanerotrema cf. *P. grayvillense* (Norwood and Pratten)										r						
Phanerotrema sp. undet									r							
Naticopsis? sp. undet										r						
Pseudozygopleura sp. undet											r					
Soleniscus (*Macrochilina*) *brevis* White		r														
Trachydoma? sp. undet		r														
Other gastropods, mostly small individuals					c		c		c			c				

8028, 8029, 8030, 8031, 8032, 8035, 8036, 8033, 8046. Shales immediately above Secor coal.
8034, 8045. Shale 30 to 50 feet above Secor coal.
8027. Ferruginous bed 36 to 56 feet above Secor coal.
8025, 8026, 8040, 8043. Limestone or calcareous shale 200 to 250 feet above Secor coal.
8044. Siltstone 600 to 800 feet above Secor coal.
8037. Sandstone 350 feet below top and about 1,000 feet above Secor coal.
8039. Sandstone about 200 feet below top.
8038. Sandstone 40 to 60 feet below top.

COLLECTIONS FROM THE THURMAN SANDSTONE

The collections from the Thurman sandstone came from sandstones, sandy shales, and nodular ironstone beds in shales. In contrast to the small collections from the sandstones of the Boggy shale, they are large and consist mainly of marine species. Pelecypods are by far the most abundant, both in individuals and in species, but a few brachiopod species are represented by many individuals. Most of the few gastropods are internal molds that do not preserve the external ornamentation and are therefore undeterminable. Many of the pelecypods are also internal molds, but many also are external molds. Fortunately, a large proportion of those represented only by internal molds belong to genera in which species are so described that they can be recognized from internal molds, if the molds are fairly complete and show the dentition.

The most common pelecypods in the Thurman belong to the genera *Solenomya, Leda, Schizodus, Streblopteria,* and *Pleurophorus.* The brachiopod species represented by considerable numbers of individuals are *Chonetes* (*Mesolobus*) *mesolobus,* "*Productus*" (*Linoproductus*) *prattenianus,* and *Marginifera muricatina.*

At the places where collections were made from the sandstones in the Thurman the beds are abundantly fossiliferous, and many pelecypod individuals can be obtained from small pieces of sandstone.

Rarely are fossils seen on the surfaces of the beds. Although fossils are abundant at the localities where the collections were made, they were not obtained at many localities. This may be due to the lack of intensive search for fossils in many places, or the pelecypods may be "spotty" in occurrence.

The collections from the nodular ironstones came from thin yellow-brown nodular ferruginous shales or ironstones in shale intervals.

Six fossil zones are represented by the collections from the Thurman sandstone. The lowest is a bluish-gray to greenish-gray shale that weathers yellow brown. It is about 30 feet above the base of the Thurman. The second zone is about 65 feet above the base of the formation. It is a medium-grained yellow-brown to slightly reddish-brown friable sandstone. Individuals of three species of *Schizodus* are very abundant in it. Fossil plants were obtained from this same sandstone body but not from the same bed. The third zone is a darker-brown sandstone, about 130 feet above the base of the Thurman. Individuals of species of *Schizodus* are the most common in the collections from this zone, but "*Productus*" (*Linoproductus*) *prattenianus* is represented by many individuals. The fourth zone, which is about 175 feet above the base of the Thurman, consists of a light-tan sandstone. Ledas, Solenomyas, and young individuals of *Pleurophorus subcostatus* are the most abundant forms in it. The fifth zone, about 190 feet above the base of the Thurman, is a medium-to fine-grained tan or greenish-tan sandstone that weathers to a medium to dark brown. The most abundant species in the collection from this zone are *Solenomorpha solenoides* and a *Streblopteria* that is probably an undescribed species. Ledas and a gastropod that is probably a *Goniasma* are also common. The sixth zone is about 40 feet below the top of the Thurman and about 105 feet above the fifth zone. The collections from this zone came from thin brown nodular ferruginous shales or ironstones in shaly beds. The two collections may have come from the same bed, but it is more likely that they came from separate beds that are not far apart stratigraphically. The most abundant fossils in this zone are brachiopods. Gastropods are fairly common, and pelecypods are rare. The common brachiopod species are *Marginifera muricatina* and young individuals of a species that is probably *Lingula carbonaria.* One specimen questionably identified as *Chonetes* (*Mesolobus*) *mesolobus* also occurs in this zone.

The species collected in the Thurman sandstone are listed by zones and collection numbers in the following table. Comparisons between the fauna of the Thurman and the faunas of other formations in the area, age determinations, and correlations are discussed on pages 182–189.

Fossil invertebrates collected from the Thurman sandstone

	8050	8051	8047	8061	8054	8048	8049
Brachiopoda:							
Lingula carbonaria Shumard				c			
Lingula carbonaria Shumard, young only						c	
Chonetes granulifer Owen	?	c					
Chonetes (*Mesolobus*) *mesolobus* (Norwood and Pratten)	vc	r				?	
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten			vc				
"*Productus*" (*Linoproductus*) sp. undet.	r	r					
Marginifera muricatina Dunbar and Condra						vc	
Pelecypoda:							
Solenomya n. sp.? A				vc			
Solenomya n. sp.? B				r			
Solenomorpha solenoides (Geinitz)					a		
Edmondia ovata Meek and Worthen					r		
Edmondia n. sp. A, aff. *E. reflexa* Girty, 1899					r		
"*Nucula*" sp. undet.						r	
Anthraconeilo sp. undet.						?	
Leda bellistriata Stevens var. near *L. arata*				a	vc		
Leda bellistriata Stevens	r					r	
Leda? sp. undet.				r			
Myalina perniformis Cox		?					
Myalina perniformis Cox var.				c			
Myalina swallovi McChesney		c				?	
Schizodus affinis Herrick		vc	vc				
Schizodus meekanus Girty		c	c				
Schizodus telliniformis Girty		vc	c				
"*Aviculipecten*" *herzeri* Meek						?	
Deltopecten occidentalis (Shumard)					?		
Deltopecten? occidentalis (Shumard), young only	r						
Deltopecten? sp. undet.			r				
Streblopteria? n. sp.? aff. *S. similis* Walcott					a		
Streblopteria tenuilineata Meek and Worthen	r						
Lima retifera Shumard						?	
Allerisma terminale Hall					r		
Sedgwickia? n. sp.?		r					

Fossil invertebrates collected from the Thurman sandstone—Continued

	8050	8051	8047	8061	8054	8048	8049
Pelecypoda—Continued.							
Pleurophorus subcostatus Meek and Worthen, young				a			
Pleurophorus taffi Girty			c				
Pleurophorus? sp. undet				r			
Gastropoda:							
Bellerophon? sp. undet., internal molds			?			?	
Patellostium sp. undet., molds		r	?				
Euphemites? sp. undet., molds			?			?	r
Bucanopsis? sp. undet., molds		?		r			
Goniasma? sp. undet			r		c		
Phanerotrema sp. undet						c	
Naticopsis? sp. undet			r			?	
Meekospira? sp. undet						r	

8050. Sandy shale 30 feet above base.
8051. Sandstone 65 feet above base.
8047. Sandstone about 135 feet above base.
8061. Sandstone about 175 feet above base.
8054. Sandstone about 190 feet above base.
8048, 8049. Ferruginous bed about 40 feet below top.

COLLECTIONS FROM THE STUART SHALE

Only four collections were obtained from the Stuart shale, but more could have been made had time been available. These collections show that the fauna of the Stuart consists predominantly of marine pelecypods. Brachiopods, though not represented by so many species or individuals as the pelecypods, are not uncommon, and two species are represented by many individuals. Gastropods are rare, and crinoids, corals, and most of the other classes of fossils have not been found. One very fragmentary cephalopod, which is probably a *Coloceras*, was collected from a bed near the base of the Stuart.

Of the pelecypods, the genera *Solenomya*, *Deltopecten*, *Myalina*, and *Pleurophorus* are most abundantly represented, either in species or in individuals of one or more species. The most common brachiopods are "*Productus*" (*Linoproductus*) *prattenianus* and "*Productus*" (*Juresania*) *nebrascensis*. The brachiopods are common only in the ferruginous beds. The sandstone beds contain little other than pelecypods, which are very abundant in some beds. Several gastropods are present, though rare, in one collection from a sandstone bed. In the main, the thin sandstone beds yield the fossils, whereas the thicker beds, most of which are of coarser sands and many of which are within a few feet of the thin beds, may be barren.

The four Stuart collections were obtained from four different zones. The lowest zone is a very ferruginous yellow-brown nodular bed in shale, from which fossils weather out easily. The zone next above is also in a very ferruginous thin nodular bed which occurs in a section of shales. It is about 106 feet above the base of the Stuart. It contains many individuals of "*Productus*" (*Linoproductus*) *prattenianus* and "*Productus*" (*Juresania*) *nebrascensis*. Three or four other brachiopod species are present, as are a few pelecypods. The collection from this zone came from a roadside ditch north of an isolated hill in the western part of the Quinton-Scipio district, in sec. 30, T. 7 N., R. 13 E. The two higher zones in the Stuart are in sandstone. One of these is about 145 feet above the base of the formation, in a thin tan to greenish-yellow sandstone. On split slabs the sandstone is seen to be almost entirely composed of pelecypod molds, together with a few gastropods. The most common species are *Deltopecten occidentalis*, a new species of *Solenomya*, and a form that is either a new variety of *Myalina pernaformis* or a new species. The genus *Pleurophorus* is represented by many individuals belonging probably to two species. The highest zone is about 175 feet above the base of the Stuart and therefore probably about 160 feet below the top. It is a very light tan to yellowish-gray sandstone. As in the sandstone below, the fossils are mostly pelecypods, but they are not so numerous either in species or in individuals as in the lower zone. *Deltopecten occidentalis* and the new variety of *Myalina pernaformis* are the only common forms.

The species collected in the Stuart shale are listed by zones and by collection numbers in the following table. Comparisons between the fauna of the Stuart and the faunas of other formations in the Quinton-Scipio district and correlations are discussed on pages 182–189.

Fossil invertebrates collected from the Stuart shale

	8056	8060	8059	8057
Brachiopoda:				
Lingula carbonaria Shumard				r
Chonetes (Mesolobus) mesolobus (Norwood and Pratten)	r			
"*Productus*" (*Juresania*) *nebrascensis* Owen		c		
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten		vc		
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pretten, young only		r		
Marginifera muricatina Dunbar and Condra		r		
Crurithyris planoconvexa (Shumard)	r	r		
Pelecypoda:				
Solenomya n. sp.? B			vc	
Cardiomorpha? sp. undet			r	
Edmondia reflexa? Meek		r		
Edmondia n. sp. B	r			
"*Nucula*" *anodontoides* Meek	r			
Pteria cf. *P. ohioense* (Herrick)			r	
Myalina pernaformis Cox	r			
Myalina pernaformis Cox var			vc	c
Schizodus affinis Herrick			r	
Deltopecten occidentalis (Shumard)		r	a	vc
Deltopecten? occidentalis (Shumard), young only				r
Modiola subelliptica Meek	r		r	
Allerisma n. sp.?, small form		r		
Sedgwickia? sp. undet			r	
Pleurophorus angulatus Meek and Worthen			?	
Pleurophorus subcostatus Meek and Worthen			c	
Pleurophorus subcostatus Meek and Worthen, young				r
Pleurophorus? sp. undet			c	
Gastropoda:				
Bellerophon? sp. undet., internal molds			r	
Patellostium sp. undet., molds			r	
Pharkidonotus? sp. undet			r	
Goniasma lasallensis (Worthen)			?	
Goniasma? sp. undet			r	
Cephalopoda:				
Coloceras? sp. undet., fragments	r			

8056. Ferruginous zone 50 feet above base.
8060. Ferruginous zone 106 feet above base.
8059. Sandstone 145 feet above base.
8057. Sandstone 175 feet above base.

COMPARISONS OF FAUNAS

Some interesting conclusions may be drawn concerning the relations of the faunas of the several Carboniferous formations exposed in the district, provided the writers' collections are sufficient in number and in stratigraphic and geographic spacing to be representative. Owing to the large number of types of sedimentary and faunal facies in the area, however, it is necessary to weigh all stratigraphic inferences drawn from the distribution of the fossils against possible facies influences before the conclusions can be relied upon. For this reason and also because, if useful at all, the paleontologic conclusions will be most useful in distinguishing between stratigraphically contiguous formations, the following comparisons are made between similar lithologic units in such formations. Even though the units compared are alike in lithology, there is of course no assurance that like environmental conditions existed during their formation. Moreover, the recurrence of like environmental conditions would not of necessity bring back into any one area all the species that may have been there previously or that existed in nearby areas at the time of the recurrence. Despite these qualifications, comparisons between the faunas of like lithologic units are probably more significant than comparisons between the faunas of unlike units.

The invertebrate fossil-bearing beds in the Savanna sandstone in the Quinton-Scipio district are all thin limestones or calcareous shales. With a single exception, the faunules consist of great numbers of brachiopods, largely *Marginifera muricatina missouriensis* and *Spirifer opimus* var. Bryozoa are not uncommon and in one collection are abundant. *Prismopora* occurs at two localities, at one of which there is a variety close to a Morrow species. Crinoid stems and plates are common in at least one zone. *Chonetes* (*Mesolobus*) *mesolobus* and the normal variety of *Marginifera muricatina* are rare, if present at all. *Hustedia mormoni miseri*, another Morrow form, occurs in two of the limestones. Pelecypods and gastropods are rare.

All the collections from the thin limestones and calcareous shales of the Boggy formation were obtained above the Secor coal. Some of these limestones are almost devoid of fossils. One partly oolitic limestone contains only small gastropods. Another sandy limestone or limy sandstone is almost certainly of fresh-water origin. It contains only *Naiadites elongata* and unidentifiable pelecypods. The more fossiliferous limestones, like the limestones of the Savanna, contain brachiopod faunas, but the abundant species are not the same as the abundant species in the Savanna limestones, and some of the Savanna species do not extend into the limestones of the Boggy. These Savanna species that were not found in the Boggy include *Marginifera muricatina missouriensis*, *Hustedia mormoni miseri*, *Wellerella osagensis immatura*, and *Spirifer opimus* var. A. Also included in the Savanna is the bryozoan *Prismopora triangulata* var. Forms that may be the same as the last three just named are listed from beds above the Savanna in nearby areas, however.[27] *Marginifera muricatina*, *Chonetes* (*Mesolobus*) *mesolobus*, and *Derbya crassa* are the most common forms in the limestones of the Boggy formation. No limestone similar to the *Campophyllum*-bearing limestones of the upper Boggy of the Stonewall area [28] was seen in the Quinton-Scipio district.

No fossils other than plants were collected from the sandstones, the noncalcareous shales, or the ironstones of the Savanna in the Quinton-Scipio district. That the Savanna sandstones are, in part at least, marine and fossiliferous is attested by the presence of marine faunules in them in nearby regions. A comparison of faunal lists [29] shows that the Savanna sandstones of nearby regions are more fossiliferous and probably have a greater proportion of marine sediments than the Boggy sandstones of the Quinton-Scipio district. One or more large faunules have also been collected from the Savanna in nearby areas, from the ironstones in shale.[30] Ironstones occur sparingly in the Boggy, and their faunas are small.

Our collections from the sandstone beds of the Thurman formation show striking differences from our collections from the sandstones of the Boggy. They strongly indicate that the Thurman sandstones are more fossiliferous and have a greater proportion of marine sediments than the Boggy sandstones. The Thurman sandstones, where fossiliferous, contain abundant pelecypods. These belong mainly to marine genera, such as *Edmondia*, *Solenomya*, *Leda*, *Schizodus*, and *Streblopteria*, all of which are absent from our collections from the Boggy sandstones. Some of these genera have, however, been reported from the Boggy in the McAlester district,[31] but they may not have come from sandstones. No one of these genera is confined to the Thurman. As representatives of all these genera occur both above the Thurman and below the Boggy, any of them may be found in the Boggy on further collecting. The presence of this assemblage in the Thurman, even though it may be due merely to a facies condition, is significant locally, because the assemblage has not been found by us or reported in the literature from the sandstones of the Boggy. The table showing the range of species in the four formations from which fossils were obtained in the Quinton-Scipio district (pp. 186–187) shows at once the dissimilarities between the pelecypod assemblages of the Boggy and Thurman formations, but some of the Boggy pelecypods did not come from sandstones.

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[27] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 1, The McAlester district: Geol. Survey Bull. 874-A, p. 24, 1937. Morgan, G. D., op. cit., pp. 82, 88.

[28] Morgan, G. D., op. cit., p. 78.

[29] Hendricks, T. A., op. cit., p. 20–21. Morgan, G. D., op. cit., p. 76.

[30] Idem, p. 22.

[31] Idem, p. 24.

No collections were obtained in the Thurman from black fissile shales similar to those that occur above the Secor coal, in the Boggy formation, and none of the Aviculipectens that occur in these black shales occur in our collections from the Thurman or have been reported by others. The fresh-water *Naiadites* is also absent from the Thurman. The lack of collections from other shales in the Thurman may mean that the marine shales of the Thurman are less fossiliferous than the marine shales of the Boggy. No fossil-bearing limestones or very calcareous shales like those that occur in the Boggy are known in the Thurman.

Ferruginous beds or nodules in shales are the source of the collections from the uppermost zone of the Thurman. The faunas of these beds are larger and more varied than the faunas of the ferruginous beds of the Boggy, but I do not think that the differences are significant, because the ferruginous beds in both formations are thin, nodular, and lenticular, and it therefore seems likely that ferruginous beds in the Boggy that have considerable faunas may have been overlooked.

The collections from the Stuart shale, like those from the Thurman sandstone, came from only two types of rocks—sandstones and ferruginous nodules and beds in shale. In the Stuart the ferruginous beds that yielded fossil collections are near the base of the formation, whereas in the Thurman the ferruginous beds from which collections were obtained are near the top of the formation. In both formations these beds have faunas in which the most common elements are brachiopods, but in both they also contain a few pelecypods and gastropods. The most common brachiopods in the Thurman collections made in the Quinton-Scipio district are *Lingula carbonaria* and *Marginifera muricatina*. The most common brachiopods in the Stuart are "*Productus*" (*Linoproductus*) *prattenianus* and "*Productus*" (*Juresania*) *nebrascensis*.

The faunas of the Stuart sandstones are not unlike those of the Thurman sandstones in general composition, but the genera *Schizodus* and *Leda* are not so abundantly represented in them, and Deltopectens and Myalinas are therefore relatively more important. *Solenomorpha solenoides*, an abundant species in one of our Thurman sandstone collections, was not found in the Stuart. Other species that occur in the sandstones of one formation do not occur in our collections from the sandstones of the other, but as many of these species are rare and long-ranging, their stratigraphic significance is probably slight.

STRATIGRAPHIC RANGE OF SIGNIFICANT SPECIES

If the collections from the Quinton-Scipio district alone were considered, it would appear that each of the four formations from which fossils were obtained had a distinctive fauna and that many species were restricted to one or two formations. When consideration is given to the fact that some of these formations have lithologic facies not represented in the others, doubt is cast on the reliability of these seeming species restrictions for correlation. When consideration is also given to published data on other and nearby areas, it is found that few of the species identified from the Quinton-Scipio district are sufficiently limited in stratigraphic range to be of widespread use in the identification of the different formations.

A few species or varieties, however, have relatively restricted ranges that have not yet been shown to be local or due to insufficient collecting. Prominent among these are *Marginifera muricatina missouriensis*, *Spirifer opimus* var. A, and *Hustedia mormoni miseri*. The first does not occur in our collections from any formation younger than the Savanna, and I have seen no published record of its occurrence above the Savanna. There are records of the occurrence, above the Savanna, of varieties of *Marginifera muricatina*, presumably distinct from the typical variety, but none is definitely referred to the variety *missouriensis*. *Spirifer opimus* is a lower Pennsylvanian species, and the variety here listed is restricted to the Savanna and Boggy formations. *Hustedia mormoni miseri* has not previously been found as high as the Savanna, but it is common in the Morrow group. A form here listed as *Prismopora triangulata* var. is close to a Morrow species. It is not known from formations above the Savanna. *Marginifera muricatina* and *Chonetes* (*Mesolobus*) *mesolobus* are in our collections much more abundant above the Savanna than in that formation, but as the relative abundance of the various forms is not given in many published lists, I do not know that this has been found to be true by other investigators.

Naiadites elongata seems to be restricted to the Boggy in this general region, but it is found in formations elsewhere that are probably younger. Some other pelecypods in the Boggy collections have not been found in any of the younger formations of the Quinton-Scipio district, but they also occur in formations elsewhere that are probably or certainly younger than the Boggy. Some of these may be found to be reliable locally as index fossils for beds of Boggy age. They include *Aviculipecten rectilaterarius*, *A. pellucidus*, and *A. whitei*. I believe that their limitation to the Boggy shale and older beds in the Quinton-Scipio and nearby areas is really more the result of facies limitations than of geologic age limitations.

Many of the pelecypods that appear in the stratigraphic column in the Quinton-Scipio district for the first time in the Thurman occur in formations undoubtedly older in other regions and so have little value as widespread age determinants.

The range of the various species in our collections in the formations exposed in the Quinton-Scipio district is given in the following table:

Fossil invertebrates collected in Quinton-Scipio district.

	Savanna sandstone	Boggy shale	Thurman sandstone	Stuart shale
Spongiae:				
Sponge? borings	×			
Anthozoa:				
Lophophyllum profundum Edwards and Haime	×	×		
Vermes:				
Worm markings		×		
Pelmatozoa:				
Crinoid columnals	×	×		
Hydreionocrinus acanthoporus (Meek and Worthen)	×			
Hydreionocrinus mucrospinus (McChesney)	×			
Bryozoa:				
Tabulipora? sp. undet	×			
Fenestella? sp. undet	×			
Prismopora triangulata White var	×			
Prismopora? sp. undet	×			
Other Bryozoa, branching types	×			
Brachiopoda:				
Lingula carbonaria Shumard		?	×	×
Lingula carbonaria Shumard, young only			×	
Lingula? sp. undet		×		
Derbya crassa (Meek and Hayden)	×			
Derbya crassa (Meek and Hayden), young only	×	×		
Derbya sp. undet., immature	×			
Chonetes granulifer Owen			×	
Chonetes (*Mesolobus*) *mesolobus* (Norwood and Pratten)		×	×	×
Chonetes (*Mesolobus*) *mesolobus* (Norwood and Pratten) var.	?			
Chonetes? sp. undet		×		
"*Productus*" (*Juresania*) *nebrascensis* Owen	×			×
"*Productus*" (*Juresania*) sp. undet., young	×			
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten	?		×	×
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten, young only				×
"*Productus*" (*Linoproductus*) sp. undet	×		×	
Marginifera muricatina Dunbar and Condra	?	×	×	×
Marginifera muricatina missouriensis Girty	×			
Marginifera sp. undet., young		×		
Wellerella? osagensis immatura Dunbar and Condra	×			
Dielasma bovidens (Morton)	×			
Spirifer opimus Hall, var. A	×			
Spirifer sp. undet., fragments		×		
Squamularia perplexa (McChesney)	×			
Squamularia sp. undet., young	×			
Crurithyris planoconvexa (Shumard)		×		×
Crurithyris? sp. undet		×		
Punctospirifer kentuckyensis (Shumard)	×			
Hustedia mormoni (Marcou)	×	×		
Hustedia mormoni miseri (Mather)	×			
Composita sp. undet	×			
Cleiothyridina orbicularis (McChesney)	×			
Pelecypoda:				
Solenomya n. sp.? A			×	
Solenomya n. sp.? B			×	×
Solenomorpha solenoides (Geinitz)			×	
Clinopistha radiata levis Meek and Worthen		×		
Cardiomorpha? sp. undet				×
Edmondia ovata Meek and Worthen			×	
Edmondia reflexa? Meek				×
Edmondia n. sp. A aff. *E. reflexa* Girty, 1899			×	
Edmondia n. sp. B				×
Edmondia sp. undet	×	?		
"*Nucula*" *anodontoides* Meek				×
"*Nucula*" sp. undet			×	
Anthraconeilo sp. undet			?	
Leda bellistriata Stevens			×	
Leda bellistriata Stevens, var. near *L. arata*			×	
Leda? sp. undet		×	×	
Parallelodon cf. *P. obsoletus* (Meek)		×		
Parallelodon "*tenuistriatus*" (Meek and Worthen)		×		
Parallelodon sp. undet		×		
Pteria cf. *P. ohioense* (Herrick)				×
Pteria? sp. undet		×		
Myalina perniformis Cox			?	×
Myalina perniformis Cox var			×	×
Myalina swallovi McChesney			×	
Myalina sp. undet	×	×		

Fossil invertebrates collected in Quinton-Scipio district—Continued

	Savanna sandstone	Boggy shale	Thurman sandstone	Stuart shale
Pelecypoda—Continued.				
Naiadites? elongata Dawson		×		
Schizodus affinis Herrick			×	×
Schizodus meekanus Girty	×		×	
Schizodus telliniformis Girty			×	
"*Aviculipecten*" *herzeri* Meek		×	?	
Aviculipecten cf. *A. pellucidus* Meek and Worthen		?		
Aviculipecten rectilaterarius (Cox)		×		
Aviculipecten cf. *A. whitei* Meek		×		
Aviculipecten whitei Meek var.		×		
Deltopecten occidentalis (Shumard)			?	×
Deltopecten? occidentalis (Shumard), young only	×		×	×
Deltopecten? occidentalis (Shumard) var.		×		
Deltopecten? sp. undet.	×		×	
Euchondria? neglecta (Geinitz)		×		
Streblopteria? n. sp.? aff. *S. similis* Walcott			×	
Streblopteria tenuilineata Meek and Worthen	×		×	
Lima retifera Shumard			?	
Limatula? fasciculata Girty		×		
Limatulina? sp. undet.	×			
Modiola subelliptica Meek				×
Allerisma terminale Hall		×	×	
Allerisma n. sp., small form				×
Sedgwickia? n. sp.?			×	
Sedgwickia? sp. undet.				×
Pleurophorus angulatus Meek and Worthen				?
Pleurophorus subcostatus Meek and Worthen				×
Pleurophorus subcostatus Meek and Worthen, young			×	×
Pleurophorus taffi Girty			×	
Pleurophorus? sp. undet.		×	×	×
Astartella concentrica? Conrad	×			
Astartella? cencentrica Conrad		×		
Other pelecypods		×		
Gastropoda:				
Bellerophon? sp. undet., internal molds		×	?	×
Patellostium sp. undet., molds		×	×	×
Euphemites? carbonarius (Cox)		×		
Euphemites? sp. undet., molds	×		×	
Bucanopsis? sp. undet., molds	×		×	
Pharkidonotus? percarinatus (Conrad)		×		
Pharkidonotus? sp. undet.	×			×
Goniasma lasallensis (Worthen)				?
Goniasma? sp. undet.			×	×
Phanerotrema cf. *P. grayvillense* (Norwood and Pratten)		×		
Phanerotrema sp. undet.		×	×	
Naticopsis? sp. undet.		×	×	
Pseudozygopleura sp. undet.		×		
Soleniscus (*Macrochilina*) *brevis* White		×		
Meekospira? sp. undet.			×	
Trachydoma? sp. undet.		×		
Other gastropods, mostly small individuals		×		
Cephalopodas:				
Coloceras? sp. undet., fragments				×

AGE ASSIGNMENT AND CORRELATIONS

The Pennsylvanian age of the formations bearing the collections here discussed is well established by their faunas and stratigraphic positions. Several species limit all the formations to the lower Pennsylvanian. These species, none of which occur above the Des Moines group in the northern Midcontinent region or above rocks of equivalent age elsewhere, are *Chonetes* (*Mesolobus*) *mesolobus*, *Marginifera muricatina*, *Marginifera muricatina missouriensis*, *Spirifer opimus*, *Prismopora triangulata*, and some pelecypods. All the formations here considered are of Des Moines age, as both the first and second of the species mentioned above occur in the Stuart shale, the highest formation from which collections were obtained.

Definite correlations of formations and zones in the Quinton-Scipio district with formations and zones in other regions are, however, much more difficult, if not impossible to make on the paleontologic data available, mainly because most of the species are long-ranging. However, some groups, such as the pelecypods and bryozoans, have not recently been carefully studied, and revisional studies may show that the species are more restricted than they now appear to be. Another deterrent to the correlation of formations is that some of the species included in the fossil lists of nearby areas have since been renamed or subdivided, and it is impossible now, without the study of collections, to determine the present-day species and varieties that are represented by the listed names. Still another obstacle to correlation is the occurrence of so many different lithologic and paleontologic facies, which no doubt are represented, at least in some parts of the formations, by wedges that may reasonably be supposed to be in different stratigraphic positions in the same formations in other areas. Another deterrent to the regional correlation of individual fossil zones and even formations is the fact that many of the zones of some of the formations in the Quinton-Scipio district are thin. Regional correlation by fossils of thin fossil zones is not to be expected unless evolution has proceeded at an unusually rapid rate, for otherwise these units of like lithology, stratigraphically near together, could not reasonably be expected to have distinctive faunas or, for that matter, distinctive species. Unless carefully checked by widespread collecting or widespread experience, the seeming limitation of one or more species to a single thin formation is not to be accepted without some doubt and is more frequently due to incomplete knowledge and collecting than to faunal distinctions. Local correlations are, however, often suggested by the relative abundance of certain long-ranging species in given beds, and these suggestions are certainly significant, if due allowance is made for possible facies influences and for the "spotty" occurrence characteristic of some classes of fossils. Relative abundance cannot, however, be safely used for long-distance correlation of Pennsylvanian rocks in the Midcontinent region.

A few forms in our collections suggest certain correlations that should be considered. For instance, *Marginifera muricatina missouriensis* is limited to the lower 100 to 200 feet of the Cherokee shale as exposed in Missouri and to the Bluejacket sandstone member or beds below it in southeastern Kansas. The highest occurrence of this variety in the Quinton-Scipio district is in the upper part of the Savanna formation. This limitation would suggest that the top of the Bluejacket sandstone in southeastern Kansas was equivalent to the top of the Savanna sandstone in the Quinton-Scipio district. Because *Marginifera muricatina missouriensis* is the only form suggesting so definite a correlation and because it is only a variety of a species and represents only one class of fossils, such a correlation would not be on very substantial grounds in any event. In addition, the lower part of the Boggy shale up to the Secor coal has not yielded marine fossils, and it is therefore quite possible that the zone within which *Marginifera muricatina missouriensis* occurs in marine beds in Kansas may be equivalent to some or all of the nonmarine beds of the lower part of the Boggy shale in the Quinton-Scipio district. Present knowledge of the distribution of *Marginifera muricatina missouriensis* accordingly suggests only that the top of the Bluejacket sandstone in southeastern Kansas is equivalent to some horizon below the Secor coal.

The Savanna is on substantial grounds believed to be no younger than the latest Cherokee of Missouri and Kansas. Such an age restriction is validated by the presence in it, in addition to *Marginifera muricatina missouriensis*, of *Spirifer opimus* Hall and is suggested by the presence of *Hustedia mormoni miseri* and *Prismopora triangulata* var.

The Cherokee age of the Boggy and perhaps of the Thurman also is suggested by the abundance of *Marginifera muricatina* and *Chonetes* (*Mesolobus*) *mesolobus* in these formations. There is nothing in our collections to fix the age of the Stuart more closely than from upper Cherokee to uppermost Des Moines. The abundance of *M. muricatina* in the Senora formation of the Stonewall quadrangle,[32] which overlies the Stuart, gives a slight suggestion that both the Senora and Stuart are also of Cherokee age.

REGISTER OF LOCALITIES

7936. Sans Bois quadrangle, about half a mile south and half a mile east from Quinton, along road on south line of sec. 36, T. 8 N., R. 18 E., roadside ditch on north side of road about 2,700 feet east of southwest corner of sec. 36, about halfway up a hill and about 30 feet west of and 2 feet above a pipe line. Savanna sandstone, thin limestone and weathered calcareous shale 150 to 180 feet below top.

7937. Sans Bois quadrangle, about 2 miles south and 1 mile east from Quinton, along Quinton-Wilburton road about 3,600 feet south and 100 feet east from northwest corner of sec. 7, T. 7 N., R. 19 E., and about half a mile southwest of a bridge over Sans Bois Creek, roadside ditch on east side of a curve to north of and below a hill. Savanna sandstone, thin calcareous zone in yellow-brown shales, within a few feet of base.

7939. Sans Bois quadrangle, same locality as 7936, except near crest of hill and about 15 feet above the pipe line. Savanna sandstone, 10-inch shaly limestone immediately above a 2-inch coaly streak and about 12 feet above the limestone of 7936.

7940. Sans Bois quadrangle, same locality and horizon as 7939.

7941. Sans Bois quadrangle, same locality and horizon as 7937.

7942. Sans Bois quadrangle, same locality and horizon as 7936.

7943. Sans Bois quadrangle, about half a mile southeast of Featherston, along section-line road between secs. 14 and 23, T. 7 N., R. 17 E., about 1,900 feet east

[32] Morgan, G. D., op. cit., p. 88.

of northwest corner of sec. 23. Savanna sandstone, 8-inch sandy limestone about 80 to 100 feet below top.

7944. Sans Bois quadrangle, same locality as 7936, except a few inches higher on hillside. Savanna sandstone, ferruginous and calcareous shales 2 to 8 inches above limestone of 7936.

7945. Sans Bois quadrangle, same locality and horizon as 7944.

8025. Sans Bois quadrangle, about 3½ miles north and 0.9 mile west from Russellville, coal mine about 900 feet south and 600 feet east from northwest corner of sec. 6, T. 8 N., R. 18 E. Boggy shale, very shaly limestone a few inches above a coal that is estimated to be 200 to 250 feet above Secor coal.

8026. Sans Bois quadrangle, same locality and horizon as 8025.

8027. Canadian quadrangle, about 1½ miles south and 3½ miles west from Blocker, along creek above a coal bed that has been mined and also above the sandstone that overlies the coal bed, about 700 feet north of the southwest corner of sec. 28, T. 7 N., R. 16 E. This creek is crossed by the main traveled road about a quarter of a mile east of the Lochmanese coal mine. Boggy shale, nodular beds of ironstone in black shale about 2 or 3 feet above a local coal that lies above a sandstone and 30 to 50 feet above the Secor coal.

8028. Canadian quadrangle, about 3 miles north and 2½ miles east from North McAlester coal slope mine, in SW¼ sec. 10, T. 6 N., R. 15 E., about 2,200 feet north and 1,700 feet east from southwest corner. Boggy shale, black shales immediately above Secor coal.

8029. Sans Bois quadrangle, about a quarter of a mile south of Russellville, strip pit about 650 feet north and 250 feet west from the southeast corner of sec. 19, T. 8 N., R. 18 E. Boggy shale, brownish and dark-gray shales immediately above Secor coal.

8030. McAlester quadrangle, about 9 miles east and 1 mile north from North McAlester, in an abandoned mine on a hillside about 2,000 feet west and 750 feet north from southeast corner of sec. 21, T. 6 N., R. 16 E. Boggy shale, shales about 3 feet above Secor coal.

8031. Canadian quadrangle, about 1 mile south of Blocker, in strip pit east of a house and 2,000 feet west and 1,800 feet south from northeast corner of sec. 25, T. 7 N., R. 16 E. Boggy shale, from float on coal dump, but probably from the black shale that occurs here immediately above the Secor coal.

8032. Canadian quadrangle, about 1½ miles south and 4 miles west from Blocker, in Lochmanese coal mine, about 1,300 feet west and 350 feet north from southeast corner of sec. 29, T. 7 N., R. 16 E. Boggy shale, black shales immediately above Secor coal.

8033. Canadian quadrangle, about 3½ miles south and 1 mile west from Featherston, in an old prospect pit about 2,100 feet north and 1,200 feet west from southeast corner of sec. 33, T. 7 N., R. 17 E. Boggy shale, black shales immediately above Secor coal.

8034. Canadian quadrangle, same locality as 8027. Boggy shale, gray clay shale immediately above to 3 feet above a local coal that is above a sandstone and is 30 to 50 feet above the Secor coal. This collection was obtained 1 foot or so below collection 8027.

8035. Canadian quadrangle, same locality and horizon as 8032.

8036. Canadian quadrangle, same locality and horizon as 8032 and 8035.

8037. Canadian quadrangle, about 8 miles south and 1 mile west from Thurman, small isolated elongated hill on east side of Bull Creek about 1,200 feet west and 750 feet north from southeast corner of sec. 36, T. 7 N., R. 13 E. Boggy shale, thin yellow sandstone about 350 feet below top.

8038. Canadian quadrangle, about 7 miles south and 3 miles west from Thurman and half a mile south and 2¼ miles east from Scipio store (which is about 1 mile south and half a mile west from mapped portion of Scipio on map of Canadian quadrangle), sandstone ledge exposed near top of a hill along an abandoned road about 2,000 feet west of northeast corner of sec. 34, T. 7 N., R. 13 E. Boggy shale, sandstone within 50 or 60 feet of top.

8039. Canadian quadrangle, about 1½ miles south and 1½ miles west from South Canadian, along a section-line road about 300 feet south of northwest corner of sec. 24, T. 8 N., R. 15 E. Boggy shale, calcareous sandstone about 1,200 to 1,400 feet above Secor coal.

8040. Sans Bois quadrangle, about 1½ miles south and 3 miles west from Russellville, in roadside ditch near but below top of a hill about 700 feet west of northeast corner of sec. 34, T. 8 N., R. 17 E. Boggy shale, pinkish-gray fine-grained limestone about 1 foot above a coal that is about 200 to 250 feet above the horizon of the top of the Secor coal.

8043. Canadian quadrangle, about 3½ miles west and 4½ miles south from Blocker, in feed lots about 100 yards S. 40° W. of a house and a few hundred feet west of a turn in a road in breaks above Gaines Creek flats, about 4,050 feet west of southeast corner of sec. 9, T. 6 N., R. 16 E. Boggy shale, nodular lead-gray argillaceous limestone that weathers yellow brown and is about 225 to 250 feet above the Secor coal.

8044. Canadian quadrangle, about 5 miles north and 2 miles east from North McAlester, along a road about 1,700 feet north and 2,300 feet west from southeast corner of sec. 34, T. 7 N., R. 15 E. Boggy shale, noncalcareous micaceous green siltstone in a sandstone unit, about 600 to 800 feet above the Secor coal.

8045. Canadian quadrangle, same locality and horizon as 8034.

8046. Canadian quadrangle, about 4 miles south and 3½ miles west from Blocker, on south side of a small stream, about 1,000 feet west of a country road about 2,750 feet west and 1,275 feet south from northwest corner of sec. 8, T. 6 N., R. 16 E. Boggy shale, shales above and within 15 inches of the top of the Secor coal in a 5-foot zone of black fissile shale that immediately overlies the Secor coal.

8047. Canadian quadrangle, about half a mile south and 1½ miles east from the present store at Scipio (which is about 1 mile south and half a mile west from the place where Scipio is shown on the topographic map), on west side of a hill, along a roadside ditch on north side of road that runs along the north line of sec. 33, T. 7 N., R. 13 E., 1,100 feet west of northeast corner of sec. 33. Thurman sandstone, yellow-brown sandstone about 130 feet above base.

8048. Canadian quadrangle, about a quarter mile north and half a mile east from present store at Scipio, about 28 to 30 feet below northwesternmost point on an isolated hill and near west section line of sec. 28, T. 7 N., R. 13 E., about 1,000 feet south of northwest corner. Thurman sandstone, thin yellow-brown nodular ferruginous bed in a shaly zone about 40 feet below top.

8049. Canadian quadrangle, slightly less than half a mile north of present store at Scipio, in roadside ditch south of and below an isolated hill, on east side of a north-south road that runs through the center of sec. 29, T. 7 N., R. 13 E., 400 feet south of the north line of sec. 29. Thurman sandstone, ironstone nodules from a zone about 40 feet below top.

8050. Canadian quadrangle, about 2½ miles north and 2½ miles east from present store at Scipio, along a roadside ditch on a hillside 30 to 40 feet above a draw and on north side of a road along north line of sec. 14, T. 7 N., R. 13 E., about 400 feet east of the northwest corner. Thurman sandstone, bluish-gray to greenish-gray shale, which weathers yellow brown, about 30 feet above base.

8051. Canadian quadrangle, about half a mile south and 1½ miles east from present store at Scipio, roadside ditch about 200 feet east and 5 feet below crest of a hill, across road from a house, on south side of a road along the north line of sec. 34, T. 7 N., R. 13 E., about 600 feet east of northeast corner. Thurman sandstone, medium-grained yellow-brown sandstone about 65 feet above base.

8054. Canadian quadrangle, about 3½ miles south and 2 miles west from Indianola, on highest point of a bald hill about 1,800 feet west and 1,150 feet north from southeast corner of sec. 3, T. 7 N., R. 14 E. Thurman sandstone, tan sandstone about 190 feet above base.

8056. Canadian quadrangle, about half a mile east and 5½ miles north from present store at Scipio, along an approximately north-south road 150 feet west and 600 feet north from northeast corner of sec. 32, T. 8 N., R. 13 E. Stuart shale, ferruginous nodular bed in shale zone about 50 feet above base.

8057. Canadian quadrangle, about half a mile east and 5 miles north from present store at Scipio, along road north of a school, on east line of sec. 32, T. 8 N., R. 13 E., about 2,500 feet south of northeast corner. Stuart shale, float of a tan saccharoidal sandstone that is probably from a sandstone about 175 feet above base.

8059. Canadian quadrangle, about 4¾ miles north and 1½ miles east from present store at Scipio, thin sandstone 20 to 30 feet below a thick sandstone that caps the southern part of a hill 700 feet west and 1,000 feet north from southeast corner of sec. 33, T. 8 N., R. 13 E. Stuart shale, thin tan sandstone about 145 feet above base.

8060. Canadian quadrangle, about half a mile north and 1½ miles west from present store at Scipio, roadside ditch north of an isolated hill and on south side of a road along north side of sec. 30, T. 7 N., R. 13 E., about 800 feet east of northwest corner. Stuart shale, ferruginous nodular zone in shale about 106 feet above base.

8061. Canadian quadrangle, about half a mile east and 3¼ miles north from present store at Scipio, at top of an isolated hill about 1,050 feet east and 1,500 feet south from northwest corner of sec. 9, T. 7 N., R. 13 E. Thurman sandstone, thin light-brown fine-grained sandstone about 175 feet above base.

STRUCTURE

In the southeastern half of the Quinton-Scipio district the rocks exposed at the surface are folded into anticlines that trend approximately east-northeast. These anticlines are separated by relatively broad, flat synclines. In the northern part of the district the rocks dip gently northwestward, but the regional dip is interrupted by a few broad open folds and terraces without distinct structural trend. In the western part of the district there is a broad, low anticline, whose axis extends only slightly east of north through the western part of Tps. 6, 7, and 8 N., R. 14 E. The structural features exhibited by the rocks exposed at the surface are represented on the structure-contour map (pl. 13) by the contour lines in black. Each of these lines is so drawn as to include all points of equal altitude above or below sea level on the horizon contoured, successive lines being drawn at intervals of 50 feet in altitude.

In the course of the field work it was early noted that observed dips on individual outcrops, even where they appeared to be reliable, were much in excess of the dips computed from altitudes determined at several places on traceable lithologic units. In the compilation of the structure map (and also of the stratigraphic sections) the computed dips were used in preference to observed outcrop dips. On the Flowery Mound anticline, chiefly in the northeastern part of T. 6 N., R.

15 E., the outcrops are rather narrow strike ridges, and it was impossible to obtain altitudes on the beds at widely spaced points. The contouring of the flanks of that anticline is therefore based largely on the most reliable dips observed.

In the eastern half of the area the Secor coal was selected as the horizon on which to draw contours representing the structural deformation of the surface rocks. The stratigraphic intervals to various sandstones outcropping above and below the coal are known with some accuracy, and the coal crops out in at least part of nine townships in the eastern part of the district. The contours were drawn wholly on the basis of dips and altitudes of the beds exposed at the surface.

The thickness of the portion of the Boggy shale exposed above the Secor coal in the northwestern part of T. 6 N., R. 15 E., is, however, considerably greater than the thickness exposed in Tps. 7 and 8 N., R. 16 E. (See columnar sections, pls. 14, 15, and 16.) To have contoured the western half of the district on the Secor coal would therefore have involved the application of convergence to the structure of the surface rocks, and the westward component of such convergence would have been based on unsatisfactory data. In addition, the application of convergence, the surface dips being low, would have produced a materially altered picture of the structural relations as seen in the surface rocks. For this reason it was thought desirable to contour the western half of the district on a higher horizon. For convenience an arbitrary horizon was chosen 650 feet below the base of a persistent sandstone in the Boggy shale, which is 400 to 600 feet below the base of the Thurman sandstone. This persistent sandstone in the Boggy crops out on both sides of Coal Creek in Tps. 6 and 7 N., R. 15 E., and between Gaines and Mathuldy Creeks in T. 7 N., R. 16 E. (See pl. 12.) The selection of the horizon 650 feet below the base of this sandstone brings the contours into numerical conformity with the contours on the Secor coal along the boundary between T. 8 N., R. 15 E., and T. 8 N., R. 16 E. To the south the large alluvial area along Gaines Creek separates the contours drawn on different horizons. In the southeastern part of T. 7 N., R. 15 E., and the northern part of T. 6 N., R. 15 E., the contours are drawn on the horizon of the Secor coal within the line of the outcrop of the coal around the Flowery Mound anticline. In secs. 5–8, T. 6 N., R. 15 E., the contours are drawn on the arbitrary horizon above described, and in the intervening portion of the township up the flanks of the Flowery Mound anticline as far as the line of the crop of the Secor coal, the contours are gradually adjusted to the lower datum, being thus strictly "strike lines" rather than structure contours.

During the progress of the mapping, offsetting of sandstone beds and other evidences of faulting were observed at many localities, but

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attempts to trace such faults were futile. Although the amounts of displacement were rarely determinable, the faults in the district are all believed to be small. The presence of faults inferred in the field at two localities—one in sec. 11, T. 6 N., R. 13 E., and the other in sec. 21, T. 8 N., R. 17 E.—was confirmed by the office study of the data on altitudes. These faults are shown on the areal map (pl. 12) and the structure-contour map (pl. 13). The larger one, that in sec. 21, T. 8 N., R. 17 E., has a throw of slightly more than 100 feet.

The east-northeastward-trending anticlines of the southeastern part of the district include the Enterprise, Kinta, Burning Springs, Flowery Mound, and Lake McAlester anticlines.

The Enterprise anticline enters the district near the center of the north line of T. 8 N., R. 18 E., and extends southwestward to a point near the center of the west line of that township. Although the axis cannot be accurately drawn farther to the west, the anticline appears to continue westward as a very broad plunging arch with a suggestion of northwestward trend. The Russellville syncline, so called from the post office of that name in the western part of sec. 20, T. 8 N., R. 18 E., roughly parallels it on the south.

The Kinta anticline enters the district in the northeast corner of T. 7 N., R. 18 E., and extends southwestward through that township and westward through the central part of T. 7 N., R. 17 E. The west end of the Kinta anticline is separated from the east end of the Flowery Mound anticline by a broad flat saddle, but the anticlinal axis appears to extend more directly into a northwestward-plunging nose, which in turn merges into a broad northward-plunging anticlinal fold. The Panther Mountain syncline, so named from Panther Mountain, in secs. 23 and 24, T. 7 N., R. 18 E., lies parallel to and about 2 miles south of the axis of the Kinta anticline.

The Burning Springs anticline, named by Hendricks,[33] extends east-northeastward from the McAlester district through the northern part of T. 6 N., R. 17 E.

The Flowery Mound anticline, so named from the school in sec. 2, T. 6 N., R. 15 E., extends east-northeastward through the northeastern part of T. 6 N., R. 15 E., into the southwestern part of T. 7 N., R. 16 E. Its eastern termination is separated by a broad flat saddle from the west end of the Kinta anticline and by a similar saddle from a nose plunging northwestward from the Burning Springs anticline.

The Talawanda syncline, named by Hendricks,[34] extends northeastward from the McAlester district into the northwestern part of T. 6 N., R. 16 E.

The axis of the Lake McAlester anticline extends slightly north of east through secs. 4 and 5, T. 6 N., R. 14 E.; secs. 33-36, T. 7 N.

[33] Hendricks, T. A., op. cit., p. 45.
[34] Idem, p. 45.

R. 14 E.; and sec. 31, T. 7 N., R. 15 E. Its eastern end is separated by a broad saddle from a nose plunging northwestward from the Flowery Mound anticline.

The steepness of the folding diminishes from east to west and from south to north. The five anticlines described have nevertheless a common habit or form. The crown of the anticline is broadly rounded for a width of about a mile, but on each flank the dips increase rather abruptly away from the axis. The dips are steeper on the north flank, but this belt of steep dips is narrow, and the beds appear to flatten out rather abruptly away from the anticlinal axis.

In general, the distance from the anticlinal axis to the synclinal axis on the north is greater than that to the synclinal axis to the south. This fact and the relative steepness of the north flanks result in a progressive decrease northward in the altitudes of the anticlinal crests. The synclines of the district are broad and shallow, and the precise location of their axes is difficult to determine.

The structural features described are clearly related to the Ouachita Mountain orogeny. In their east-northeast alinement and structural form they resemble the sharper and more highly compressed folds that lie to the south. In the western part of the Quinton-Scipio district, however, the principal structural feature has a trend only slightly east of north. This is the Lilypad Creek anticline, so named in this report from the small creek in the western part of T. 7 N., R. 14 E., which drains southward near the crest of part of the anticline. The east flank of this fold is somewhat steeper than the west flank. The highest part of the fold, on which there is a closure of more than 200 feet in the surface rocks, lies in sec. 6, T. 6 N., R. 14 E., in line with the westward prolongation of the Lake McAlester anticline. The anticline extends northward to the Canadian River, and the trend is apparently continued northward through McIntosh County by a fault extending somewhat east of north through R. 14 E. in that county.[35] This fault is downthrown to the east about 200 feet. The nearly northward trend of the Lilypad Creek anticline is duplicated farther east in the Quinton-Scipio district by an anticlinal nose that plunges northward from the west end of the Kinta anticline in Tps. 7 and 8 N., R. 16 E., and possibly by a sharp northward bend of the Russellville syncline in T. 8 N., R. 18 E. Although these features may possibly reflect the influence of a different system of folding superimposed upon the folds that are clearly related to the Ouachita orogeny, there is within the limits of the district nothing to show that they may not simply be a response to a component of stress present during the Ouachita folding.

The rocks exposed at the surface in the Quinton-Scipio district appear to have been folded during a single period of deformation. No

[35] Clark, R. W., Oil and gas in Oklahoma, McIntosh County: Oklahoma Geol. Survey Bull. 40, vol. 3, map 13, 1930.

change of dip at the contact between the Savanna sandstone and the Boggy shale, at the contact between the Boggy shale and the Thurman sandstone, or at any horizon within the Boggy shale was observed.

COAL

GENERAL FEATURES

Coal has been mined intermittently on a small scale in the Quinton-Scipio district since 1902 or earlier. Most of the coal that has found a commercial outlet has come from strip pits or small slope mines most favorably located near the Fort Smith & Western Railway. This railroad has at times consumed coal produced in this district, and considerable quantities have also been shipped out. The coal is a bituminous coal of good quality, but competition with thicker or more advantageously located coals in adjoining districts has, for the most part, been too keen to permit successful exploitation of the coal of this district except for short periods of time. A small amount of "dead coal", obtained chiefly from small strip pits, was sold to the smelter at Quinton while it was in operation. "Dead coal", the result of the action of weathering, has practically no fuel value, but it is used in smelting as a reducer of zinc oxide.[36] At present the coal of the district is used only locally.

The only coal bed of this district that has been mined commercially is the Secor coal, which lies 450 to 500 feet above the base of the Boggy shale. The outcrop of this coal is shown on plate 12. Other coals in the Boggy formation above and below the Secor coal have been prospected at various places but are apparently of minable thickness for only short distances. The outcrop of a coal above the Secor coal is shown in the eastern part of T. 8 N., R. 17 E., and in sec. 6, T. 8 N., R. 18 E. The outcrop of a coal below the Secor is shown in parts of Tps. 6 and 7 N., R. 16 E., and T. 6 N., R. 17 E. The thickness and distribution of coal in the Quinton-Scipio district are described by townships on the following pages. Natural exposures of the coal are rare, but it has been prospected extensively, and in many of the prospect pits the coal is partly or wholly exposed. Figure 9 shows sections of the Secor coal measured at localities indicated by the corresponding numbers on the map (pl. 12).

TOWNSHIP DESCRIPTIONS

T. 8 N., R. 18 E.

The Secor coal crops out extensively in the southern and eastern parts of T. 8 N., R. 18 E., and also in sec. 6 and the NW¼ sec. 5. In the NW¼ sec. 11 a small slope exposes, near the mouth, 18 inches of coal, with a shale roof and shale and sandstone floor, but the coal bed may be thicker, as it is described by residents as being 28 inches thick. In the NE¼ sec. 15 the coal has been mined at two small strip pits and from a small tunnel at locality 1, where there is exposed 24 inches

[36] Young, C. M., Kansas coal, pt. 1, Occurrence and production: Kansas Univ. Eng. Bull. 13, q. 111, 1925.

of coal with a shale parting half an inch thick. (See pl. 12 and fig. 9.) In the SE¼ sec. 15 there is only 20 inches of coal. In the southern part of sec. 23 the coal has been stripped on a larger scale than at the localities above mentioned. At locality 3 (pl. 19, *B*) there is 25 inches of coal, but there is also a parting of carbonaceous shale 7 inches thick. Localities 4 and 5, in the SE¼ sec. 23, are in the Charles Glenn strip pit, which has shipped out as much as 100 cars of coal a year but since 1920 has sold coal only to the smelter at Quinton and for local fuel. Another section of the coal in this pit is given on page 203, and a chemical analysis of the coal is recorded on page 202. The bed is described by Mr. Glenn as containing an upper bed of coal 18 inches thick, a dirt layer 8 inches thick, and a lower bed 8 inches thick. He also states that there is a coal bed 12 to 14 inches thick from 20 to 25 feet above the Secor coal and another bed 40 to 50 feet below it. The Barnes slope mine, in the northern part of sec. 25, has not been operated for many years, and no section of the coal was measured. The Garretson mine, in the SE¼ sec. 25, has been operated within the last decade and is reported to have produced 5,000 tons in 1924, most of which was shipped out of the district. The coal is reported to have consisted of an upper coal bed 18 to 24 inches thick, which in places was bony, a shale bed 4 to 12 inches thick, and a lower coal bed 8 to 10 inches thick. At two small slope mines in the southern part of sec. 26 and a strip pit in the NE¼ sec. 27 the coal was not accessible to measurement. At locality 6, in the NE¼ sec. 27, however, the upper part of the Secor coal is exposed in a strip pit and is 20 inches thick. The lower part of the bed is not exposed. In the SE¼ sec. 27, west of the road from Quinton to Enterprise, the Secor coal was completely exposed at an abandoned mine at locality 7 and was measured as 22 inches thick. This mine and the two to the south, known as the Miller (?) and Kimball mines, have not been operated for many years.

The Secor coal has been stripped at several localities in secs. 19, 29, and 30 for local use. At locality 8 the coal is not completely exposed but is more than 12 inches thick. A small pit from which the coal has been stripped for local use exposes 21 inches of coal at locality 9, in the SE¼ sec. 31. The base of a 6-inch coal bed lies 23 feet above the top of the Secor coal at this locality and thus corresponds in stratigraphic position with the thin bed above the Secor coal reported by Mr. Glenn in sec. 23.

The Secor coal has been stripped for local use at a small pit in the NE¼ sec. 6, where it is more than 10 inches thick. In the NW¼ sec. 6 a coal bed that lies about 200 feet stratigraphically above the Secor coal has been prospected and found to be only 10 inches thick.

T. 8 N., R. 17 E.

The Secor coal crops out in the eastern portion of T. 8 N., R. 17 E., around the westward-plunging end of the Enterprise anticline, but the outcrop is largely concealed by the alluvium and terrace deposits along Longtown Creek and its tributaries. In the NW¼ sec. 12 the coal has been exposed in a prospect pit from which some coal has been stripped. The coal ranges from 10 to 20 inches in thickness within a short distance and is overlain by black carbonaceous shale. A small prospect near Longtown Creek, in the western part of sec. 15, exposes the coal. It also has been stripped in two pits in the NE¼ sec. 26, and at one of these (locality 10) the bed is 26 inches thick (pl. 19, *A*).

About 200 feet above the Secor coal lies a coal bed that has been occasionally dug for local use from the bed of Lick Creek in the NW¼ sec. 27. The coal is reported to be 22 inches thick and is overlain by black shale, near the base of which is a fossiliferous limestone a few inches thick. Inasmuch as this limestone is exposed in the NE¼ sec. 34, the coal is inferred to be present in this vicinity also, probably nearly in the position shown on the map (pl. 12).

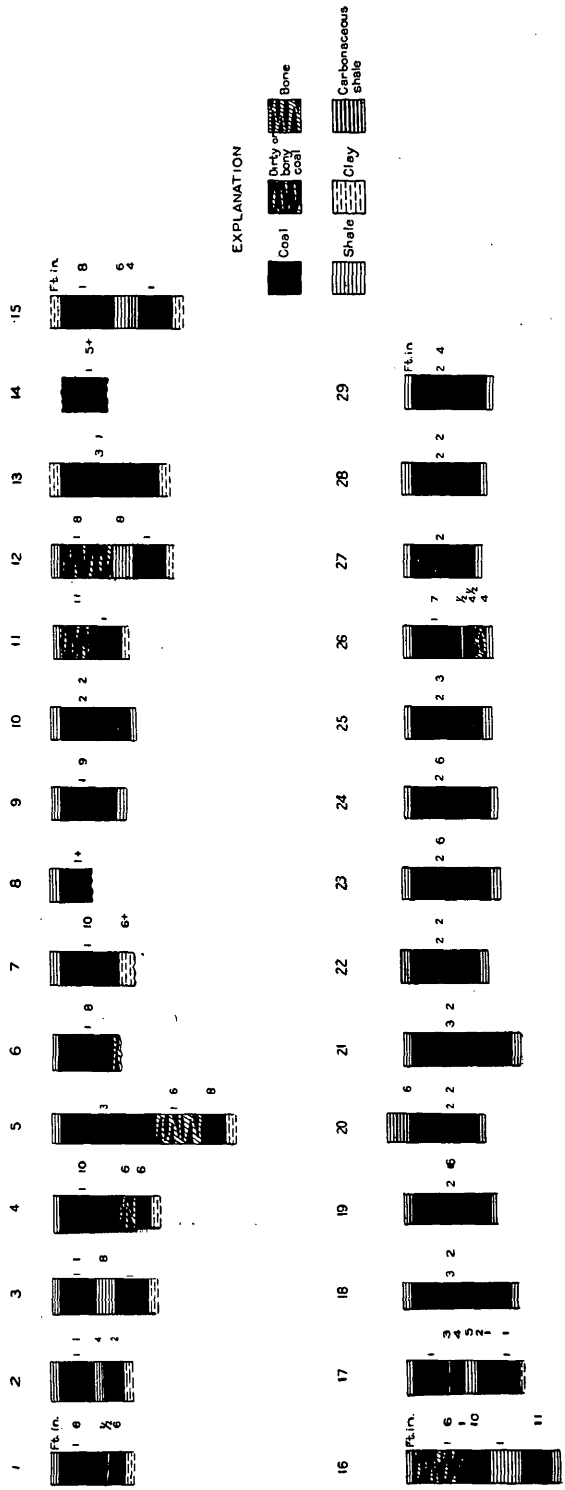

FIGURE 9.—Measured sections of the Secor coal.

NORTHERN PART OF T. 7 N., R. 18 E.

The Secor coal is known to crop out only in the northwest corner of T. 7 N., R. 18 E. At locality 11, in the NE¼ sec. 6, the coal has been exposed by prospecting and has a thickness of 23 inches. The Secor coal should crop out on the north slopes of Panther Mountain in secs. 21 to 24, but no natural exposures were seen, nor has it been exposed by prospecting, so far as could be learned. Its inferred position in sec. 23 is shown on plate 12.

T. 7 N., R. 17 E.

The Secor coal crops out in the northern half of T. 7 N., R. 17 E., along the north side of the Kinta anticline, in a line extending somewhat south of west from sec. 12 to sec. 18, and also in the southwest quarter of the township in a line partly encircling a large hill that lies in the western part of the Panther Mountain syncline. North of Featherston there are two slope mines, neither of which has been worked since 1922. The bed at the eastern slope (locality 12) is reported to have contained 32 inches of coal.

The strip pit in the west-central part of sec. 30, about a mile south of Blocker, was operated before 1910 by the Blocker Coal & Land Co., and some coal was shipped out. It is now used only for pick and shovel mining of coal for local use. At locality 13 the coal bed is 3 feet 1 inch thick. In the SE¼ sec. 29 (at locality 14) an old slope mine, now caved in, operated on a bed that was more than 17 inches thick. Neither the top nor the bottom of this bed is now exposed. In the SW¼ sec. 28 a mine variously known as the Brooks, Buchanan, or McHoma Coal Co. mine operated on a considerable scale for several years. It is reported to have produced about 8,000 tons of coal in 1925 and continued to ship coal until 1927. A section measured near the mouth of the abandoned slope (locality 15) shows 32 inches of coal in the bed. An analysis of the coal from this mine and a section measured 500 feet in from the mouth in 1926 are given on pages 202 and 203. In the northwest corner and the SE¼ sec. 33 there are other abandoned slopes. At the latter locality, where only a few tons has been taken out for local use (locality 16), the bed contains in all 39 inches of coal.

NORTHERN PART OF T. 6 N., R. 17 E.

In the part of T. 6 N., R. 17 E., that was mapped the Secor coal crops out in secs. 5 and 6, on the north flank of the Burning Springs anticline. At locality 17 a few tons of coal has been taken out of a small slope, which is now abandoned. A coal 50 to 75 feet below the Secor coal has been prospected in a small pit near the center of sec. 6. This lower bed has a thickness of at least 26 inches at this locality.

T. 7 N., R. 16 E.

The Secor coal in T. 7 N., R. 16 E., crops out near the town of Blocker, around the westward-plunging end of the Kinta anticline, in secs. 13, 14, 23, 25, and 26, and also in the southwestern part of the township, on the north flank of the Flowery Mound anticline.

In the SW¼ sec. 13, 1 mile north of Blocker, a slope mine opened by Pollock & Jerome and subsequently operated by the Tri-State Coal & Coke Co. has shipped out coal but is now abandoned. This is also known as the C. M. Lee mine. The thickness of the coal bed in this mine could not be determined, nor could it be measured in two abandoned slope mines in the southeastern part of sec. 14. In the NW¼ sec. 23 a large strip pit, called the Mason or Heisel pit, was operated by the Midway Coal Co. from 1922 to 1925 and produced coal that was sold to the Fort Smith & Western Railway and also shipped out of the district. This pit is not now in use. The Lee strip pit, in the NE¼ sec. 26, was operated intermittently from 1923 to 1927, selling coal chiefly to the railroad. A small slope was started in the pit, and one carload of coal was produced in 1933. At present the coal is used only locally. The coal is reported to run 32 inches in thickness and in places to reach 42 inches. The Leflore pit, in the eastern part of sec. 25, was opened in 1902 and operated intermittently until 1909, selling coal chiefly to the Fort Smith & Western Railway. The coal now finds only small local use.

At locality 18, in the SW¼ sec. 35, an abandoned tunnel in the Secor coal and outcrops nearby show that the coal is 38 inches thick. In the SW¼ sec. 27, at locality 19, the Secor coal is 30 inches thick in a small prospect pit. In the SE¼ sec. 29 the coal has been prospected at several localities, and in the Lochmanese mine, a small timbered slope, the coal is from 24 to 28 inches thick. This mine is now operating on a small scale and supplies some coal to Crowder and Quinton. An analysis of the coal and a section 30 feet in from the mouth of the slope, measured in 1926, are given on pages 202 and 203. At that time the mine was operated by the Crowder Coal Co. There is an abandoned slope mine on the Secor coal in the western part of sec. 31, but no information on the thickness of the coal at that place is available.

About 30 feet stratigraphically above the Secor coal, at localities 19 and 20 and elsewhere in the southern part of T. 7 N., R. 16 E., there is a coal bed that ranges from 10 to 13 inches in thickness. This thin coal is presumably to be correlated with the thin bed 20 to 25 feet above the Secor coal in T. 8 N., R. 18 E., above described.

About 150 feet below the Secor coal in secs. 32 and 33 a coal bed crops out at a few places. In the northeast corner of sec. 33 it has been stripped for local use and is reported to be 30 inches thick. Elsewhere it is believed to be only a thin bed.

NORTHERN PART OF T. 6 N., R. 16 E.

In the part of T. 6 N., R. 16 E., here mapped, the Secor coal crops out in secs. 1 and 2, dipping northward on the north flank of the Burning Springs anticline, and in secs. 3, 4, and 7 to 10, dipping westward and southward into the east end of the Talawanda syncline. The only exposure of the Secor coal in the northeast corner of this township is in the NW¼ sec. 2, where a small abandoned slope (locality 21) exposes from 3 feet to 3 feet 4 inches of coal. Another coal bed that lies 50 to 75 feet below the Secor coal is 1 foot thick in the NW¼ sec. 2. At locality 22, in the eastern part of sec. 3, some coal has been obtained for local use from a small prospect pit, and at locality 23 there is a natural exposure, where the coal bed is 30 inches thick.

T. 7 N., R. 15 E.

The Secor coal crops out in secs. 35 and 36, T. 7 N., R. 15 E., on the north flank of the Flowery Mound anticline, dipping about 20° NW. At locality 24, in sec. 36, it is 24 to 30 inches thick. At locality 25, in the southwest corner of sec. 36, and at locality 26, in the southeast corner of sec. 35, the coal is 27 or 28 inches thick in small slopes, now abandoned. About 25 feet above the Secor coal is a coal bed 10 inches thick, exposed north of locality 24, and about 200 feet above this coal a still higher coal bed is exposed in the NE¼ sec. 36, in the bluff of Coal Creek. This coal is from 9 to 12 inches thick and is succeeded by a thin sandstone, and that in turn by a limestone from 8 to 10 inches thick. About 25 feet stratigraphically higher is a coal bed 9 inches thick, with black shale above and below.

NORTHERN PART OF T. 6 N., R. 15 E.

In the part of T. 6 N., R. 15 E., here mapped, the Secor coal crops out in secs. 2, 3, 10, 11, and 12, where it encircles the southwestward-plunging end of the Flowery Mound anticline. In the SE¼ sec. 3, at locality 27, a small mine is now operating on a 24-inch bed of coal. A few hundred feet west of this mine and 20 feet stratigraphically above the Secor coal is a 13-inch coal, which is not utilized. In the SW¼ sec. 10 there are five small slope mines. In one of these, at locality 28, the coal is 26 inches thick, and at locality 29, where the coal is now being worked for local use, it is 28 inches thick. In the SW¼ sec. 12 the coal 20 feet above the Secor coal has been prospected but is not now exposed.

PHYSICAL AND CHEMICAL CHARACTERISTICS

The coal of the Quinton-Scipio district is a bituminous coal of good quality. It consists chiefly of alternating bands of bright or dull coal but contains some partings of charcoal, pyrite, clay, and bone. The coal is tough and blocky, so that a relatively small percentage of "fines" is produced. The amount of sulphur is rather high.

The quality of coal is most commonly represented by the proximate analysis, in which the percentages of volatile matter (combustible gases), fixed carbon (combustible solid matter), moisture, and ash (noncombustible materials) are determined. In addition, the heating value is given in calories or, more commonly, in British thermal units. The ultimate analysis of a coal is supplementary to the proximate analysis and shows the percentages of sulphur, hydrogen, carbon, nitrogen, and oxygen in the sample. Both forms of analysis are given for three conditions of the coal—as received, moisture-free, and moisture- and ash-free. In addition to the analysis of the coal, the softening temperature of the ash is frequently determined. This is the temperature at which the ash produced in burning the coal begins to melt and form a slag.

The available analyses of mine samples of coal from the Quinton-Scipio district are given in the following tables.

Chemical analyses of mine samples of Secor coal from the Quinton-Scipio district

[From Bur. Mines. Tech. Paper 411]

Mine and locality	Laboratory no.	Condition	Proximate				Ultimate						Heating value		Softening temperature (° F.)
			Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Air-drying loss	Calories	British thermal units	
1. Crowder Coal Co.'s mine (now Lochmanese mine), 7 miles southeast of Crowder in SE¼ sec. 29, T. 7 N., R 16 E. Sample collected by H. I. Smith and W. W. Fleming, U. S. Geol. Survey, July 29, 1926 (30 feet from surface).	A23798	As received	2.4	36.8	51.5	9.3	5.3	5.3	70.9	1.5	7.7		7,356	13,240	2,240
		Moisture-free		37.7	52.8	9.5	5.4	5.2	72.7	1.5	5.7		7,539	13,570	
		Moisture- and ash-free		41.7	58.3		6.0	5.7	80.3	1.7	6.3		8,333	15,000	
2. McHoma Coal Co.'s mine (also known as Brooks or Buchanan mine), 2 miles southwest of Featherston, in SW¼ sec. 28, T. 7 N., R. 17 E. Sample collected by H. I. Smith and W. W. Fleming, U. S. Geol. Survey, July 28, 1926 (500 feet from pit mouth).	A23795	As received	2.7	38.6	46.6	12.1	4.3	5.4	69.0	1.4	7.8	0.9	7,133	12,840	2,210
		Moisture-free		39.7	47.8	12.5	4.5	5.2	70.9	1.5	5.4		7,333	13,200	
		Moisture- and ash-free		45.3	54.7		5.1	6.0	81.0	1.7	6.2		8,378	15,080	
3. C. E. Glenn mine, 2 miles north of Quinton, in SE¼ sec. 23 and NE¼ sec. 26, T. 8 N., R. 18 E. Sample collected by H. I. Smith and W. W. Fleming, U. S. Geol. Survey, July 28, 1926 (30 feet undergound in strip pit).	A23797	As received	2.4	36.3	47.2	14.1	6.5	5.1	68.1	1.5	4.7	.7	6,983	12,570	2,270
		Moisture-free		37.2	48.4	14.4	6.7	5.0	69.7	1.5	2.7		7,156	12,880	
		Moisture-and ash-free		43.5	56.5		7.8	5.8	81.5	1.8	3.1		8,361	15,050	

NOTE.—Measured sections of the coal in these three mines are given on the following page. 1, Crowder Coal Co.'s mine; 2, McHoma Coal Co.'s mine; 3, C. E. Glenn, mine.

1. This bed was measured as described below:

	Ft.	in.
Coal		2½
Coal and "sulphur" (not included in sample)		¾
Coal	1	11
Thickness of bed	2	2¼
Thickness of sample	2	1½

2. This bed was measured as described below:

	Ft.	in.
Coal		7
"Sulphur" band (not included in sample)		½
Coal		6¼
Soft shale (not included in sample)		8
Coal	1	4½
Sulphur (not included in sample)		¼
Coal		5½
Thickness of bed	3	8
Thickness of sample	2	11¼

3. This bed was measured as described below:

	Ft.	in.
Roof, shale.		
Coal		7½
Shale (not included in sample)		9
Bone (not included in sample)		4
Coal	1	
"Sulphur" streak.		
Coal		6
Thickness of bed	3	2½
Thickness of sample	2	1½

There is also available a record of analyses of coal delivered from the Quinton-Scipio district during the Government fiscal year from July 1, 1923, to July 1, 1924. These analyses were made from samples of not less than 1,000 pounds, systematically collected by taking equal increments at regular intervals throughout the delivery, and subsequently reduced by proper sampling methods to samples of laboratory size. The coal thus sampled from the Quinton-Scipio district is recorded [37] as mined from the Blocker No. 1 mine, near Blocker. This coal may have come from the large strip pit in the NW¼ sec. 23, T. 7 N., R. 16 E., locally known as the Heisel or Mason pit and stated to have been operated by the Midway Coal Co. of Pittsburg, Kans., from 1922(?) to 1925.

[37] Analyses of Oklahoma coals: Bur. Mines Tech. Paper 411, pp. 56, 57, 1928.

Average chemical analyses of Secor coal delivered from Quinton-Scipio district

[From Bur. Mines Tech. Paper 411]

Size of coal	Approximate quantity delivered (tons)	Proximate analysis					Calorific value, per pound						Number of analyses averaged	Place of delivery
		As received, moisture (percent)	Dry coal				As received		Dry coal		Moisture-free and ash-free			
			Volatile matter (percent)	Fixed carbon (percent)	Ash (percent)	Sulphur (percent)	British thermal units	Calories	British thermal units	Calories	British thermal units	Calories		
Lump over 2½-inch screen	2,777	2.1	38.3	49.8	11.9	4.7	12,990	7,217	13,270	7,372	15,060	8,367	4	Fort Sam Houston, Tex.
Run of mine	4,720	2.2	37.5	51.7	10.8	5.1	13,040	7,244	13,330	7,406	14,940	8,300	29	Fort Sam Houston and Kelly Field, Tex.

OIL AND GAS POSSIBILITIES AND STRATIGRAPHY AND STRUCTURE OF ROCKS NOT EXPOSED

By H. E. Rothrock

HISTORY OF DRILLING

One of the earliest attempts to develop oil or gas in northern Pittsburg County, Okla., was made south of Featherston by the Choctaw Oil Co. The test well was put down in the southwest corner of the SE¼ sec. 34, T. 7 N., R. 17 E. It was abandoned as a dry hole on July 12, 1909, at a depth of 2,112 feet.

The records show no further development until 1914, when the discovery of gas near Ashland, in the southwestern part of the county, attracted the attention of operators to the possibilities of gas elsewhere in the county. Two test holes were drilled near the town of Scipio, in sec. 29, T. 7 N., R. 13 E., by the Choctaw Oil & Gas Co. Shortly thereafter development was begun on the Lilypad Creek anticline, at the west end of Lake McAlester, where the Gypsy Oil Co. drilled three test wells but failed to find commercial quantities of gas.

The scene of operations was shifted to the eastern part of the county by the completion, in July 1915, of a gas well on the Short farm, in the southeast corner of the NE¼ sec. 1, T. 6 N., R. 15 E. This well was known as the Fish Creek well and was drilled by W. S. Weimer. The Choctaw Natural Gas Co. laid a line from the well to the city of McAlester, which abandoned its coal-gas plant in favor of natural gas.

In September 1915 D. Nottage completed a gas well near the center of the SW¼NW¼ sec. 1, T. 7 N., R. 18 E., about half a mile south of the town of Quinton. This well had an initial daily open flow of 25 million cubic feet of gas, with a rock pressure of about 500 pounds to the square inch, and began the development of the series of gas fields that occur along the crest of the Kinta anticline. These fields include the Kinta field, which lies east of the Quinton-Scipio district, the Quinton field, the Carney field, and the Blocker-Featherston field. The Kinta field is not described in this report.

The only other area in which marketable quantities of gas have been developed lies northeast of the town of Canadian, in secs. 26 and 32, T. 9 N., R. 16 E., and sec. 5, T. 8 N., R. 16 E.

Descriptions of the wells in the producing fields are given in the discussion of those fields (pp. 215–242). A list of the other test wells,[37a] as well as some of the important producing wells, is given in the table below. The index numbers of the wells in this list correspond to numbers shown on plate 13. These numbers are also used in the text to identify the wells that are being discussed.

[37a] Since the preparation of this report, the Oklahoma District Oil Co.'s Beeler No. 1, in the NE¼NE¼SW¼ sec. 7, T. 7 N., R. 14 E., has been drilled to a depth of 6,130 feet (December 1937). According to personal communications from L. M. Wilshire, this well reached the top of the Morrow formation at a depth of 4,490 feet, the top of the Cromwell(?) sand at 4,970 feet, and the top of the Wilcox sand at 6,010 feet. The altitude of the surface at the well mouth is 743 feet.

Names, depths, and locations of wells drilled outside of producing gas fields and some wells in Quinton, Carney, and Blocker-Featherston gas fields

Index number on pl. 13	Company	Well no.	Farm	Approximate location [1]	Sec.	T. N.	R. E.	Date of completion	Total depth (feet)	Remarks [2]
1	South Canadian Oil & Gas Co.	1		SEc NW¼NW¼	23	9	16		2,666	Dry, G. S. at 1,725–1,770 feet.
2	C. B. Shaffer	1	Patricho	C NW¼NW¼	26	9	16	May 1918	2,780	Dry.
3	Oklahoma Natural Gas Corporation	1	Fears	NEc SW¼NE¼	26	9	16		1,924	Gas, 1.8 Ml at 1,877–1,919 feet.
4	N. J. Weible	1	Weible	NWc SW¼SW¼	26	9	16	May 1933	610	Dry.
5	do	1	Jennings	SWc SE¼SW¼	26	9	16	January 1933	664	Do.
6	Oklahoma Natural Gas Corporation	1	Fears	NEc SE¼SE¼	26	9	16	September 1926	2,401	Gas, ½ Ml at 643–652 feet.
7	do	2	do	SWc SE¼SE¼	26	9	16	1917?	642	Gas.
8	do	3	do	C E½NW¼SW¼	25	9	16	September 1927	666	Dry.
9		1	Price	NEc NW¼NW¼	36	9	16		2,712	Dry, G. S. at 2,300 feet.
10	Western Natural Gas Co.	1	Long	C E½NW¼SE¼	36	9	16	November 1926	2,550	Dry, G. S. at 1,355–1,390 feet.
11	Pattison & Phillips	1	Smith	NEc SW¼SE¼	32	9	16	January 1927	4,505	Gas, 4,480–4,505 feet.
12	do	1	McDuff	C SE¼SW¼SE¼	32	9	16	1932	5,902	Dry, 3 Ml gas at 4,446–4,525 feet. O. S. at 5,343 feet.
13	N. J. Weible	1	Smith	C N½SE¼	32	9	16	November 1932	1,410	Gas, ½ Ml at 892 and 1,401 feet.
14	do	2	Mattucks	C W½NE¼SW¼	5	8	16		715	Dry, G. S. at 592–593 feet.
15	do	1	do	NEc NE¼SW¼	5	8	16	October 1931	460	Gas, ½ Ml at 451–452 feet.
16	do	1	Belt	C NL NW¼SE¼	5	8	16	August 1931	455	Gas, ½ Ml at 368–369 feet.
17	do	1	Smith	C E½	5	8	16	November 1930	2,030	Gas, 1 Ml at 375–380, 655 feet. G. S. at 933, 1,450, 1,635, 2,025 feet.
18	do	2	do	C E½	5	8	16	October 1933	401	Dry.
19	do	1	Eeds	SEc NE¼NW¼SE¼	5	8	16		467	Do.
20	Choctaw Oil & Gas Co.	1	Smith	C W½SW¼	4	8	16	June 1917	2,723	Dry, G. S. at 1,600 feet.
21	Gillock Oil Co.	1		C WL SE¼NW¼	18	8	16	1917	3,157	Dry, G. S. at 1,750 feet.
22	Cannaday			SWc NE¼SW¼	9	8	14			Dry.
23				C	27	8	14			Do.
24	Cannaday	1	Turner	C N½NW¼	14	8	14		3,210	Dry, G. S. at 1,650, 2,180, 2,690 feet.
25				NEc NW¼NW¼	28	8	15	September 1924	2,550	Dry.
26	H. A. Whitley	1	Allen	NWc SW¼SW¼	8	8	18	August 1920	4,785	Dry, 3 Ml gas at 3,120–3,367 feet.
27	Paraffine Oil & Gas Co.	1	Parkins	SEc SE¼SW¼	12	7	12	September 1932	3,243	Dry, G. S. at 2,220 and 2,485 feet.
28	Paraffine & Reliance Oil Co.	1	Pratt	NEc SE¼NE¼	13	7	12	July 1924	4,288	Dry, 5 Ml gas at 1,006, 1,398, 1,412, 1,532, 3,253, and 4,217 feet.
29	Apex Oil & Gas Co.	1	Heskett	C SE¼NW¼	18	7	13	October 1930	1,455	Dry, 2 Ml gas at 975–1,005 feet.
30	do	1	Walker	C NW¼SE¼	18	7	13	August 1930	1,600	Dry, 1 Ml gas at 1,000–1,005 feet.
31	Choctoka Oil & Gas Co.	1	do	SEc NW¼SW¼	29	7	13	1914	1,705	Dry, O. S. at 1,588–1,605 feet.
32	S. Mercer			C SE¼	29	7	13	December 1914	2,540	Dry.
33				NWc NE¼	4	6	13		476?	Do.

34	Windsor Oil & Gas Co.	1	Brown	C N½	24	7	13		4,307	Dry, G. S. at 850 and 1,100 feet
35	Gypsy Oil Co.	1	J. McCarty	C NL SW¼SE¼	31	7	14	April 1916	1,605	Dry, G. S. at 611-625 feet.
36	Red Bank Oil Co.	1	Campbell	NEc SE¼NW¼	6	6	14	September 1931	758	Dry.
37	Gypsy Oil Co.	1	W. McCarty	NEc SE¼	1	6	13	June 1916	1,855	Do.
38	do	1	McCarty	NEc SW¼	6	6	14	1914?	4,303	Gas, 2 Ml at 600.
39	Joe Perrine et al	1	Tannehill	C WL SW¼SE¼	6	6	14	1932?		Dry.
40		1	Reidt	C SW¼NW¼	7	6	14		1,103	Do.
41	Tate Oil Co.	1	Wilkinson	SEc SE¼	34	7	14	1932?	2,975	Do.
42	Joe Perrine	1	Ringland	NEc NE¼NW¼	7	6	15	April 1931	1,505	Do.
43	W. A. Glimpse	1		SWc NW¼SE¼	28	7	15	1930?	1,810	Do.
44	Byllesby	1		NEc NE¼	10	6	15		2,710	Dry, gas 2,700-2,710 feet.
45	Choctaw Natural Gas Co.	1	Short	C EL SE¼NE¼	1	6	15	July 1915	3,192	Gas, 1 Ml at 1,920-2,120 feet.
46	Joe Perrine et al	1		C WL SW¼NW¼	6	6	16	1932		Gas.
47	McAlester Gas & Coke Co.	1	Sawyer	SEc SE¼SE¼	6	6	16	August 1920	2,534	Dry.
48	Empire Oil & Refining Co.	1	Williams	C NE¼SW¼	33	7	16	June 1930	3,980	Dry, G. S. at 1,678 feet.
49		1		C NW¼SE¼	9	6	16			
50	Quinton Spelter Co.	1	Brown	C W½SW¼NE¼	23	7	16	January 1924	3,235	Dry.
51	Gladys Belle Oil Co.	1	Bassett	NEc SE¼	19	7	17	March 1916	2,550	Gas, at 2,490-2,550 feet.
52	Quinton Spelter Co.	1	L. C. Featherston	C W½NW¼	21	7	17	January 1928	2,629	Gas, 2 Ml at 2,540-2,560 feet.
53	do	1	Yoho	NWc NE¼SE¼	21	7	17	March 1928	2,644	Gas, 1½ Ml at 2,520 feet.
54	do	1	McFall	NWc NW¼SE¼	22	7	17	October 1926	2,605	Gas, 1 Ml at 2,475-2,595 feet.
55	do	1	Hughes	C NL SW¼NE¼	24	7	17	March 1929	2,484	Gas, 2½ Ml.
56	do	1	S. Carney	C NW¼SE¼	18	7	18	August 1923	2,380	Gas, 1 Ml.
57	Utilities Production Corporation	1	Colbert	SWc SW¼	9	7	18	April 1931	2,138	Gas, 3½ Ml.
58	Quinton Spelter Co.	1	Daugherty	NWc SW¼NE¼	10	7	18	December 1928	2,033	Gas, 30 Ml.
59	Quinton Relief Oil & Gas Co.	3	Curry	NWc NE¼NW¼	12	7	18	August 1921	1,643	Gas, 3 Ml.
60	Quinton Spelter Co.	2	Aldridge	SWc SW¼	6	7	19	March 1924	1,475	Gas, 9 Ml.
61	do	3	do	C N½NE¼	7	7	19	June 1924	1,457	Gas, 9½ Ml.
62	do	1	Cotton	NEc NE¼	8	7	19	December 1922	1,380	Dry.
63	Costanso Coal & Mining Co.	1	Klug	NEc NE¼SE¼	26	7	17	March 1920	2,605	Do.
64	Choctaw Oil Co.	1	Allotment	SWc SE¼SE¼	34	7	17	July 1909	2,112	Do.
65			Hancock?	C N½SW¼	9	6	17		1,370	Gas at 1,091-1,101 feet.
66				C NE¼SW¼	9	6	17			Gas.
67	Cities Service Gas Co.	1	Featherston	C NW¼SE¼	9	6	17	October 1930	3,004	Dry.
68	do	1	Hughes	NWc NW¼	16	6	17	December 1931	2,285	Dry, G. S. at 2,105-2,145, 2,205 feet.
69	Choctaw Gas Co.	1	Weaver	C NE¼NW¼	4	6	18	April 1931	3,475	Dry.
70	N. J. Weible	1	Grossman and Brown	NWc SW¼SW¼SW¼	14	8	15	July 1935	881	Dry, little salt water at 794 feet.
71	Oklahoma District Oil Co.	1		C NE¼NE¼NE¼	7	7	14			

[1] C, center; c, corner; NL, EL, north line, east line, etc.

[2] G. S., show of gas; O. S., show of oil; Ml, million cubic feet.

STRATIGRAPHY OF ROCKS NOT EXPOSED

GENERAL FEATURES

The determination of formation boundaries in the subsurface study of this district is based upon drillers' logs, and the inaccuracies inherent in such records may be reflected in the geologic interpretation made from them. Aside from the water, oil, or gas content of the rock, the driller's chief concern is whether the formation is hard and abrasive or soft and subject to caving. Under this classification hard rocks, such as sandstone, limestone, dolomite, and chert, are often not differentiated by the driller. Likewise soft rocks, such as clay, shale, marl, and coal, are often undifferentiated. Furthermore, as the driller's business is to complete the well quickly, he usually cuts as much hole as possible before pulling out the tools, bailing the well, and observing the character of the rock penetrated. Thin beds are likely to escape notice, particularly soft beds like coal. Accordingly, the absence of an expectable coal in a driller's record is not significant, unless it is consistently omitted from the records of other wells also. Many thick resistant sandstones are logged as limestones, but the few thin limestones that occur in the stratigraphic section between the Boggy shale and the Atoka formation are seldom reported accurately. The subsurface data presented by the drillers' logs are for these reasons not wholly satisfactory, but the conclusions here reached are thought to be essentially correct, and it is hoped that they will serve a useful purpose until more precise data from complete sample logs become available. The altitude of some horizons distinguished in some of the more productive wells is shown in the following table:

Position, in feet above or below sea level, of horizons identified in wells

Number of well	Altitude at well mouth	Top of Thurman sandstone	Top of Boggy shale	Top of Savanna sandstone	Top of McAlester shale	Top of Upper Hartshorne coal or an equivalent horizon	Top of Atoka formation	Remarks
1	520	--------	--------	−962	−1, 244	−2, 139?	--------	
2	550	--------	--------	−650	--------	−1, 780?	−1, 850	
6	684	--------	--------	−500	--------	−1, 664?	−1, 701	
9	632	--------	--------	−429	−668?	−1, 631?	−1, 740	
10	816	--------	--------	−424	--------	--------	--------	
11	597	--------	--------	−328	−459?	−1, 303?	−1, 308	Top of Morrow formation at −3, 439 feet
12	585	--------	--------	--------	--------	--------	--------	Top of Morrow formation at −3,469 feet; Viola lime at −4,680 feet.
17	625	--------	--------	−300	--------	−1, 405?	--------	
20	631	--------	--------	--------	--------	--------	−1, 537	
21	623	--------	--------	−562	--------	−1, 862	−1, 982	
24	664	--------	+500	−831	−1, 451	--------	--------	
26	641	--------	--------	+381	−43	−1, 149	−1, 319	
27	796	+581	+356	−544	−800	--------	--------	

Position, in feet above or below sea level, of horizons identified in wells—Continued

Number of well	Altitude at well month	Top of Thurman sandstone	Top of Boggy shale	Top of Savanna sandstone	Top of McAlester shale	Top of Upper Hartshorne coal or an equivalent horizon	Top of Atoka formation	Remarks
28	723	+547	+381	−610	−882	−2,182	-------	Top of Morrow formation at −3,184 feet.
34	823	-------	+848	-------	-------	−2,367?	−2,387	
38	694	-------	-------	+194	−76	−1,909	−2,051	
41	654	-------	-------	-------	−189	−2,256	-------	
44	622	-------	-------	+482	−183?	−1,978	-------	
46	581	-------	-------	-------	+381	−1,249	−1,539	
47	620	-------	-------	-------	+160	−1,523	−1,735	
48	562	-------	-------	+447	−118	−1,863	−2,031	
50	633	-------	-------	−72?	−522	−2,209	−2,317	
51	649	-------	-------	+389	−171	−1,736	−1,916	
52	668	-------	-------	+573	−2	−1,632	−1,917	
53	649	-------	-------	+614	+34	−1,646	−1,971	
54	710	-------	-------	-------	+145	−1,545	−1,885	
55	793	-------	-------	-------	+363	−1,313	−1,622	
56	615	-------	-------	-------	+397	−1,225	−1,425	
57	617	-------	-------	-------	+505	−1,115	−1,303	
58	734	-------	-------	-------	-------	−1,019	-------	
59	573	-------	-------	-------	-------	−822	−1,154	
60	570	-------	-------	-------	-------	−500	−700	
61	568	-------	-------	-------	-------	−657	−846	
62	558	-------	-------	-------	-------	−604	−702	
64	636	-------	-------	+401	−234	-------	-------	
67	768	-------	-------	-------	+658	−1,212	−1,412	
68	709	-------	-------	-------	+598?	−1,293	−1,586	
69	1,009	-------	-------	+569	+119	−1,776	−2,018	

The formations which are revealed by drilling but which do not come to the surface in the Quinton-Scipio district range from the McAlester shale, of the Pennsylvanian series, to limestone of Ordovician age. Only the uppermost part of the McAlester shale crops out in secs. 1, 2, 11, 12, T. 7 N., R. 18 E. The rest of the formation and the successively underlying Hartshorne and Atoka formations, also of Pennsylvanian age, are penetrated by many wells in the district. The Morrow formation, of Pennsylvanian age, was penetrated by the Paraffine & Reliance Oil Co.'s No. 1 Pratt well, in the northeast corner of the SE¼NE¼ sec. 13, T. 7 N., R. 12 E., and the Pattison-Phillips No. 1 McDuff well, in the center of the SE¼SW¼SE¼ sec. 32, T. 9 N., R. 16 E. Only the McDuff well has penetrated older Paleozoic formations.

The surface exposures of the McAlester shale, Hartshorne sandstone, and upper part of the Atoka formation in adjoining areas to the south and east have recently been described.[38] The following description of these formations where penetrated by wells in the Quinton-Scipio district is based almost wholly on a study of the well records and accordingly deals chiefly with the thickness and gross lithology of the formations.

[38] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 1, The McAlester district: U. S. Geol. Survey Bull. 874-A, pp. 10-16, 1937. Wilson, C. W., Jr., Age and correlation of Pennsylvanian surface formations and of oil and gas sands of Muskogee County, Okla.: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 4, pp. 505-508, 1935.

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McALESTER SHALE

The McAlester shale lies beneath the Savanna sandstone and above the Hartshorne sandstone. The change in lithology between the Savanna and the McAlester is known from surface exposures to be gradational, but it is sufficiently abrupt to be readily discernible in most of the well logs. The McAlester shale in the McAlester district has been divided into three parts, upper, middle, and lower,[39] and these three parts can be recognized in the well records in the Quinton-Scipio district, most easily in the eastern part of the district, where they have average thicknesses of 900, 300, and 400 feet, respectively.

The upper shale is generally logged as blue or light-colored shale, but it contains also discontinuous sandy zones. Coals are sometimes recorded, but only a coal which, because of its position in the stratigraphic section, is correlated with the Stigler or Upper McAlester coal is shown often enough to be useful as a key bed. A coal that is probably the Lehigh or Lower McAlester coal is occasionally logged at the base of this upper part of the formation.

The middle sandstone and sandy shale part of the formation is easily recognized in the eastern part of the district, but its individual beds cannot be traced definitely very far north or west. Where it is developed best it is predominantly sandstone but contains in its upper half a shale zone from 50 to 100 feet thick. The upper beds of this part of the formation are gas-bearing in some wells, but the lower beds almost invariably carry a "hole full of water."

The lower shale part of the formation is usually logged as brown or dark shale in its upper portion and black shale at the base. The Upper Hartshorne coal occurs within this black-shale zone. The coal is usually logged in the east half of the area covered by this report, but it is not recorded in wells west or north of the Lilypad Creek anticline. In the McAlester district[40] the Upper Hartshorne coal lies from 1 to 50 feet above the base of the McAlester shale, and the top of the underlying Hartshorne sandstone may be either a massive sandstone or a sandy shale. It is therefore difficult to locate the McAlester-Hartshorne contact precisely in the well records of the Quinton-Scipio district. The interval between the base of the Upper Hartshorne coal and the first thick sandstone bed below the coal ranges from 0 to 100 feet, though it is not more than 50 feet in most of the records.

The McAlester shale has only a small range in thickness across the southern part of the district. In the Carney field it is 1,600 feet thick; on the Burning Springs anticline it is about 1,900 feet, and in the vicinity of Scipio it is about 1,650 feet. In general, the formation thins northward, being but 800 feet thick in the Pattison-Phillips well (no. 11), 2 miles northeast of Canadian. However, the rate of

[39] Hendricks, T. A., op. cit., p. 13.
[40] Hendricks, T. A., op. cit., p. 49.

thinning is not regular but is most pronounced over the larger anticlines. On the Flowery Mound anticline the McAlester shale on the top of the fold is 1,635 feet thick (well 45), but 1 mile to the east it has increased to 1,765 feet [41] (well 48), and 2 miles to the west it amounts to about 1,795 feet (well 44). On the crest of the Lilypad Creek anticline the McAlester shale is 1,833 feet thick (well 38), whereas well 41, 3½ miles to the east on the Lake McAlester anticline, indicates a thickness of 2,067 feet. Most of the change of thickness occurs in the lower part of the formation, for the interval between the Stigler or Upper McAlester coal and the top of the formation varies but little. (See cross section, pl. 20.)

HARTSHORNE SANDSTONE

The Hartshorne sandstone, which underlies the McAlester shale, consists of fine-grained white or light-gray sandstone and gray sandy shale. The top of the formation lies from 0 to 50 feet below the Upper Hartshorne coal and is recorded in the well logs as sandy shale or sandstone.

In the McAlester district the Hartshorne sandstone grades downward into the Atoka formation, but in areas farther east in Oklahoma the contact may locally exhibit erosional irregularity.[42] In most wells drilled in the Quinton-Scipio district the underlying Atoka formation is easily recognized by the drillers because of its dark-colored shales, and the change in lithology is in most places abrupt. The position of the top of the Atoka in the wells shows abrupt changes in the thickness of the Hartshorne sandstone. These variations of thickness are of such magnitude and irregularity that they suggest an erosional unconformity between the Hartshorne sandstone and the Atoka formation.

The Hartshorne is extremely variable in its thickness, which may be very slight or as much as 369 feet. The general direction of thinning is toward the north and northwest, but local variation occurs throughout the Quinton-Scipio district. In the Quinton field the Hartshorne sandstone averages 125 feet in thickness, in the Carney field 261 feet, in the Blocker-Featherston field 326 feet, whereas in the northwestern part of the county it is either entirely absent or its lithology has changed to so great an extent that it cannot be definitely recognized.

The local variations in the thickness of the formation are shown best in the well records from three gas fields. The logs of wells that reached the Atoka formation show that the difference between the maximum and minimum thicknesses is 79 feet in the Blocker-Featherston field, 244 feet in the Carney field, and 200 feet in the Quinton field.

[41] These figures have not been corrected for the difference in angle of dips at the several locations, because this correction at the localities cited would not significantly affect the comparison, and it was thought preferable to retain the figures as directly derived from well records.

[42] Hendricks, T. A., personal communication.

In the Blocker-Featherston field virtually all of this variation in thickness occurs in the lower part of the formation, because the Upper Hartshorne coal in most places rests directly on the top of the Hartshorne sandstone. In the Carney field it is impossible to tell how much of the variation occurs at the top and how much at the base of the formation, because the reference bed, the Upper Hartshorne coal, is present at but few places. In the Quinton field, where the Upper Hartshorne coal is usually recorded, the 200 feet of variation in thickness is distributed about equally between the upper and lower parts of the formation. Plate 20 illustrates these conditions and suggests that the Hartshorne sandstone was deposited on a very irregular surface which in the Quinton area had a relief of 100 feet, and that its upper surface is also very irregular, possibly owing to intertonguing of sandstone and shale in the lower part of the McAlester shale below the Upper Hartshorne coal.

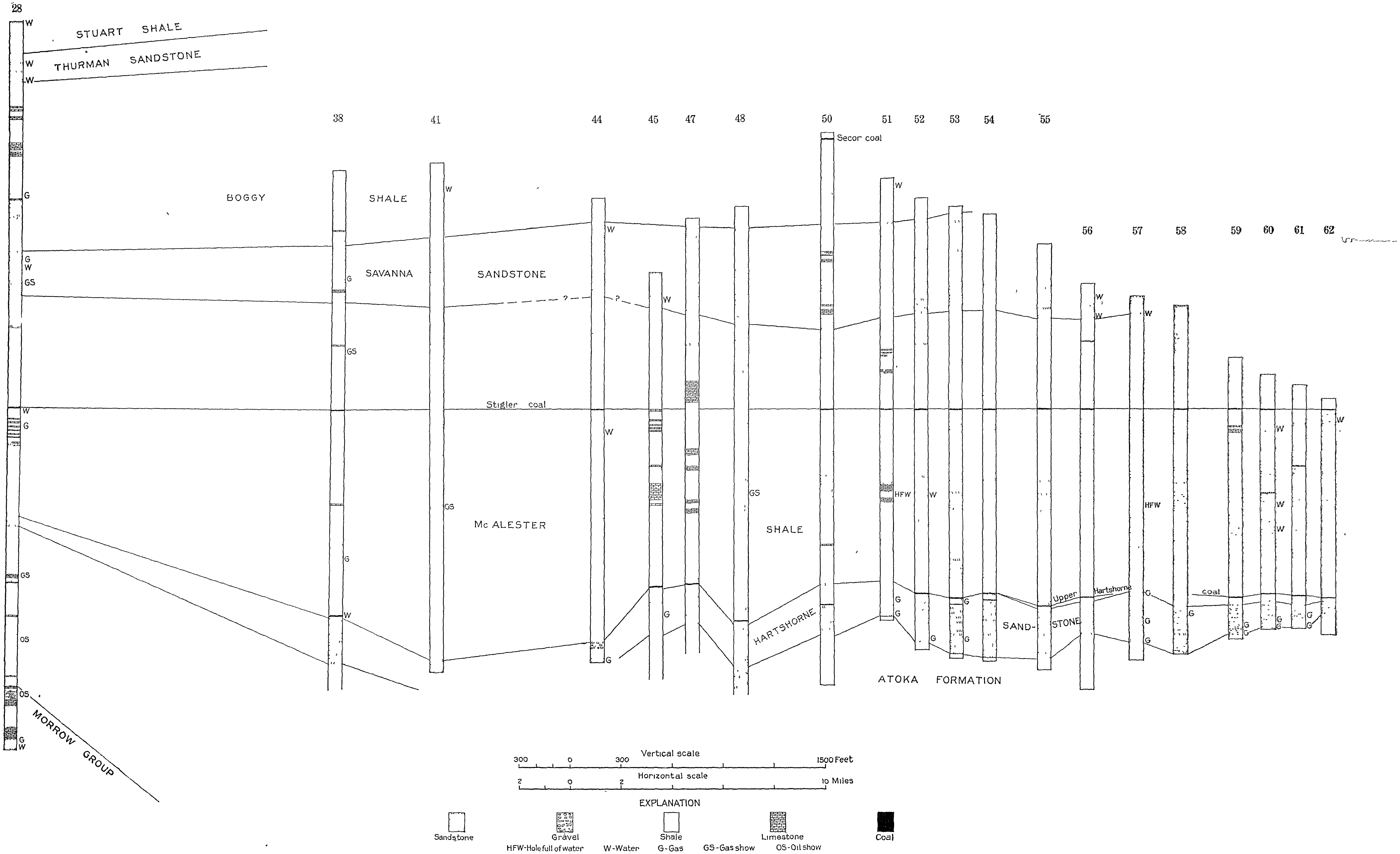
The Hartshorne sandstone is the chief gas-producing formation in this area but is barren of liquids at atmospheric pressures.

ATOKA FORMATION

The Atoka formation, which lies below the Hartshorne sandstone, is logged as dark-blue, black, or dark shale, or shale and shells. It has been drilled through by only two wells within the district. In the Pattison-Phillips No. 1 McDuff well (no. 12), in sec. 32, T. 9 N., R. 16 E., the top of the formation is not determinable from the driller's record but was probably encountered at a depth between 1,905 and 2,100 feet. The base of the Atoka was found at 4,044 feet, which gives an approximate thickness of 2,000 feet for the formation. In sec. 13, T. 7 N., R. 12 E., the Paraffine & Reliance Oil Co.'s No. 1 Pratt well (no. 28) probably reached the top of the Atoka formation at 2,957 feet. This interpretation is based on the correlation of the shallower formations. As the base of the formation was encountered at 3,907 feet, the thickness of the Atoka in this well is about 950 feet.

An eastward component of thickening of the Atoka is thus indicated by these two wells. Neither discloses the maximum thickness of the formation in this district. The Whitley No. 1 Allen well (no. 26), in sec. 8, T. 8 N., R. 18 E., penetrated at least 2,925 feet of the formation. The nearest significant deep test well south of the district is the well of the Limestone Oil & Gas Co., 3 miles west of Wilburton and 15 miles south of Quinton, in sec. 15, T. 5 N., R. 18 E. This well began drilling about 1,000 feet below the top of the Atoka, and at a total depth of 4,038 feet was still in the same formation, indicating a thickness in excess of 5,000 feet at this point.[42a] The thickness of the Atoka at any locality in the area covered by this report is con-

[42a] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, part 4, The Howe-Wilburton district, Latimer and Le Flore Counties: U. S. Geol. Survey Bull. 874-D (in preparation).



CORRELATION OF DRILLERS' LOGS OF WELLS IN THE SOUTHERN PART OF THE QUINTON-SCIPIO DISTRICT.

jectural and probably depends not only upon the rate of thickening of the formation but also upon the magnitude of the unconformity at its base.

FORMATIONS OLDER THAN THE ATOKA

Rocks below the Atoka formation have been penetrated in this district only by the Pattison-Phillips and the Paraffine & Reliance Oil Co. wells. (See footnote 37a, p. 205.) Underlying the Atoka in these wells is a unit consisting of two thick limestones separated by a shale and resting on a sandstone or sandy limestone. This calcareous unit is regarded as the Morrow formation, of Pennsylvanian age. In the Pattison-Phillips well the unit was found to be 480 feet thick and yielded 3 million cubic feet of gas from the sandy phase near its base. In the other well it had a thickness of 380 feet and yielded half a million cubic feet of gas in the top and water in the bottom. The sandy limestone or sandstone near the base is probably equivalent to the Cromwell sand, which contains oil and gas elsewhere in Oklahoma. The remainder of the stratigraphic section was penetrated only by the Pattison-Phillips well (no. 12). The following log of that well was compiled from sample determinations, scout reports, and miscellaneous sources of information:

Partial log of the Pattison-Phillips No. 1 McDuff well, in the center of the SE¼ SW¼SE¼ sec. 32, T. 9 N., R. 16 E., Pittsburg County, Okla.

	Feet
Atoka formation	4, 044
Morrow formation	4, 044–4, 530
Cromwell (?) sand	4, 405–4, 530
Fayetteville shale: Dark-gray and black shale	4, 530–4, 940
Moorefield (?) shale: Dark calcareous gritty shale	4, 940–5, 059
Chattanooga shale: Black shale	5, 059–5, 085
Hunton limestone (?): White and buff cherty siliceous limestone	5, 085–5, 213
Sylvan shale: Green shale	5, 213–5, 263
Viola limestone: White crystalline limestone	5, 263–5, 297
Simpson formation:	
Buff dense limestone	5, 297–5, 320
Buff arenaceous dolomite with much included sandstone	5, 320–5, 343
Hard quartzitic sandstone; oil show	5, 343–5, 420
Dolomite	5, 420–5, 440
Hard quartzitic sandstone	5, 440–5, 455
Dolomite	5, 455–5, 460
Sandstone	5, 460–5, 520
Dolomite	5, 520–5, 544
Green shale and sand	5, 544–5, 650
Sandy limestone	5, 650–5, 683
Limestone	5, 683–5, 700
Sand	5, 700–5, 725
Limestone	5, 725–5, 735
Limestone and green shale	5, 735–5, 805
Arbuckle limestone	5, 805–5, 902

STRUCTURE OF ROCKS NOT EXPOSED

GENERAL FEATURES

The subsurface structure of the district is shown on plate 13 by structure contours on the top of the Upper Hartshorne coal, which is the oldest bed that is readily determinable in most of the wells drilled in the area. The coal was deposited after most of any irregularities that may have been present on the top of the Hartshorne sandstone had been eliminated, and hence it is a satisfactory key bed for determining the amount of deformation that has taken place since early McAlester time.

The structure on this key bed shows that the rocks have been folded into a series of anticlines and synclines, the axes of which coincide approximately with those of the folds as shown by the surface rocks. (See pl. 13.) The dips on the Upper Hartshorne coal are in most places considerably steeper than the dips in the surface rocks, suggesting recurrent periods of deformation. In some places on the flanks of the folds the dip on the Upper Hartshorne coal is three times as great as the dip in the surface rocks. The general trend of the axes of the anticlines and synclines is N. 75° E. In the northeastern part of the district this trend becomes N. 45° E., but in Tps. 6 and 7 N., R. 14 E., it is almost due east. Over most of the district the folds plunge to the west, but toward the western boundary of the district a reversal of dip appears in the deeper subsurface formations. The limestones of the Morrow formation show a pronounced southeast dip from the area northwest of the district toward Scipio.

EFFECT OF CONVERGENCE

In the surface rocks the principal structural features of the district are the Kinta, Burning Springs, Flowery Mound, Lake McAlester, and Lilypad Creek anticlines and the terrace northeast of the town of Canadian. All these features change in character with depth to a greater or less degree by the northwestward thinning of the Pennsylvanian sediments. The northwestward thinning of the interval between the base of the Savanna sandstone and the top of the Morrow formation in eastern Oklahoma has been graphically represented to be 100 feet to the mile.[43] Although this figure is probably representative of the area north of the Canadian River, it appears that the rate of divergence is increased south of the river as the center of the basin is approached. The only conclusive data on this subject in northern Pittsburg County come from wells 11 and 28, but additional evidence can be obtained from the deep well near Wilburton, on the Limestone Prairie anticline (see p. 212), and from well 26. Although neither of these wells reached the limestones of the Morrow, they penetrated thick sections of the Atoka. The stratigraphic section at Limestone

[43] Clawson, W. W., Jr., Oil and gas in Oklahoma, Coal and Pittsburg Counties: Oklahoma Geol. Survey Bull. 40, vol. 3, p. 407, 1930.

Prairie, according to Hendricks,[44] contains 2,200 feet of the McAlester shale, 300 feet of the Hartshorne sandstone, and more than 5,000 feet of the Atoka formation, the thickness of the McAlester, Hartshorne, and upper part of the Atoka being obtained by measurement of beds exposed at the surface. Comparison of this section with that penetrated by wells 11 and 26 shows that the average rate of thickening between the base of the Savanna sandstone and the limestones of the Morrow formation is at least 180 feet to the mile in a S. 30° E. direction. The rate of thickening of the interval between the base of the McAlester and the top of the Morrow formation was also computed and found to be 130 feet to the mile in a S. 50° E. direction. This figure, particularly when it is resolved into its north-south and east-west components of approximately 80 and 110 feet to the mile respectively, is useful in applying convergence to the structure of the Upper Hartshorne coal, as shown on plate 13, in order to forecast the position of the tops of the folds in the pre-Pennsylvanian rocks. The data thus obtained indicate that, unless the Upper Hartshorne coal has a north dip of more than 80 feet or a northwest dip of more than 130 feet to the mile, the anticlines that are shown on the Upper Hartshorne coal will not be present in the pre-Pennsylvanian rocks. Furthermore, the tops of such gently plunging folds as the Kinta anticline may shift westward for considerable distances in the basal Pennsylvanian rocks. Steeply dipping anticlines like the Flowery Mound and Burning Springs anticlines are not greatly altered in form by applying these rates of convergence. In addition, it must be remembered that a moderate-sized unconformity in the older rocks on any of these anticlines may cancel completely the computed effect of convergence.

GAS FIELDS ON THE KINTA ANTICLINE

LOCATION, DISCOVERY, AND DEVELOPMENT

On the west end of the Kinta anticline, in the southeastern part of the Quinton-Scipio district, gas has been obtained from a nearly continuous strip of land, bearing N. 75° E., along the axis of the anticline, extending from a locality 2 miles southeast of Quinton westward to a point within 1 mile of Blocker and lying for the most part in the valley formed by the headwaters of Sans Bois Creek and some of its tributaries. Small areas of slight or no production divide this strip into three fields—the Quinton, Carney, and Blocker-Featherston fields. The Quinton field is at the east end of the group, in secs. 1, 2, 11, and 12, T. 7 N., R. 18 E., and secs. 6 and 7, T. 7 N., R. 19 E. The Carney field is in secs. 4, 5, 7, 8, 9, 10, 11, 14, 15, 16, 17, and 18, T. 7 N., R. 18 E. The Blocker-Featherston field derives its name from the two towns between which it is located and includes secs. 19, 20, 21, 22, and 24, T. 7 N., R. 17 E. The general characteristics of

[44] Hendricks, T. A., personal communication.

these fields are so similar and their development has been so closely connected that the history and general features of all three will be described together before some special features of the individual fields are considered.

The Quinton field was discovered by the success of the Nottage well, near the center of the SW¼NW¼ sec. 1, T. 7 N., R. 18 E., and only 2 months later the Blocker-Featherston field was discovered when the Gladys Belle Oil Co. encountered 7 million cubic feet of gas in the Hartshorne sandstone in a well (no. 51) drilled on the Le Flore allotment, later known as the Keys or Bassett farm. Drilling in the vicinity of these two wells proceeded as markets were developed.

A pipe line was built by the Choctaw Natural Gas Co. from McAlester to Blocker and later to Quinton, where gas was purchased by the pipe-line company at a rate of 2½ cents per thousand cubic feet. The producing companies in the field at this time were the Quinton Oil & Gas Co. and the Pittsburg Oil & Gas Co. The prospect of cheap fuel induced Messrs. L. P. Coblentz, Elmer I. Streich, and J. G. Starr to erect a zinc smelter at Quinton, which operated under the name of the Quinton Spelter Co. The smelter purchased gas from the Choctaw Natural Gas Co. at 3 cents per thousand cubic feet until 1918, when the McAlester Coal & Coke Co., which had acquired the properties of the Choctaw Natural Gas Co., raised the price to 6 cents per thousand. This figure has since been maintained, with but slight fluctuations. The prospect of 6-cent gas caused the smelter to develop its own gas supply through the Quinton Oil & Gas Co. and the Pittsburgh Oil & Gas Co., which it had purchased. During this realinement of producing and marketing companies, the Quinton Relief Oil & Gas Co. was formed to supply the town of Quinton with fuel.

In 1921 the Sans Bois Gas Co. entered the area but confined most of its operations to the Blocker-Featherston field. In 1922 the producing companies were engaged in a proration suit, which was settled by order of the Corporation Commission of Oklahoma decreeing that the withdrawals from the field be distributed ratably among the producing companies. During the same year the gas market was expanded further by the construction of a carbon-black plant at Quinton by the Western Carbon Black Co. The Quinton Relief Oil & Gas Co. supplied the plant with fuel until 1924, when the use of natural gas for the manufacture of carbon black was prohibited by order of the Corporation Commission of Oklahoma.

During the litigation against the manufacture of carbon black the Carney field was discovered. The discovery well was the Quinton Spelter Oil & Gas Co.'s No. 1 Amos, near the center of the north line of the NW¼SW¼ sec. 10, T. 7 N., R. 18 E. The well showed an initial open flow of 25 million cubic feet of gas and an initial rock pressure of 595 pounds to the square inch from a total depth of 1,786 feet.

An outpost well (no. 56) for this field had been completed in 1923 by the same compnay in sec. 18, but the gas flow from it was small, and its connection with the field is not fully understood.

In the succeeding years the several producing companies were consolidated under the management of the Quinton Spelter Co., and in 1929 all the gas properties were sold to the Utilities Production Corporation. But the development of the Carney field with its large wells brought new concerns into the district and raised the same question of equitable division of the available market that had been raised previously in the Quinton field. This question was settled by an order of the Corporation Commission of Oklahoma, which required that the amount of gas that should be taken from any well in the Carney field should depend (1) upon the ratio of the area of the drill site of that well to a unit area of 40 acres, (2) upon the ratio of the open-flow capacity of that well to the total open-flow capacity of the field, and (3) upon the ratio of the total capacity of the field to the total market demand for gas from the field.

The rate of development and the number of wells in each field are shown in the following table:

Rate of development of fields on the Kinta anticline as shown by number of wells drilled

Year	Blocker-Featherston		Carney		Quinton		Total	
	Gas	Dry	Gas	Dry	Gas	Dry	Gas	Dry
1915					1		1	
1916	1	1			2	1	3	2
1917		2			6	1	6	3
1918					5		5	
1919					7		7	
1920		1						1
1921					4	1	4	1
1922					3		3	
1923	1		1		3	1	5	1
1924					8		8	
1925	1				1	1	2	1
1926	1	1	3			1	4	2
1927	4		3			1	7	1
1928	3		3				6	
1929	1		3				4	
1930			22				22	
1931			20				20	
1932			6				6	
1933	1		2	1			3	1
1934			4				4	
1935 [1]			1				1	
Total [2]	13	6	68	1	41	11	122	18

[1] To February.
[2] Includes wells for which drilling records are not available.

At present the producing companies operating in these fields are the Utilities Production Corporation, with headquarters at Tulsa; the Public Service Co. of Oklahoma, at McAlester; the Midwestern Oil & Gas Co., at Tulsa; and the Choctaw Gas Co., at Quinton. The pipe-line companies that serve the fields are the Southwestern Natural

Gas Co., with a line north to the distributing system of the Oklahoma Natural Gas Corporation; the Public Service Co. of Oklahoma, with a line to McAlester; the Oklahoma Natural Gas Corporation, with a line east and north to Muskogee; the Tri-Cities Gas Co., with a line south to Haileyville and Hartshorne and another east to Wilburton; the Central States Power & Light Corporation, with a line to Stigler; and S. J. Campbell et al., with a line to the State penitentiary at McAlester.

PRODUCING SANDS

Two gas-producing zones have been developed on the Kinta anticline, one a sand in the middle part of the McAlester shale and the other in the Hartshorne sandstone. The sand in the McAlester shale is producing at a depth of 755 feet in the Quinton Oil & Gas Co.'s No. 2 Floyd well, in the northeast corner of the SE¼ sec. 2, T. 7 N., R. 18 E. The initial production of this well was 500,000 cubic feet of gas at a pressure of 265 pounds. A similar flow was obtained from the same horizon, but at a depth of 1,100 feet, in the Quinton Spelter Co.'s S. Carney No. 1 well, drilled in the center of the NW¼SE¼ sec. 18, T. 7 N., R. 18 E. This gas was never utilized, the flow being cased off as the well was drilled to the Hartshorne sandstone.

The Hartshorne sandstone is the principal gas-producing formation. As a rule, only a part of the formation is productive, but in many places it is difficult to differentiate between the barren and the productive zones. In some of the wells a gradual increase of gas is obtained from the top to the bottom of the sand. In most of the wells, however, there are unproductive zones of varying thickness and position in the sand. The differences in productivity of the different portions of the sand are due principally to differences in the porosity, but the zones of different porosity can seldom be correlated, even in adjacent wells. The differences in porosity are due in a large measure to differences in the degree of cementation of the sand grains, as is indicated by fragments that are blown from the wells. Some of these fragments are megascopically porous and friable; others are dense and quartzitic. The sand in the Blocker-Featherston field, according to the operators, is notably harder than the sands in the other fields.

Quantitative analyses of the physical characteristics of three samples of Hartshorne sandstone were made in April 1929 by the late A. F. Melcher and are presented here through the courtesy of James O. Lewis. The samples are believed to have come from the Carney field. Mr. Melcher's comments on his analyses were as follows:

The laboratory examination of the three samples of gas sand submitted showed them to be made up of individual grains consisting mainly of quartz with lime, silica, and iron cementing material.

The porosity of sample 1 is 12.5 percent; sample 2, 16.5 percent; sample 3, 19.2 percent.

The size of grain is fairly uniform in the three samples. The most compact sample, sample 1, has slightly the largest grain. Its grains are irregular and very compactly laid down. Its cementing material consists mainly of lime and silica. Sample 2 has not its grains so compactly laid down and has iron as well as lime and silica cementing material. The grains of sample 3 are much less compactly laid down than the grains of the other two samples. It has lime and silica for cementing material.

Enclosed is the laboratory sheet showing the size of grain and distribution of sizes of grains in each sample.

Grain sizes in samples of Hartshorne sandstone

Sieve opening		Sieve no.	Sample 1 (porosity 12.5 percent)			Sample 2 (porosity 16.5 percent)			Sample 3 (porosity 19.2 percent)		
Millimeter	Inch		Weight (grams)	Percentage through sieve	Cumulative percentage	Weight (grams)	Percentage through sieve	Cumulative percentage	Weight (grams)	Percentage through sieve	Cumulative percentage
0.883	0.0328	20	--------	--------	--------	--------	--------	--------	--------	--------	--------
.417	.0164	35	--------	--------	--------	--------	--------	--------	--------	--------	--------
.208	.0082	65	0.186	8.4	100.0	0.057	1.8	100.0	0.120	4.7	100.0
.147	.0058	100	1.142	51.5	91.6	1.139	37.9	98.2	1.008	38.7	95.3
.104	.0041	150	.578	26.0	40.1	1.094	36.4	60.3	.917	35.5	56.6
.074	.0029	200	.155	7.0	14.1	.325	10.8	23.9	.226	8.8	21.1
.061	.0024	250	.051	2.3	7.1	.125	4.1	13.1	.097	3.8	12.3
.046	.0018	300	.048	2.2	4.8	.121	3.9	9.0	.083	3.5	8.5
------	--------	Through	.057	2.6	2.6	.157	5.1	5.1	.129	5.0	5.0
			2.127	100.0	--------	3.018	100.0	--------	2.580	100.0	--------

Drillers in the Carney field report a shale break near the middle of the Hartshorne sandstone. The shale is black and concretionary and from a few inches to 30 feet thick. The following table gives the average depth to the Hartshorne sandstone and summarizes the data available on its thickness and lithology in the three fields on the Kinta anticline:

Depth to and thickness of the Hartshorne sandstone on the Kinta anticline

	Blocker-Featherston field (feet)	Carney field (feet)	Quinton field (feet)
Average depth to the Hartshorne sandstone	2,300	1,800	1,300
Thickness of the Hartshorne sandstone:			
Average	320	261	125
Maximum	369	346	220
Minimum	290	102	20
Thickness of gas-producing portion of the Hartshorne sandstone:			
Average	99	86	27
Maximum	240	208	50
Minimum	38	15	5
Average thickness of the predominant kinds of rock in the Hartshorne sandstone:			
Shale and sandy shale	150	60	65
Sandstone definitely recorded as gas-producing	99	86	27
Other sandstone	71	115	33
	320	261	125

GAS PRODUCTION

No oil has ever been produced from any of these fields. One of the wells on the north flank of the Carney field was reported to have yielded a few gallons of oil from the top of the Hartshorne sandstone, but no other occurrence of oil could be substantiated.

The gas from these fields is classified by operators as a dry gas. It has a high methane content, as indicated by the following analysis, made by the Oklahoma Natural Gas Corporation in 1934:

Analysis of gas from Quinton-Scipio district

Carbon dioxide (CO_2)	0. 5
Oxygen (O_2)	None
Methane (CH_4)	95. 0
Ethane (C_2H_6)	4. 4
Nitrogen (N)	
	99. 9
British thermal units per cubic foot	1, 035
Gravity	0. 5800

The total yield of these fields will never be known, owing to the escape of large quantities of gas. However, the metered yield, the volume of which is computed at a 2-pound base pressure (2 pounds above atmospheric pressure), constitutes the greater part of the output and is a matter of record.

In addition to the metered yield an appreciable amount of gas is used in drilling. An estimate of this amount can be obtained by multiplying the daily consumption of a drilling boiler, which is 70,000 cubic feet, by the average number of days required to complete a well in each of the fields and by the number of wells in each field. Another significant addition to the metered yield should be made for gas that has escaped during the completion of the well. While the producing zone is being penetrated and during subsequent completion operations the wells are, of necessity, allowed to flow unrestricted. For the smaller wells the gas thus lost may be estimated as amounting to 2 days' flow; for the larger wells it may amount to only 1 day's flow.

Estimates of the amount of gas used for fuel and the amount escaping during the completion of the well have been added to the metered yield, giving the following total figures as of January 1, 1934:

Quinton	30, 005, 720, 000
Carney	27, 784, 952, 000
Blocker-Featherston	4, 967, 938, 000
Total	61, 858, 610, 000

Other corrections that should be added to the known yield arise from leaks in the casing-seat, casing-head, and pipe-line connections, gas blown into the air during monthly or quarterly tests and during the blowing of wells to rid them of water, gas lost through the incomplete plugging of noncommercial wells, and fuel used for lease operations. These factors are appreciable, because they take place continuously over a period of several years. However, they are not included in the estimate of total production because data are not available.

GAS PRESSURE

The original pressures in the three fields are as follows:

Field	Average total depth (feet)	Original pressure (pounds per square inch)	
		Well head	Bottom of hole (computed)
Quinton	1,400	520	546
Carney	2,050	595	621
Blocker-Featherston	2,600	580?	612?

In the following discussion the term "field" is used to represent an area in which is located a reasonably continuous sequence of producing gas wells, the maximum area allotted to a well being 40 acres. The term "reservoir" is used to indicate all of the sand that contributes gas to the wells in the field. References to pressures of individual wells represent pressure measurements taken at the well head, and references to pressures of a group of wells represent the numerical average of the measurements taken at the well heads, unless it is definitely stipulated that some other meaning is intended. The study of the relation of gas production to gas pressure of a field should be based upon the pressure in the reservoir, which would be determined from the average of the bottom-hole pressures of the field and the peripheral producing zone about the field. Although the bottom-hole pressures of the fields on the Kinta anticline could be computed, the pressures in the outer limits of the reservoirs are not known. For this reason the data available are not thought to be sufficiently precise to warrant the use of computed bottom-hole pressures, and in this study numerical average well-head pressures are used. Weighted average pressures [45] of the fields in which the areas of equal pressure, in addition to the pressures themselves, are taken into account are not used, because they were found to conform very closely to the numerical average pressures.

STRUCTURE OF ROCKS NOT EXPOSED

The Quinton, Carney, and Blocker-Featherston gas fields are situated along the crest of the Kinta anticline, and accumulation of the gas is definitely related to the structure, which on the Upper Hartshorne coal is that of a plunging anticline with a sinuous crest. (See pl. 13.) This crest coincides with the axis of the surface fold, but the dips on the flanks of the subsurface anticline are from one and

[45] Stephenson, E. A., Problems in proration on the basis of gas energy: Petroleum Development and Technology, Am. Inst. Min. Met. Eng. Trans., 1931.

one-half to two times as steep as the dips at the surface. In the Quinton and Carney fields the beds below the surface on the north side of the anticline are faulted, with the upthrow to the north. This has the effect of broadening the top of the subsurface anticline.

The westward plunge of the anticline is steeper in the areas between the gas fields, which lie on terraces along the crest of the anticline. The richest accumulations of gas occur on the west ends of these terraces and within 200 feet vertically of the top of each terrace.

DRILLING PRACTICE

In the early days of development drilling was done by means of the standard derrick and churn drill, but many of the wells are now completed with portable equipment of lighter weight. The drilling time of a well has been materially reduced, in spite of the use of lighter equipment. The average time of completion for the 1,450-foot wells in the Quinton field was 1.8 months; the 2,050-foot wells in the Carney field, 1.25 months; and the 2,600-foot wells in the Blocker-Featherston field, 2.1 months. Some wells in the Carney and Blocker-Featherston fields have been completed in 3 weeks.

The Hartshorne sandstone is drilled slowly, owing to its hardness and to the fact that drilling water can be kept in the hole only with difficulty after the gas is encountered. The common practice is to allow the gas to blow into the air while the Hartshorne sandstone is being drilled. In some of the wells this loss has been obviated by filling or "loading" the hole with water to such a point that the reservoir pressure is overcome by the weight of the column of water. This practice saves the gas, but opinion is divided as to its effect, whether harmful or otherwise, on the yield of the well.

The Hartshorne sandstone is usually "shot" in order to increase the flow of gas, and the flow from some of the small wells is thereby increased as much as seven times. Wells in the Blocker-Featherston area were shot with 60 to 100 quarts of nitroglycerin as soon as the drilling was finished. In the other fields shooting is done with smaller charges to revive a declining well or to increase the initial production of a small well.

Three strings of casing are usually used in drilling a well. A short string shuts off the water from the sandstones near the surface. A second string is used to shut off the "hole full of water" that usually occurs in the sandstone member of the McAlester shale. The last string of casing is set on the Hartshorne sandstone. The two outside strings and sometimes the third string are pulled after the well is tubed.

The cost of drilling a well to the Hartshorne sandstone has ranged from $2,000 in the Quinton field to $15,000 in the Blocker-Featherston field. In 1934 the cost of a 2,000-foot well in the Carney field ranged from $7,000 to $9,000, of which about one-third can be recovered through salvage of equipment after the well has been abandoned.

QUINTON GAS FIELD

Development.—The Quinton field, located about 1 mile south of the town of Quinton, was discovered in 1915 (p. 216). During its development 52 wells, 11 of which were classed as dry holes, were drilled and 1,250 acres was proved to be productive of gas in commercial quantities. The locations of the wells are described in the following table and shown on the map of the field (pl. 21). The locations given are the results of a careful check of the wells in the field and of the original drilling reports and land records, and it is believed that the confusion that exists regarding these old records will be eliminated by the data presented here.

Chronologic drilling schedule of the Quinton field

Date of completion	Company	Well no.	Farm	Approximate location [1]	Sec.	T. N.	R. E.	Initial measurements: Open flow (M cubic feet)	Initial measurements: Rock pressure (pounds per square inch)
Sept. —, 1915	Quinton Oil & Gas Co	1	Fee	SWc NE¼SW¼NW¼	1	7	18	25,000	500
Apr. —, 1916	do	2	do	C N½NW¼SW¼	1	7	18	15,000	500
Sept. 1, 1916	do	1	Floyd	C W½SE¼SE¼	2	7	18	1,500	520
Nov. —, 1916	do	3	Fee	C EL SE¼NW¼	1	7	18	(2)	
Feb. 15, 1917	Pittsburg Oil & Gas Co	1	Olson	C NW¼SE¼	1	7	18	(3)	
Mar. 20, 1917	Quinton Oil & Gas Co	2 or 5	Floyd	NEc SE¼	2	7	18	500	265
June 27, 1917	do	4 or 6	Fee	NWc SW¼SW¼	1	7	18	7,000	440
1917	do	5	do	C SL NE¼SW¼SW¼	1	7	18	(3)	
Aug. —, 1917	Choctaw Natural Gas Co	1	C. B. Basom	NWc SW¼SE¼	2	7	18	(2)	
Aug. 16, 1917	Quinton Oil & Gas Co	7	Fee	SWc SE¼SW¼SW¼	1	7	18	6,000	600
Do	Pittsburg Oil & Gas Co	1	King	C E½NE¼SW¼	1	7	18	(3)	
Dec. 5, 1917	do	2	do	NEc SE¼SW¼	1	7	18	10,000	550
Feb. 27, 1918	do	2	Olson	SWc SW¼SE¼	1	7	18	32,000	550
Aug. 27, 1918	do	3	King	SEc SW¼NE¼SW¼	1	7	18	15,000	510
Oct. —, 1918	Quinton Relief Oil & Gas Co	1	Curry	NEc NW¼	12	7	18	30,000	500
Nov. 26, 1918	Pittsburg Oil & Gas Co	1 or 6	N. Riddle	SWc SE¼SE¼	1	7	19	17,267	500
Dec. 5, 1918	Quinton Spelter Co	1	S. Riddle	NWc NE¼	12	7	19	7,845	495
Jan. 26, 1919	do	1	C. Riddle	NWc NE¼NE¼	12	7	19	19,000	495
Mar. 13, 1919	Pittsburg Oil & Gas Co	2 or 7	N. Riddle	SEc SE¼	1	7	18	2,000	460
Mar. 24, 1919	Quinton Spelter Co	1	Baugh	NEc SW¼NW¼	12	7	18	7,200	530
May 4, 1919	Quinton Relief Oil & Gas Co	2	Curry	NW¼SE¼NW¼	12	7	18	3,500	500
May 31, 1919	Quinton Oil & Gas Co	1	C. Riddle	C SL SE¼SW¼	6	7	19	6,616	460
Aug. 15, 1919	do	1	J. Riddle	SWc SE¼	6	7	19	2,382	420
Aug. —, 1919	Quinton Relief Oil & Gas Co	1	Gray	SWc NW¼	1	7	18	2,000	250
Jan. 15, 1921	do	1	M. Pope	SWc SE¼SW¼NE¼	2	7	18	(3)	
Jan. 28, 1921	Pittsburg Oil & Gas Co	3	Olson	SWc NE¼NW¼NW¼	7	7	19	18,000	420
Apr. 1, 1921	Quinton Oil & Gas Co	1	Williams	C NE¼	6	7	19	(2)	
Mar. 1, 1921	Quinton Spelter Co	2	S. Riddle	NEc NW¼NE¼	12	7	18	10,500	370
Aug. 29, 1921	Midwestern Oil & Gas Co	1	Noblin	SEc SW¼NE¼	11	7	18	3,000	390
Do	Quinton Relief Oil & Gas Co	3	Curry	NWc NE¼NW¼	12	7	18	3,000	390
Apr. 12, 1922	Quinton Spelter Co	2	C. Riddle	NEc NE¼	12	7	18	6,110	325
May 28, 1922	do	1	Aldridge	SWc NW¼NW¼NE¼	7	7	19	14,500	370
July 25, 1922	do	2	do	SWc NW¼NE¼	7	7	19	1,300	355
Jan. 2, 1923	Quinton Oil & Gas Co	4	Olson	SEc NE¼NE¼NW¼	7	7	19	10,000	335
Feb. 7, 1923	do	5	do	C WL NW¼NW¼NW¼	7	7	19	7,000	275
Mar. 24, 1923	do	4	King	C SL SE¼SE¼SW¼	1	7	18	6,000	

June 8, 1923	do	3	Floyd	NEc SE¼SE¼	2	7	18	(2)	
Feb. 15, 1924	do	1	Nottage	C N½S½NW¼	7	7	19	1,117	275
Mar. 18, 1924	Quinton Relief Oil & Gas Co	2 or 7	Aldridge	SEc SW¼SW¼BW¼	6	7	19	9,000	215
Apr. 4, 1914	Quinton Oil & Gas Co	2	Nottage	SWc NW¼NE¼	7	7	19	4,000	240
May 5, 1924	Quinton Spelter Co	3	C. Riddle	NEc SE¼NE¼	12	7	18	1,000	240
May 24, 1924	Quinton Oil & Gas Co	3	Nottage	NEc SE¼NW¼	7	7	19	1,724	240
June 25, 1924	Quinton Relief Oil & Gas Co	3	Aldridge	NEc NW¼SW¼NE¼	7	7	19	9,644	240
Oct. 23, 1924	Quinton Oil & Gas Co	3	N. Riddle	C WL SE¼SE¼	7	7	18	1,404	220
Dec. 31, 1924	Quinton Relief Oil & Gas Co	4	Aldridge	C NE¼	7	7	19	8,153	235
Feb. 7, 1925	Quinton Spelter Co	3	do	NEc SE¼NW¼	7	7	19	8,650	220
July 18, 1925	Quinton Oil & Gas Co	4 or 1	Nottage	SEc SW¼SE¼	2	7	19	500	(4)
May 6, 1926	do	6 or 2	do	SWc SW¼SE¼	2	7	19	500	(4)
Feb. 4, 1927	do	3	do	SWc SW¼	2	7	19	500	(4)

[1] C, Center; c, corner; EL, SL, etc., east line, south line, etc.
[2] Dry.
[3] Gas.
[4] Abandoned.

Stratigraphy and structure of rocks not exposed.—The subsurface stratigraphic sequence is shown on the cross section in plate 20, and a general description of the formations is given on pages 208–213. Coal is more frequently recorded in the upper shale member of the McAlester formation in the Quinton field than elsewhere. The Upper McAlester or Stigler coal and the Lower McAlester or Lehigh coal are shown in many of the well logs. Most of the wells record one of the Hartshorne coals, probably the Upper Hartshorne, near the base of the McAlester shale. A notable exception to this is found in the wells in secs. 1 and 2, T. 7 N., R. 18 E., where not only is the coal absent but a portion of the basal McAlester appears to be missing also. The absence of the coal in secs. 1 and 2 is closely related to a faulted dome which occurs in this area (pl. 21). The presence of a fault is indicated by an apparent displacement of the key horizon in wells on opposite sides of the fault, as drawn on the map. Confirmatory evidence of its presence is given by the shortening of the McAlester shale section on the upthrown side of the fault, as compared with the equivalent sections elsewhere in the field, the presence of several dry holes in the vicinity of the fault, and the marked pressure gradient that developed locally between the dome and the rest of the anticline during the years when large amounts of gas were withdrawn from the southeastern part of the field. The north-south cross sections of the Quinton field (pl. 22) show the magnitude of the fault at the time the middle sandstone member of the McAlester shale was laid down and illustrate the fact that the wells north of the fault and on the top of the dome have from 100 to 140 feet less of the basal McAlester shale than the wells south of the fault. The date of faulting is either post-Hartshorne, pre-McAlester, or very early McAlester.

The northern portion of the gas field lies on the faulted dome. The remainder of the field is situated on a simple plunging anticline. It is terminated on the west by the low structural position of the sandstone and probably by lower porosity of the sand. On the east it is limited also by very unfavorable sand conditions and by a terracing or reversal of the structure. Although the drilling limits of the field are well defined by dry holes, abandoned wells, and small producers, the limits of the reservoir that is supplying the gas are not definitely known, owing in part to the absence of water in the sand, which would concentrate the gas within easily determinable limits.

Producing sand.—The top of the Hartshorne sandstone is found at a depth of 1,300 feet in the Quinton field. The thickness of the formation averages 125 feet but ranges from 20 to 220 feet. About one-half of the formation is composed of sandstone; the remainder is shale and sandy shale. In some of the well logs only half of the sandstone is shown as "pay" sand, but it is probable that all of the sand is gas-bearing to a greater or less degree.

Production and estimated reserves.—The annual withdrawal of metered gas plus the estimated amount of gas used in drilling and lost during completion of the wells is tabulated below.

Annual yield of gas from the Quinton field, 1915–33, in thousands of cubic feet

Year	Metered yield	Used for drilling (estimated)	Lost during completion of wells (estimated)	Total
1915			25,000	25,000
1916	25,522	21,000	33,000	79,522
1917	1,494,055	27,000	47,000	1,567,055
1918	1,836,774	19,000	122,000	1,977,774
1919	2,507,860	26,000	81,000	2,614,860
1920	2,262,515			2,262,515
1921	3,584,350	19,000	69,000	2,672,350
1922	2,857,498	11,000	44,000	2,912,498
1923	3,033,338	15,000	46,000	3,094,338
1924	2,325,337	30,000	72,000	2,427,337
1925	2,450,321	8,000	17,000	2,475,321
1926	2,224,090	4,000		2,228,090
1927	1,793,374			1,793,374
1928	1,454,493			1,454,493
1929	785,076			785,076
1930	690,461			690,461
1931	564,182			564,182
1932	299,538			299,538
1933	81,936			81,936
Total	29,270,720	180,000	556,000	30,005,720

The wells in the Quinton field are spaced so closely and have produced so evenly that the numerical average pressure of the wells was found to conform closely to the weighted average pressure of the drilled area, hence numerical average pressure data are used and, with other related information, are shown in the following table:

Production and pressure data for Quinton field, 1915–33

Year	Gas yield (thousands of cubic feet)		Average well-head pressures as of December (pounds per square inch)	Year	Gas yield (thousands of cubic feet)		Average well-head pressures as of December (pounds per square inch)
	Annual	Cumulative			Annual	Cumulative	
1915	25,000	25,000	530	1925	2,475,321	22,108,270	137
1916	79,522	104,222	(?)	1926	2,228,090	24,336,360	107
1917	1,567,055	1,671,277	(?)	1927	1,793,374	26,129,734	85
1918	1,977,774	3,649,051	425	1928	1,454,493	27,584,227	61
1919	2,614,860	6,263,911	403	1929	785,076	28,369,303	60
1920	2,262,515	8,526,426	330	1930	690,461	29,059,764	59
1921	2,672,350	11,198,776	317	1931	564,182	29,623,946	62
1922	2,912,498	14,111,274	270	1932	299,538	29,923,484	78
1923	3,094,338	17,205,612	190	1933	81,936	30,005,720	78
1924	2,427,337	19,632,949	186				

A study of these pressures justifies the conclusion that they represent only a part of the pressure that expels the gas and that an increment of higher pressure from a peripheral zone around the producing area of the field is necessary to explain the observed phenomena. The history of the field shows a uniform decline in pressure from 1918 to 1928, a period during which the field produced 71.5 million cubic feet of gas per pound of drop in pressure. During the next 2 years the withdrawals were greatly curtailed, the drop in pressure declined to 1 pound annually, and the yield per pound of drop in pressure increased to 737.5 million cubic feet. The withdrawals were reduced further during 1931, 1932, and 1933 and were accompanied by an increase in pressure throughout 1932, but thereafter the pressure remained constant. This history indicates that the drilled portion of the reservoir is being recharged by gas from the undrilled portion and that the rate of discharge from the field after 1928 was less than the rate at which it was being recharged. This process is due to a pressure differential between the two portions of the reservoir.

The maintenance of a constant pressure of 78 pounds to the square inch for 1932 and 1933 indicates that the pressure had been equalized during that period; hence this figure represents the pressure of the entire reservoir at that time. Therefore the rate of yield can be computed as follows:

Cumulative yield÷drop in effective reservoir pressure=yield per pound of drop in reservoir pressure; or

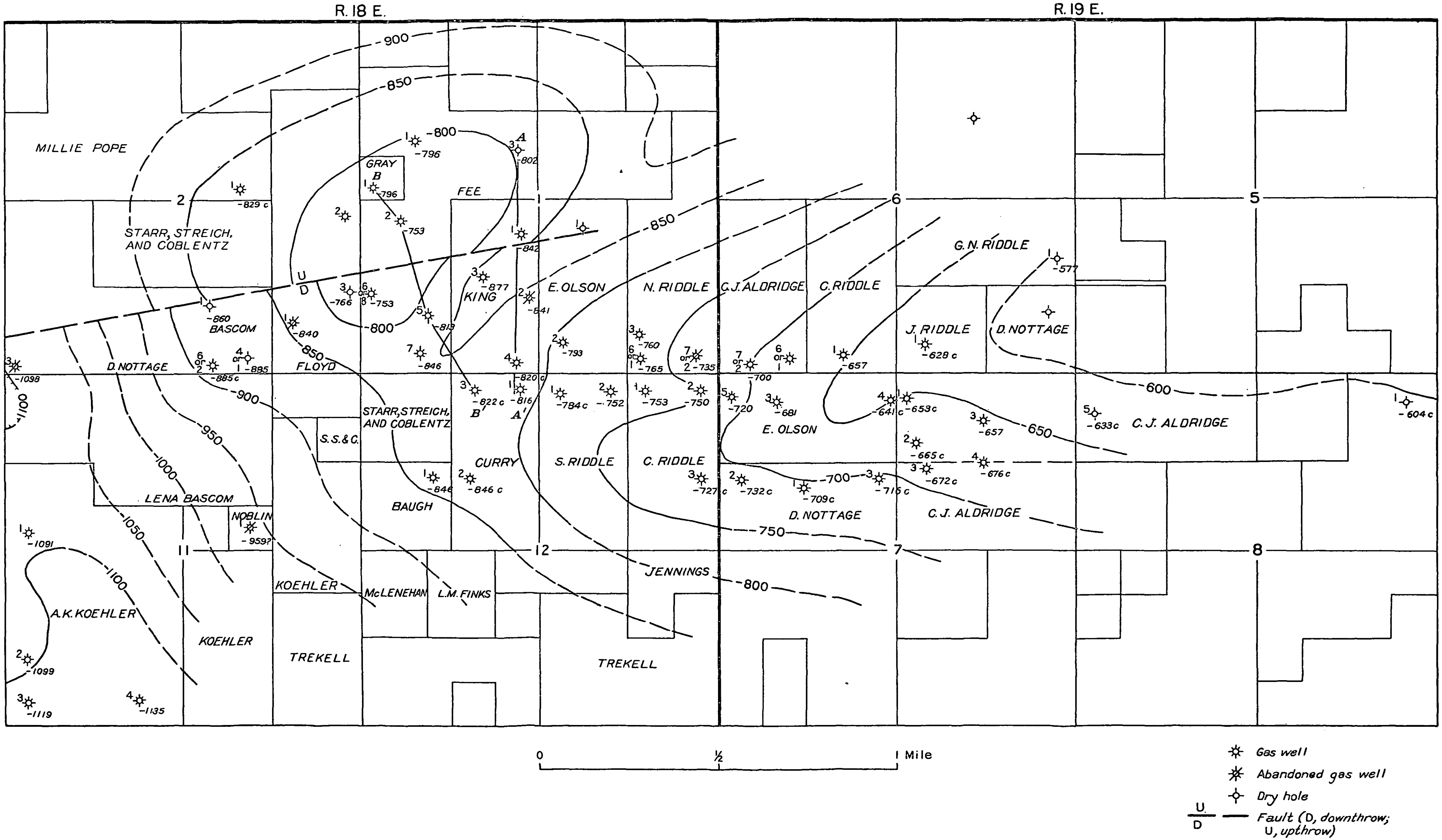
$$\frac{30{,}005{,}720{,}000}{530-78}=66{,}384{,}000 \text{ cubic feet}$$

and the gas reserves computed at atmospheric pressure would be

$$66{,}384{,}000\times 78=5{,}177{,}952{,}000 \text{ cubic feet,}$$

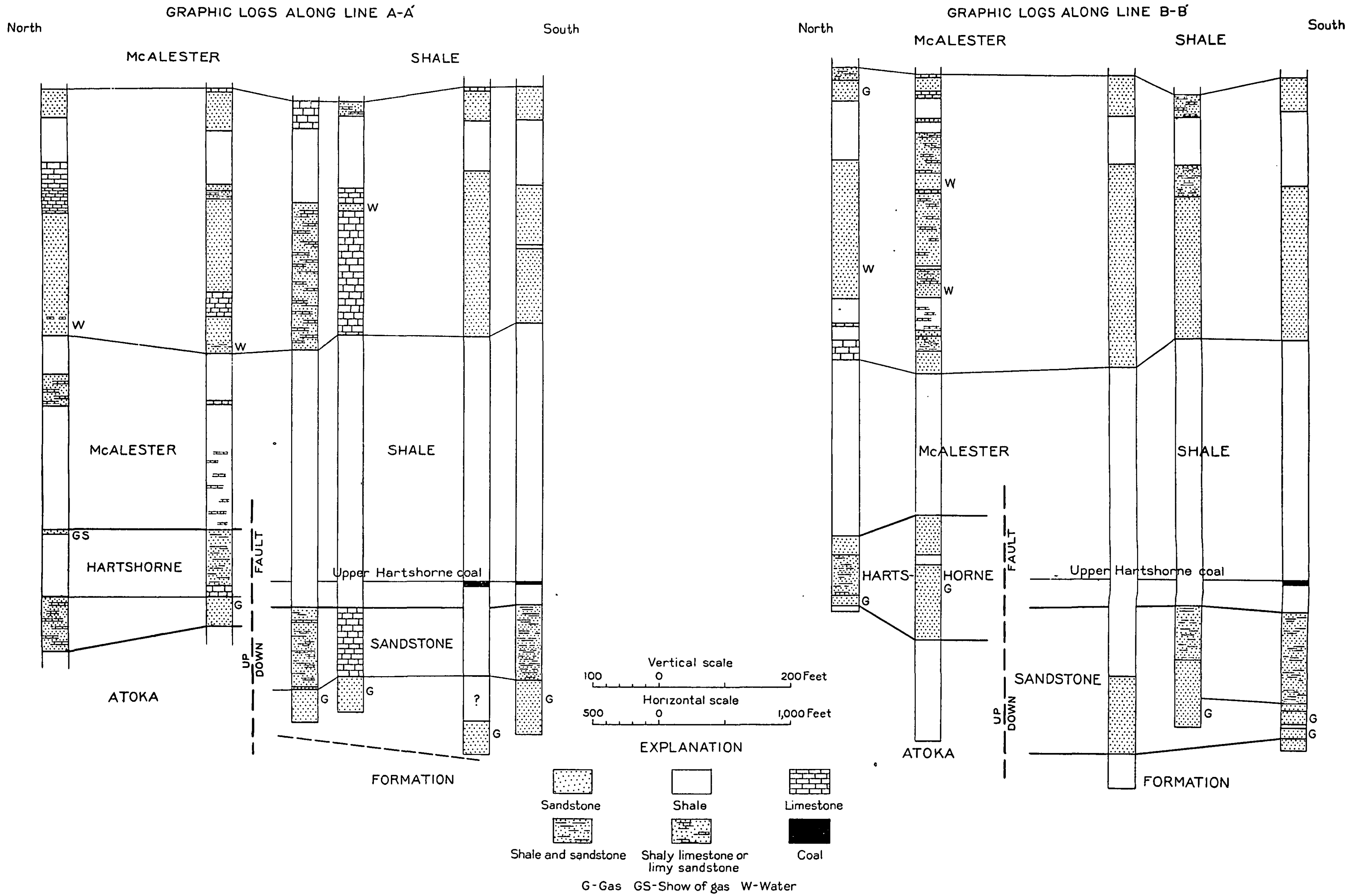
which gives a total yield at atmospheric pressure for the field of 35,183,672,000 cubic feet.

The relations between production and pressure are illustrated graphically in figure 10, which shows that the numerical average pressures (curve B) are less, by an average of 62 pounds, than the reservoir pressure (curve A). Curve A was constructed by connecting the two points 546 pounds (no gas withdrawal) and 80 pounds (30 billion cubic feet cumulative gas withdrawals). These pressure figures were obtained by reducing the well-head pressure to the bottom-hole pressure, and as they were taken after periods of quiescence, during which the reservoir pressures had been equalized, these bottom-hole pressures represent the pressure of the reservoir. The graph indicates that the ultimate production computed from curve B would be 11 percent lower than that computed from curve A. The parallelism of the two curves indicates that a constant differential pressure is maintained between the field and the remainder of the reservoir during those periods when the rate of withdrawal is in excess of the rate of recharge or equalization of pressure. As this pressure differential probably represents the result of the interstitial friction, or the resistance to the flow of gas which is offered by pore space of the reservoir sandstone outside of the periphery of the field, and is constant, it suggests that the reservoir volume from which gas flows



MAP OF THE QUINTON GAS FIELD.

Contours drawn on top of the Upper Hartshorne coal or an equivalent bed. Contour interval 50 feet. Datum mean sea level. Names on tracts are those of fee owners when wells were drilled. Numbers at left of well symbols are those assigned by lease owners. Italic numbers adjacent to the well symbols show depth below sea level of the top of the Upper Hartshorne coal or equivalent bed. The letter C following the italic number indicates that the Upper Hartshorne coal was recorded in the well log.



NORTH-SOUTH CROSS SECTIONS OF DRILLERS' LOGS OF WELLS IN THE QUINTON GAS FIELD.

Shows a pre-McAlester post-Hartshorne fault.

into the drilled portion of the field does not extend beyond a definite though unknown limit, irrespective of the drop in the field pressure.

Data are not available for computing the exact extent of the reservoir, but a minimum distance through which drainage is effective on the west side of the field can be deduced from the history of the Midwestern Oil & Gas Co.'s No. 1 Noblin well, drilled near the center of sec. 11, T. 7 N., R. 18 E., half a mile west of the nearest producing well. The Noblin well was completed in August 1921 with a pressure of 390 pounds, not greatly in excess of the average pressure of the field at the time, which was from 317 to 330 pounds. The difference between the initial pressure of the well (390 pounds) and the initial

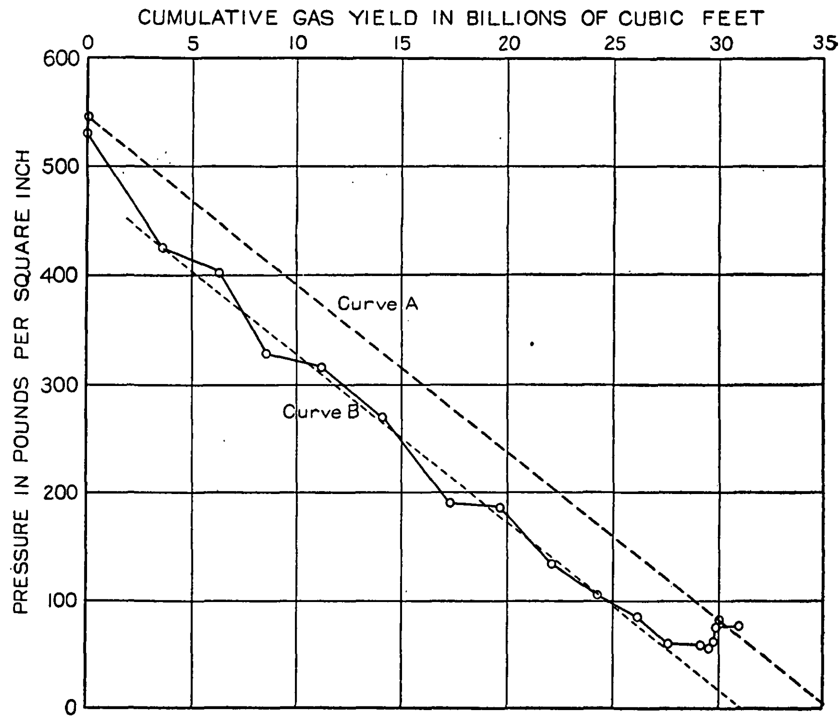


FIGURE 10.—Graph showing the relation between cumulative gas yield and reservoir and well-head pressures in the Quinton gas field. A, Reservoir pressures; B, numerical-average well-head pressures.

field pressure (530 pounds) is the drop in pressure that took place while the field was producing about 10,000,000,000 cubic feet of gas, from 1915 until August 1921. The ratio between pressure and production indicated by this well is a drop of 14 pounds per billion cubic feet of gas produced. This figure corresponds so closely to the pressure-production ratio for the entire life of the field—namely, 15 pounds per billion cubic feet—that it strongly suggests a connection between the Noblin well and the field and justifies the assumption that, in this area at least, gas flows into the producing part of the field from a distance of at least half a mile.

The maximum limit of drainage lies somewhere between the distances of half a mile and 1 mile in this area, because the Carney field, the eastern edge of which is half a mile west of the Noblin well, or 1 mile west of the Quinton field, showed a field pressure higher than the original pressure of the Quinton reservoir, although development in the Carney field began after the Quinton field had been greatly depleted. The only significant exception to the higher pressures encountered in the Carney field is recorded in the completion history of the Sans Bois Gas Co. No. 1 Koehler well, in the southwest corner of the NW¼ sec. 11, T. 7. N., R. 18 E., approximately 1 mile west of the nearest producing well in the Quinton field. This well penetrated two separate gas sands, one at a depth of 1,871 to 1,900 feet and the other at 1,915 to 1,960 feet, and was completed on June 15, 1927, as a small gas well with a pressure of 400 pounds. At this time the pressure of the Quinton field was about 95 pounds, and the pressure of the Carney field was 585 pounds. The operators plugged back the lower sand, whereupon the pressure rose to 580 pounds. As the Hartshorne sandstone was not known to contain low-pressure zones, it was thought that the lower sand was connected with the partly depleted Quinton reservoir. Although this assumption may be correct, the evidence is inconclusive.

For the purpose of computing the porosity of the reservoir rock, it has been assumed, for the reasons given above, that the gas reservoir extends for half a mile beyond the producing limits of the field except on the east side, where the sand is very thin. The gas-containing reservoir of the Quinton field, under this assumption, covers an area of about 2,270 acres, or 98,881,200 square feet. The average thickness of gas-producing sand in the Quinton field being accepted as 60 feet, the volume of the reservoir is 5,932,872,000 cubic feet.

The effective porosity—that is, the percentage of pore space through which gas will be delivered to the wells—can be computed by determining the volume that would be occupied at the original pressure of the reservoir by all of the gas producible from the field and dividing the volume thus determined by the total volume of the reservoir rock. The figure obtained for the Quinton field is 16.

The volume of gas originally present in the reservoir of the Quinton gas field was determined by the following formula:

$$Vr=\frac{PVTr}{PrT}C$$

which combines the formulas given by Diehl [46] for the pressure-volume-temperature relations of perfect gases and the deviation of natural gas from those formulas.

[46] Diehl, J. C., Natural-gas handbook, pp. 50, 201, Erie, Pa., American Meter Co., Inc., 1927.

In this formula Vr=volume of gas in the reservoir.
Pr=absolute pressure in the reservoir.
Tr=absolute temperature in the reservoir.
V=volume of gas at the surface.
P=absolute pressure at the surface.
T=absolute temperature at the surface.
C=a compressibility factor for the gas.

For the Quinton field the various factors to be inserted in the formula were determined as follows:

P is equal to the atmospheric pressure plus the base pressure at which the gas was measured, a total of 16.4 pounds per square inch.

V is the estimated total volume at the surface of the gas of the Quinton field, 35 billion cubic feet.

Tr was considered to be 543° Abs. (the mean annual temperature at the surface, 60° F., plus an increase of temperature of 1° F. in each 60 feet of depth in a 1,400-foot well, amounting to 23° F., plus 460° to convert Fahrenheit temperature to the absolute temperature required by the formula).

Pr was considered to be 560.4 pounds per square inch (the original well pressure, 530 pounds per square inch; plus atmospheric pressure, 14.4 pounds per square inch; plus the pressure of a 1,400-foot column of gas of 0.58 gravity, 16 pounds per square inch).

T is 520° Abs. (the mean annual temperature at the surface, 60° F., plus 460° to convert Fahrenheit temperature to absolute temperature).

C, the compressibility factor for the gas of the Quinton field, was taken as 0.904, as determined by the formula.[47]

$$B=\frac{0.154p(m+4e+3c+0.22a)}{1,000}$$

In this formula
B=deviation factor, in percent.
p=gage pressure, in pounds per square inch.
m=methane content, in percent.
e=ethane content, in percent.
c=carbon dioxide content, in percent.
a=air content, in percent.

The factors for the Quinton field that are to be inserted in this formula are as follows:

p=well-head pressure of 530 pounds plus pressure of 16 pounds per square inch due to a column of gas 1,400 feet high of 0.58 gravity =546 pounds per square inch.
m=95 percent, by analysis.
e=4.4 percent, by analysis.

[47] Diehl, J. C., op. cit., p. 201.

$c = 0.5$ percent, by analysis.

$a = 0.1$ percent, by analysis.

Substituting these figures in the formula, we have

$$B = \frac{0.154 \times 546 (0.95 + [4 \times 0.044] + [3 \times 0.005] + [0.22 \times 0.001]) = 0.096}{1{,}000}$$

$$C, \text{ the compressibility factor} = 100 \text{ percent} - B = 0.904$$

Inserting this figure in the formula, we have

$$Vr = \frac{16.4 \times 35{,}000{,}000{,}000 \times 543 \times 0.904}{560.4 \times 520} = 967{,}000{,}000 \text{ cubic feet.}$$

Dividing the volume of gas originally present in the reservoir by the previously computed volume of the reservoir rock gives the effective porosity of the reservoir rock—16 percent.

CARNEY GAS FIELD

Development.—In the Carney field 68 wells and 1 dry hole have been completed. The rate of development, location, and size of the wells, together with other pertinent data, are shown in the following table:

Chronologic drilling schedule of the Carney field, in T. 7 N., R. 18 E.

Date of completion	Company	Well no.	Farm	Approximate location [1]	Sec.	Initial measurements: Open flow (M cubic feet)	Initial measurements: Rock pressure (pounds per square inch)
Aug. 21, 1923	Quinton Spelter Co.	1	S. Carney	C NW¼SE¼	18	1,000	576
July 15, 1926	do	1	Amos	SWc NW¼NW¼	10	25,500	595
Sept. 21, 1926	Quinton Relief Oil & Gas Co.	1	S. Carney	NEc SE¼NE¼SE¼	9	32,500	595
Dec. 30, 1926	do	1	C. Bascom	NWc NE¼SW¼	10	40,144	590
Mar. 7, 1927	do	1	L. Bascom	NWc NW¼SE¼	10	33,420	590
June 15, 1927	Sans Bois Gas Co.	1	Koehler	SWc SW¼NW¼	11	5,830	580
Feb. 20, 1928	Quinton Spelter Co.	1	Houston	C N½NE¼NE¼	17	14,500	585
May 10, 1928	do	1	Curry	NEc NW¼SE¼SE¼	9	47,049	580
Sept. 29, 1928	do	1	Vail	SEc SE¼SE¼	8	10,981	585
Dec. 15, 1928	do	1	Daugherty	NWc SW¼NE¼	10	30,460	555
Oct. 18, 1929	Midwestern Oil & Gas Co.	1	Gunn	NEc SE¼SE¼	10	30,000	550
Nov. 12, 1929	do	1	E. Carney	NEc NE¼NW¼	15	17,000	520
Dec. —, 1929	do	1	Tucker	SEc SW¼SE¼	9	9,000	500
Jan. —, 1930	do	1	Benedict	SWc SE¼SE¼	10	23,000	550
Mar. 2, 1930	Utilities Production Corporation.	1	Wilbur State Bank.	NWc SE¼SE¼NE¼	9	25,000	520
Mar. —, 1930	Midwestern Oil & Gas Co.	2	Carney	NEc NW¼NE¼	15	25,100	550
May 6, 1930	do	1	Treckell	NWc NW¼NW¼	14	20,000	550
June —, 1930	Choctaw Gas Co.	1	Brown	SEc NE¼NE¼SE¼	9	25,000	500
June 13, 1930	Midwestern Oil & Gas Co.	1	Curry	C S½NW¼NE¼	9	15,000	540
June 29, 1930	do	1	Bascom	SEc SE¼SE¼	10	32,000	550
July 1, 1930	Utilities Production Corporation.	2	C. Bascom	NW¼SE¼SE¼	10	24,800	520
Aug. 25, 1930	Midwestern Oil & Gas Co.	1	Dyer	C S½SE¼SW¼	4	14,000	550
Sept. 12, 1930	Utilities Production Corporation.	1	C. Riddle	NWc NE¼NW¼	15	22,000	520
Sept. 18, 1930	Choctaw Gas Co.	1	School	SEc SE¼SW¼	9	8,500	505
Sept. 22, 1930	Utilities Production Corporation.	2	Koehler	NWc SW¼SW¼	11	17,000	520
Oct. 14, 1930	Midwestern Oil & Gas Co. et al.	1	do	NWc NE¼NE¼	15	10,000	500

[1] C, center; c, corner; SL, south line.

Chronologic drilling schedule of the Carney field, in T. 7 N., R. 18 E.—Continued

Date of completion	Company	Well no.	Farm	Approximate location	Sec.	Initial measurements	
						Open flow (M cubic feet)	Rock pressure (pounds per square inch)
Oct. 22, 1930	Midwestern Oil & Gas Co. et al.	2	Curry	SWc SE¼SE¼	9	9,200	520
Oct. 26, 1930	Utilities Production Corporation.	3	do	SWc SW¼SW¼	11	25,000	520
Do	Public Service Co	1	E. Carney	NEc NE¼NW¼	16	8,000	580
Nov. 20, 1930	Utilities Production Corporation.	2	Wilbur State Bank.	C N½SW¼NE¼	9	17,898	520
Nov. 29, 1930	do	1	Hinton	SWc SW¼SE¼	9	7,864	520
Dec. 12, 1930	Public Service Co	2	E. Carney	NWc NW¼NW¼	16	15,000	580
Dec. 15, 1930	Midwestern Oil & Gas Co. et al.	2	Koehler	NEc NE¼NE¼	15	12,449	530
Jan. 2, 1931	Utilities Production Corporation.	3	C. Bascom	SWc SW¼NE¼	10	24,067	470
	Choctaw Gas Co. et al	1	Hayhurst	NWc NE¼NE¼	16	10,000	------
Jan. 24, 1931	Choctaw Gas Co	1	Hendrickson	SWc NE¼SE¼	8	12,855	515
Jan. 28, 1931	do	2	do	NEc NW¼NW¼	16	6,412	510
Feb. 11, 1931	Choctaw Gas Co. et al	3	Hayhurst	NWc NW¼NE¼	16	5,000	520
Feb. 15, 1931	Midwestern Oil & Gas Co.	1	White	SEc NE¼SE¼	8	22,000	550
Mar. 4, 1931	do	2	Treckell	C N½NE¼NW¼	14	27,120	560
Mar. 23, 1931	Utilities Production Corporation.	1	J. Carney	NWc NW¼NE¼	9	21,000	495
Apr. 2, 1931	do	1	W. Carney	SWc SW¼SW¼	9	3,500	480
Apr. 20, 1931	do	4	C. Bascom	SEc SE¼SW¼	10	23,000	480
May 21, 1931	Choctaw Gas Co	1	Louvier	NEc SE¼NE¼	8	28,895	510
May 22, 1931	Utilities Production Corporation.	2	Vail	NEc SE¼SE¼	8	9,293	505
May 25, 1931	do	3	Wilbur State Bank.	C N½NE¼NW¼	9	10,900	505
May 31, 1931	Midwestern Oil & Gas Co.	1	Mattocks	C NW¼SE¼	8	970	590
June 20, 1931	Utilities Production Corporation.	3	Vail	NWc SE¼SE¼	8	10,170	510
June 26, 1931	Choctaw Gas Co	1	Ross	NWc NW¼SW¼	17	2,170	575
June 27, 1931	Utilities Production Corporation.	4	Wilbur State Bank.	SWc NW¼SW¼	9	13,765	510
July 28, 1931	Choctaw Gas Co	2	Louvier	NWc SE¼NE¼	8	16,599	520
Sept. 10, 1931	Utilities Production Corporation.	5	C. Bascom	SWc SE¼SW¼	10	27,542	490
Oct. 23, 1931	do	4	Koehler	C SL SE¼SW¼	11	16,070	500
Jan. 20, 1932	Midwestern Oil & Gas Co.	2	Mattocks	C NE¼NE¼	8	12,000	590
Do	do	3	do	C W½SW¼NE¼	8	1,000	590
Feb. 13, 1932	Utilities Production Corporation.	1	Church	NEc NW¼NE¼	16	6,927	500
Oct. 26, 1932	Midwestern Oil & Gas Co.	1	Ogden	C SE¼SE¼	5	8,000	------
Nov. 21, 1932	do	1	Hall	C S½SE¼NE¼	8	2,000	------
Dec. 4, 1932	do	2	Dyer	C SW¼SW¼	4	8,000	------
Oct. 22, 1933	do	5	Wilbur State Bank.	NWc SW¼NW¼	9	16,000	400
Oct. 30, 1933	Utilities Production Corporation.	1	Zelinka	SWc NW¼NW¼	10	2,000	400
Dec. 15, 1933	do	1	W. Carney	SE¼NE¼NE¼	9	[2]	------
Feb. 15, 1934	do	6	Wilbur State Bank.	C NW¼NW¼	9	22,500	------
Mar. 10, 1934	Midwestern Oil & Gas Co.	1	Garis	NWc SE¼NW¼	8	4,435	500
Mar. 31, 1934	do	1	Courts-Shelton	SEc SE¼NW¼	7	700	500
June 5, 1934	do	2	Ogden	C NE¼NW¼	8	947	515
Jan. 23, 1935	do	1	Colbert	NEc SE¼NE¼	15	2,850	325
1930?	do	2	L. Bascom	SEc SW¼SE¼	10	[3]	------
1930?	Utilities Production Corporation.	1		NEc NE¼NE¼	16	[3]	------

[2] Dry. [3] Gas.

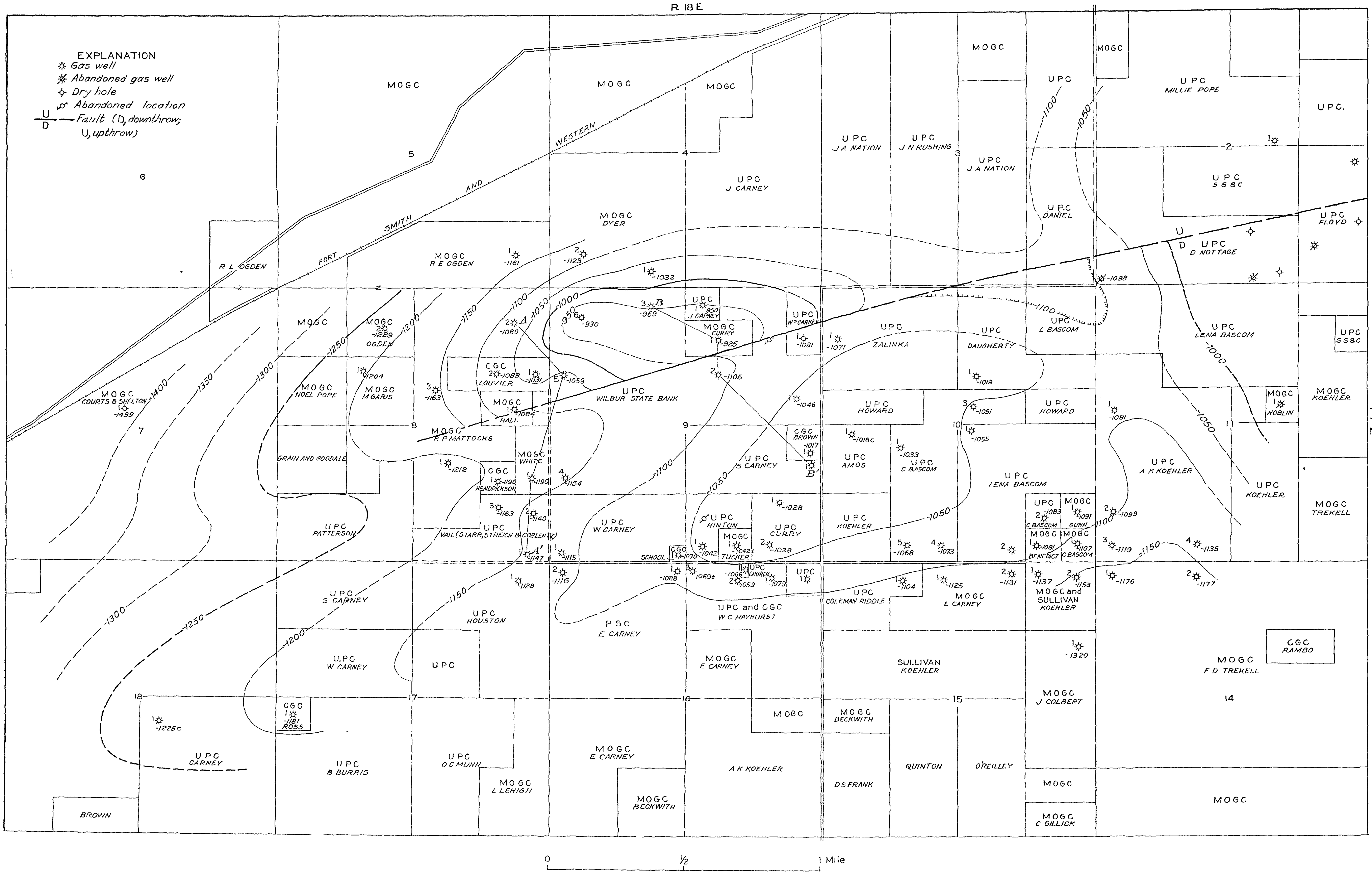
The area in which commercial quantities of gas have been developed is about 2,600 acres. The gas reservoir, however, is considerably larger. This field is the most productive one in the county. It has produced almost as much gas as the Quinton field, and yet its pressure has been depleted only one-third.

Stratigraphy and structure of rocks not exposed.—The Hartshorne sandstone in the Carney field lies in a plunging anticline with a broad faulted top in secs. 9 and 10, T. 7 N., R. 18 E., very little closure on the east, dips of 7° on the north and south flanks, and an elongated western extremity that extends through sec. 18 into the adjoining township on the west. (See pl. 23.) The fault is similar to the one in the Quinton field, in that the break occurs on the north flank of the anticline and the downthrown side is on the south. The fault is approximately parallel with the axis of the Kinta anticline and is in close alinement with the fault in the Quinton field. The position of the fault is indicated by marked differences in the depth to the Hartshorne sandstone in offset wells, by a belt of erratic production in its vicinity, and by thinning of the lower part of the McAlester shale north of the fault.

Among the wells that mark the course of the fault are the Utilities Production Corporation's No. 1 M. Carney, in the SE¼NE¼NE¼ sec. 9, which was dry, although surrounded by producing wells on all but the north side. The Midwestern Oil & Gas Corporation's No. 1 Hall well, in the center of the S½SE¼NE¼ sec. 8, and the same company's No. 1 Mattocks well, in the center of the NW¼SE¼ sec. 8, are very small producers as compared with their north and south offsets, although their structural position is not unfavorable. The small production from these wells may be due to low porosity of the Hartshorne sandstone induced by alteration of the rock in the vicinity of the fault plane.

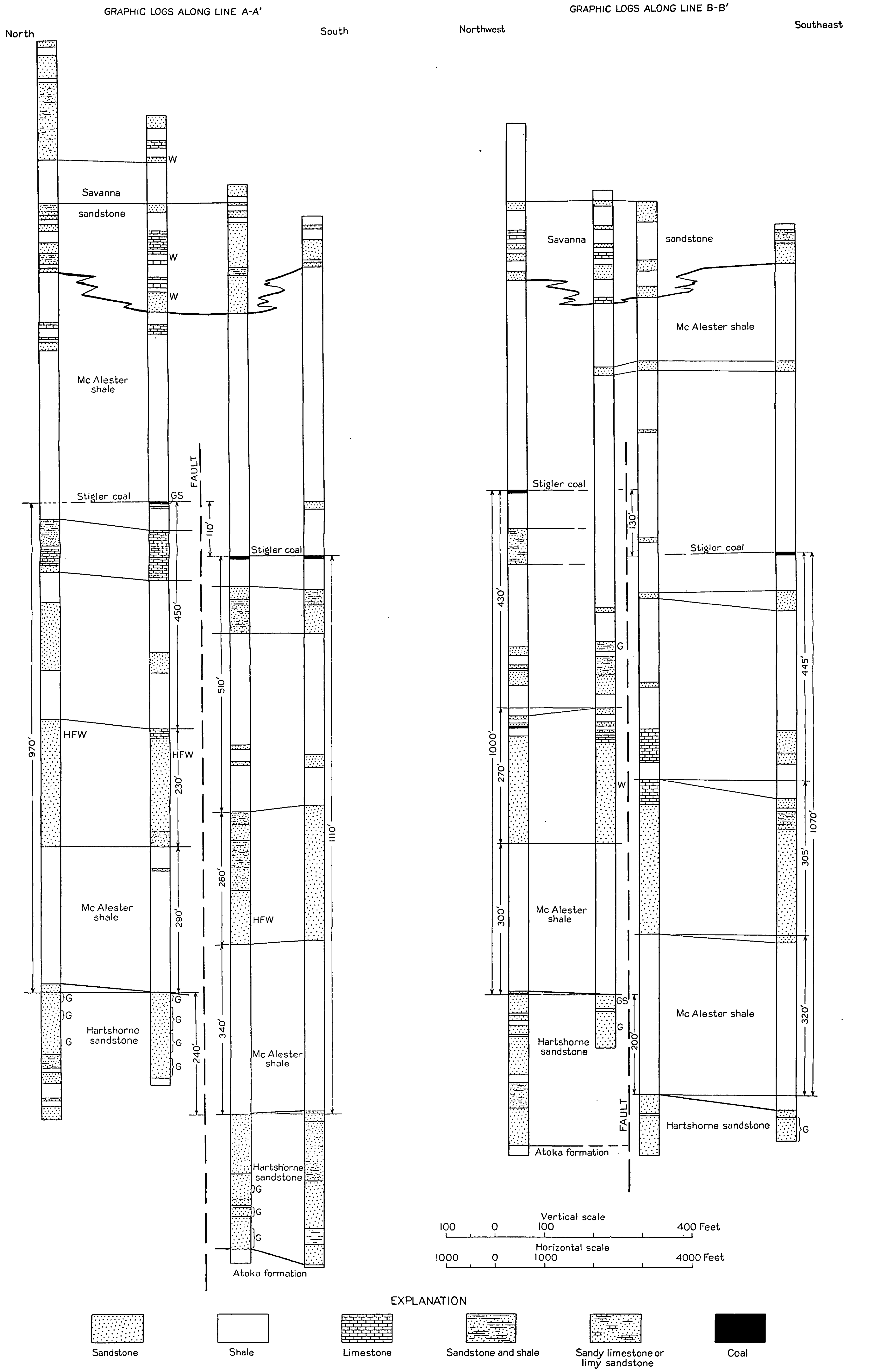
The evidence revealed by the well records and the cross sections (pl. 24) indicates that the fault does not break the rocks exposed at the surface and that its present form is the result of a series of movements that began shortly after the Hartshorne sandstone was deposited and did not end until after the Stigler coal was laid down, in late McAlester time. The average displacement of the Hartshorne sandstone, as shown in the cross sections on plate 24, amounts to about 220 feet, whereas in the Stigler coal it amounts to only about 120 feet. Correlation of the Savanna beds at and near the surface shows no displacement. The difference of 100 feet between the displacement of the Hartshorne sandstone and the Stigler coal is approximately equal to the average difference of 105 feet in the thickness of the beds north and south of the fault. One-third of this difference occurs in the lower shale portion of the McAlester shale, and the remaining two-thirds in the beds above this lower shale and below the Stigler coal.

The Upper Hartshorne coal is absent in nearly all the well records from the Carney field. Whether this is due to elevation of the surface to a level too high to permit the deposition of coal at the end of Hartshorne time, or whether the coal was deposited and subsequently eroded from the top of the anticline after the folding had raised it above baselevel, cannot be determined from the data at hand.



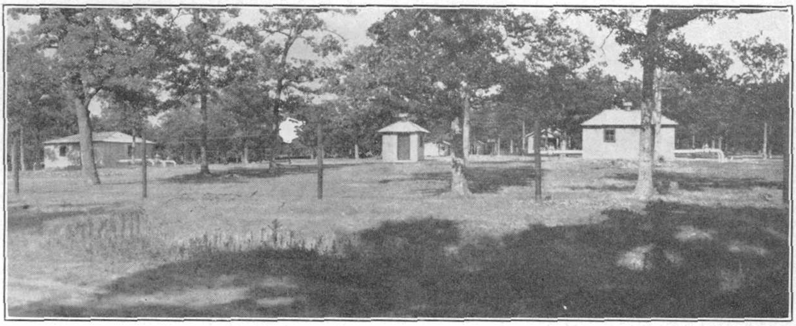
MAP OF THE CARNEY GAS FIELD.

Contours drawn on top of the Hartshorne sandstone Contour interval 50 feet Datum mean sea level Names in italic on tracts are those of fee owners when wells were drilled Names or abbreviations above the fee owners' names are those of the lease owners Numbers at left of well symbols are those assigned by lease owners Italic numbers adjacent to the well symbols show depth below sea level of the top of the Hartshorne sandstone The letter C following the italic number indicates that the Upper Hartshorne coal was recorded in the well log. C G C, Choctaw Gas Co, M O G C, Midwestern Oil & Gas Co, P S C, Public Service Co, S S & C, Starr, Streich & Coblentz, U P C, Utilities Production Corporation

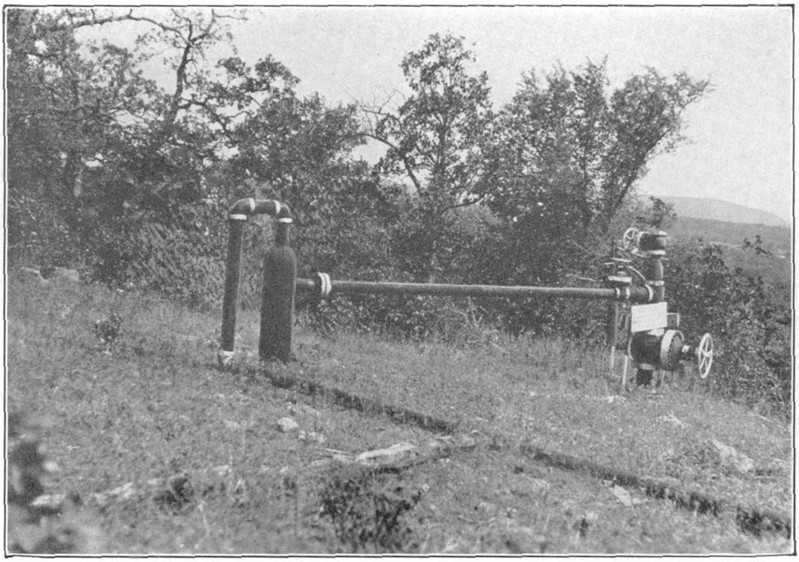


CROSS SECTIONS OF DRILLERS' LOGS OF WELLS IN THE CARNEY GAS FIELD.

Shows a pre-Savanna post-Hartshorne fault.



A. METER AND REGULATOR STATION IN THE CARNEY GAS FIELD.



B. TYPICAL GAS WELL IN THE CARNEY FIELD

Utilities Production Corporation No. 1, Carney.

Producing sand.—The top of the Hartshorne sandstone lies at an average depth of 1,800 feet in the Carney field. The formation is about twice as thick here as it is in the Quinton field and consists chiefly of sandstone. In many of the wells in the Carney field the Hartshorne sandstone consists of two sandstones with an intervening bed of black, dense concretionary shale. The operators expect gas in both sandstones. Only 39 of the 69 wells in the field have been drilled to the Atoka formation, but the remainder are being deepened to the lower "pay" sand and into the top of the Atoka as the necessity for additional gas arises. An analysis of the thickness of the component parts of the Hartshorne in the wells that reached the Atoka formation is tabulated below.

Thickness, in feet, of Hartshorne formation in Carney field

	Average	Maximum	Minimum
Total thickness of the formation	261	346	102
Total thickness of the sandstone beds in the formation	201	323	67
Total thickness of the sandstone beds that are definitely recorded as being gas-bearing	86	208	15
Total thickness of other sandstones	115	263	8

Production and estimated reserves.—The annual metered production of the field together with estimated amounts for drilling and loss during completion, are shown in the following table:

Annual yield of gas from the Carney field, in thousands of cubic feet

Year	Metered yield	Used for drilling (estimated)	Lost during completion of wells (estimated)	Total
1926	142, 242	8, 000	98, 000	248, 242
1927	897, 789	8, 000	77, 000	982, 789
1928	1, 469, 042	8, 000	106, 000	1, 583, 042
1929	2, 107, 058	8, 000	82, 000	2, 197, 058
1930	3, 142, 153	58, 000	478, 000	3, 678, 153
1931	5, 288, 120	53, 000	384, 000	5, 725, 120
1932	7, 152, 769	16, 000	72, 000	7, 240, 769
1933	6, 084, 779	9, 000	36, 000	6, 129, 779
Total	26, 283, 952	168, 000	1, 333, 000	27, 784, 952

These figures are combined to give the annual cumulative production and are shown with well pressures in the following table:

Production and pressure data for Carney field, 1916–33

Year	Gas yield (M cubic feet)		Numerical average well-head pressure, as of December (pounds per square inch)	Year	Gas yield (M cubic feet)		Numerical average well-head pressure, as of December (pounds per square inch)
	Annual	Cumulative			Annual	Cumulative	
1916			595	1930	3, 678, 153	8, 689, 284	476
1926	248, 242	248, 242	582	1931	5, 725, 120	14, 414, 404	486
1927	982, 789	1, 231, 031	573	1932	7, 240, 769	21, 655, 173	437
1928	1, 583, 042	2. 814, 073	533	1933	6, 129, 779	27, 784, 952	380
1929	2, 197, 058	5, 011, 131	528				

The rate of yield of the Carney field per pound of drop in numerical average well-head pressure through 1933 has been:

$$\frac{27,784,952,000}{595-380}=129,232,000 \text{ cubic feet}$$

and the reserves as of January 1, 1934, at atmospheric pressure would be

$$129,232,000\times380=49,108,160,000 \text{ cubic feet}$$

which gives a total ultimate production at atmospheric pressure of 76,893,012,000 cubic feet.

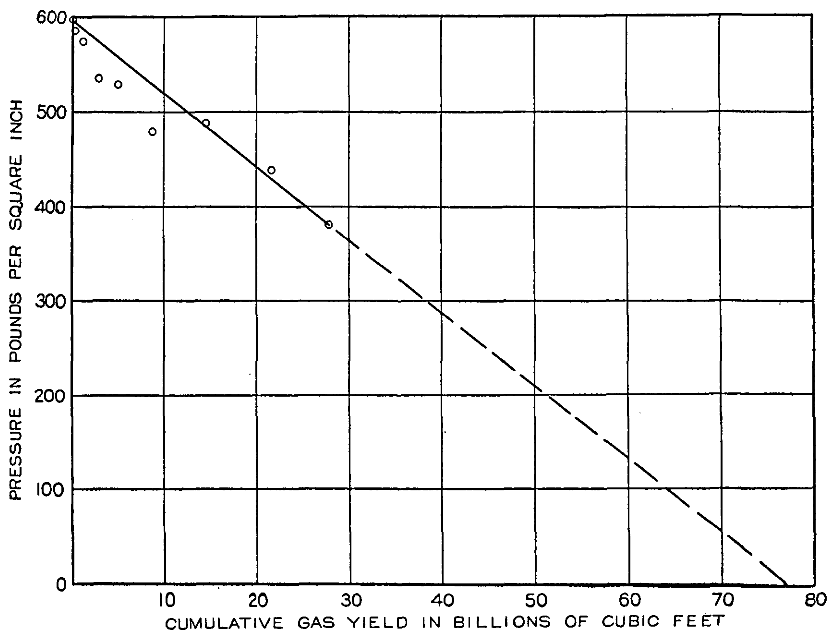


FIGURE 11.—Graph showing the relation between cumulative gas yield and numerical-average well-head pressures in the Carney gas field.

These relations are shown graphically in figure 11. Experience has shown that the estimates of recovery based upon numerical-average pressures are often lower (11 percent in the Quinton field) than the actual recovery; hence this estimate for Carney field may be too low. As back pressure is usually maintained upon a field, any figures representing reserves based upon atmospheric pressure will have to be corrected by an amount that is proportional to the pressure required by operating conditions.

Another means of obtaining an estimate of the total yield of gas is by the use of the porosity method, which depends upon the formula

$$V=\frac{A\times t\times p\times Pr\times T}{P\times Tr\times C}$$

where V=total yield at base pressure.
A=area of the reservoir.
t=thickness of the gas-producing sand.
p=effective porosity of the gas-producing sand.
Pr=original reservoir pressure.
T=absolute temperature at the surface.
P=final pressure at the surface or base pressure.
Tr=absolute temperature in the reservoir.
C=a compressibility factor for the gas.

For the Carney field the factors in the above-stated formula are accurately known, with the exception of A, t, and p, and these can be determined with a good degree of probability.

The area of the reservoir, A, can be judged from the fact that the wells which have been drilled half a mile in advance of the field or which are situated less than half a mile from the nearest producing well in the field show a rate of decline in pressure that is approximately the same as the rate of decline for the field. But the rate of decline of wells that are situated at distances greater than half a mile is only one-third as much as the field decline. (See table, p. 238.) The change in the rate of decline in pressure is abrupt and suggests that a large part of the gas that is produced from the field will come from the zone within half a mile of the drilling limits of the field. On this basis the reservoir would contain about 4,000 acres.

The thickness of the gas-producing zone, t, is based upon the available records, which indicate an average thickness of 86 feet of gas-producing sand.

The effective porosity, p, accepted for the Carney field is 16 percent. This is the figure that was computed for the Quinton field (see p. 232), and it seems reasonable to assume that the same figure holds for the Carney field also, in view of the porosity determinations for the Hartshorne sandstone by Melcher (p. 218).

The remaining factors in the formula may be computed as follows:

Pr, the original reservoir pressure, is the original well-head pressure (595 pounds per square inch), plus atmospheric pressure (14.4 pounds per square inch), plus the weight of a 2,050-foot column of gas (26 pounds per square inch), and is thus equal to 635.4 pounds per square inch.

T, the absolute temperature at the surface, is the mean annual temperature at the surface (60° F.) plus the 460° required to convert to absolute temperature and is thus equal to 520° Abs.

P, the final pressure at the surface, or the base pressure, is 2 pounds per square inch, plus atmospheric pressure, and is thus equal to 16.4 pounds per square inch.

Tr, the absolute temperature in the reservoir, is equal to the mean annual temperature at the surface (60° F.) plus an increase in temperature with the depth below the surface of 1° F. for each 60 feet in wells of an average depth of 2,050 feet (34° F.), plus the 460° required to convert to absolute temperature, and is thus equal to 554° Abs.

C, the compressibility factor for the gas, is taken as equal to 0.904 for reasons given on pages 231–232.

Inserting the figures thus obtained in the formula, we have

$$V=\frac{174{,}240{,}000\times 86\times 0.16\times 635.4\times 520}{16.4\times 554\times 0.904}=96{,}000{,}000{,}000 \text{ cubic feet}$$

for the ultimate yield of the Carney field, as compared with the estimate of 76,893,012,000 cubic feet obtained by computing the yield per pound of drop in pressure.

Rate of decline of pressure in outpost wells in the reservoir south of the fault in the Carney field

Well	Pressure drop of well per billion cubic feet of gas extracted from reservoir (pounds)	Approximate distance of well from nearest producing well at time of measurement of pressure (miles)
Quinton Oil & Gas Co. No. 1 Daugherty	12	¼
Midwestern Oil & Gas Co. No. 1 Tucker	8	¼
Midwestern Oil & Gas Co. No. 1 Benedict	8	¼
Choctaw Gas Co. No. 1 Henderson	8	¼
Utilities Production Corporation No. 1 Zalinka	7	¼
Midwestern Oil & Gas Co. No. 1 Colbert	8	¼
Midwestern Oil & Gas Co. No. 2 Treckel	8	½
Utilities Production Corporation No. 4 Koehler	7	½
Utilities Production Corporation No. 1 Koehler	10	½
Utilities Production Corporation No. 1 Houston	3½	¾
Utilities Production Corporation No. 1 Vail	2	¾
Midwestern Oil & Gas Co. No. 1 Courts-Shelton	3	⅞
Choctaw Gas Co. No. 1 Ross	2	1
Utilities Production Corporation No. 1 Carney (pl. 25, *B*)	2	1½
Field average	7½	

BLOCKER-FEATHERSTON GAS FIELD

Development.—The Blocker-Featherston gas field, the most westerly producing area on the Kinta anticline, is situated in the rolling valley floor of Sans Bois Creek. The wells in the west end of the field begin in the basal shale portion of the Boggy shale; those in the eastern part are located on the top of the Savanna sandstone. The field derives its name from the two towns between which it is situated—Blocker on the west and Featherston on the east.

The discovery of the field is described on page 216. The results of drilling operations are shown in the following table:

Chronologic drilling schedule of the Blocker-Featherston field, in T. 7 N., R. 17 E.

Date of completion	Company	Well no.	Farm	Approximate location [1]	Sec.	Initial measurements	
						Open flow (M cubic feet)	Rock pressure (pounds per square inch)
Mar. 10, 1916	Choctaw Natural Gas Co.	1	Bassett	NEc NE¼SE¼	19	7,000	------
April 1916	do	----	LeFlore (McGaha).	SEc SW¼NE¼	20	[2] 1,500	------
	do	3	LeFlore (Burr)	C NL NW¼SW¼	20	[2] 1,250	------
Mar. 17, 1920	do	4	do	C EL NW¼SE¼	19	(3)	------
Mar. 17, 1920	Costanso Coal & Mining Co.	1	Klug	NEc NE¼SE¼	26	(4)	------
Apr. 30, 1923	Quinton Spelter Co.	1	Pickerell	SEc SE¼NE¼	19	3,850	545
June 11, 1925	Sans Bois Gas Co.	1	Burr	NWc NW¼SW¼	20	7,155	547
June 9, 1926	McAlester Gas & Coke Co.	2	Bassett	SEc NE¼SE¼	19	[2] 500	210
Oct. 11, 1926	Quinton Spelter Co.	1	McFall	NWc NW¼SE¼	22	1,091	510
Jan. 2, 1927	San Bois Gas Co.	2	Burr	SWc SW¼NW¼	20	7,300	------
May 15, 1927	Quinton Spelter Co.	1	Stringer	C W½NE¼	21	2,844	525
July 30, 1927	do	1	E. M. Featherston.	C W½SW¼NW¼	22	5,400	555
Oct. 7, 1927	do	1	M. A. Featherston.	NWc SW¼NE¼	22	350	530
Jan. 13, 1928	do	1	L. C. Featherston.	SWc NW¼NW¼	21	1,040	545
Apr. 23, 1928	do	1	Yoho	C NL NE¼SE¼	21	681	580
July 21, 1928	Sans Bois Gas Co.	1	McGaha	SW SW¼NE¼	20	1,522	520
Mar. 18, 1929	Quinton Spelter Co.	1	Hughes	C W½NE¼	24	2,610	560
Sept. 10, 1933	Utilities Production Corporation.	1	Cooper	NEc NE¼SW¼	22	100	520
(5)	------	1	Lockwood	C EL SW¼NE¼	23	------	------

[1] C, Center; c, corner; NL, EL, north line; east line.
[2] Plugged.
[3] Dry. Total depth, 2,307 feet.
[4] Dry. Total depth, 2,605 feet.
[5] No reliable log.

Stratigraphy and structure of rocks not exposed.—Gas accumulation on the anticline is controlled to a large extent by a pronounced flattening of the plunge of the anticlinal axis, which forms an elongated terrace. Upon this terrace two subsidiary domes with less than 50 feet of closure have been formed. The subsurface map (pl. 26) illustrates these conditions graphically.

The stratigraphic sequence and the thickness of the penetrated formations is shown in the cross section on plate 20. The Hartshorne sandstone is much thicker in this field than it is in either the Quinton or the Carney field, but this does not result in more productive wells, as might be expected. The small yield of the wells may be due to a high degree of cementation, resulting in low effective porosity, as indicated by drillers' reports of unusually hard sand in this field. This condition probably also accounts for the long life of the discovery well, which is still producing its quota of gas.

Production.—Complete production figures from the field are not available, but the data on record are tabulated below.

Annual yield of gas from the Blocker-Featherston field, 1923–33, in thousands of cubic feet

Year	Metered yield	Used for drilling (estimated)	Lost during completion of wells (estimated)	Total	Year	Metered yield	Used for drilling (estimated)	Lost during completion of wells (estimated)	Total
1923	--------	5,000	7,000	12,000	1930	504,288	--------	--------	504,288
1924	12,728	--------	--------	12,728	1931	495,747	--------	--------	495,747
1925	107,277	5,000	15,000	127,277	1932	420,451	--------	--------	420,451
1926	332,202	9,000	2,000	343,202	1933	358,668	5,000	--------	363,668
1927	551,272	18,000	34,000	603,272					
1928	598,664	13,000	6,000	617,664	Total	3,938,936	60,000	69,000	4,067,938
1929	557,639	5,000	5,000	567,639					

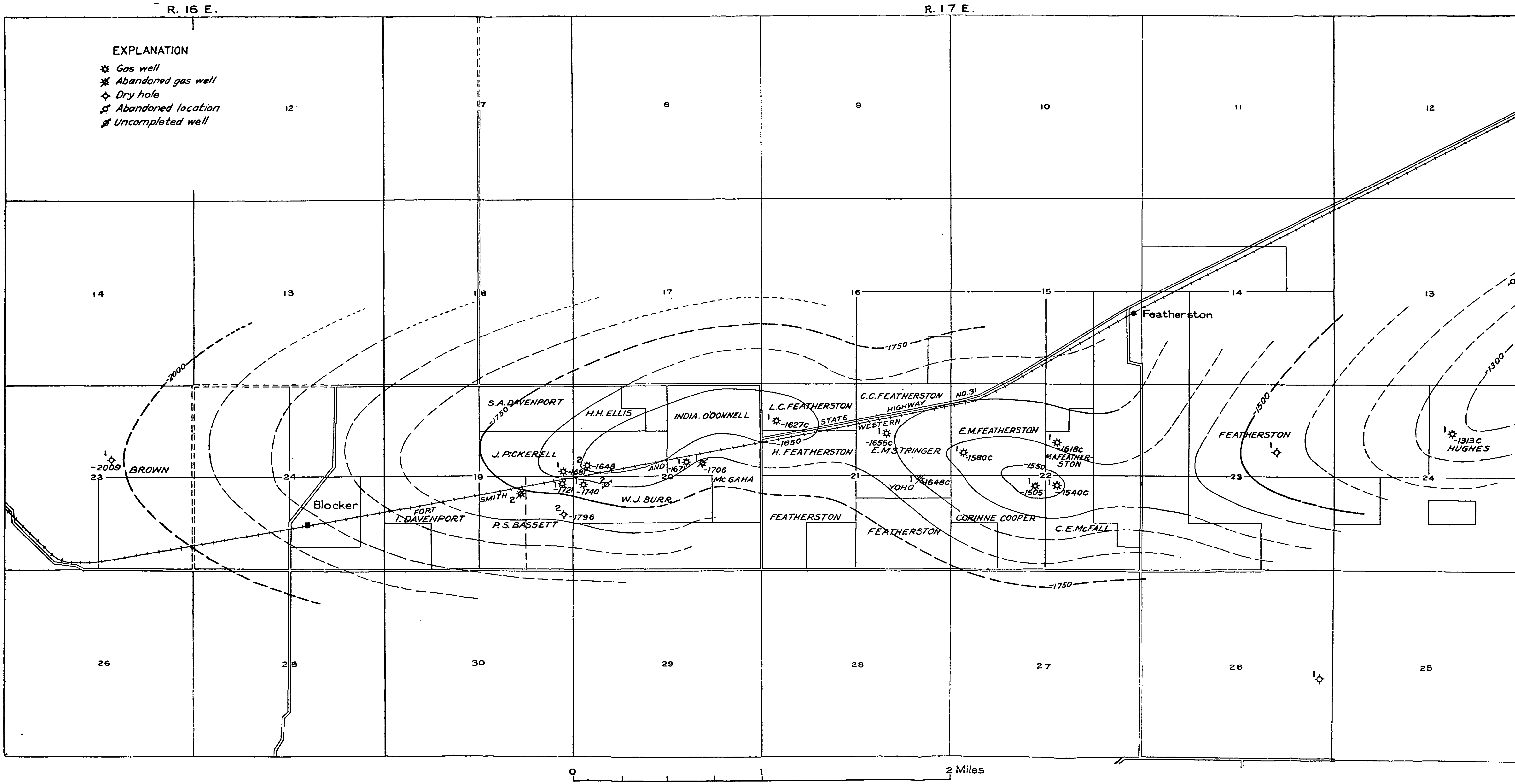
To these figures should be added the gas that was sold to McAlester by the Choctaw Natural Gas Co. from the discovery well during the years 1916 to 1924, which amounted to about 7 billion cubic feet, if the original pressure was 580 pounds per square inch, as it was in the wells near Featherston.

For purposes of analysis, the wells in the field have been divided into three groups. On the west end of the field the discovery well and its three offsets, called the Bassett group, constitute one division; in the middle portion the McGaha and L. C. Featherston wells are another group; and on the east end the remaining wells form a third. (See pl. 26.) The Bassett wells have produced 95 percent of all the metered gas from the field. The second group has supplied very little gas to the line but has shown a large drop in pressure. The third group has produced an insignificant amount of gas and has shown very little drop in pressure. The average well-head pressure of these groups is shown in the following table:

Numerical-average well-head pressures in the Blocker-Featherston field as of December, 1916–33, in pounds per square inch

Year	Group 1, Bassett wells	Group 2		Group 3, other wells	Year	Group 1, Bassett wells	Group 2		Group 3, other wells
		McGaha well	L. C. Featherston well				McGaha well	L. C. Featherston well	
1916	580?	--------	--------	--------	1929	324	410	480	553
1924	545	--------	--------	--------	1930	298	355	445	561
1925	395	--------	--------	--------	1931	288	355	445	576
1926	(?)	--------	--------	--------	1932	288	390	420	545
1927	380	520	545	578	1933	302	370	420	569
1928	308	535	505	574					

A general idea of the productivity of the Hartshorne sandstone in this area can be obtained by a study of the total pressure drop and total production since 1925 for the Bassett group of wells. During this period these wells produced about 3.5 billion cubic feet of gas and the pressure dropped from 395 to 302 pounds. The total with-



MAP OF THE BLOCKER-FEATHERSTON GAS FIELD.

Contours drawn on top of the Upper Hartshorne coal or an equivalent bed. Contour interval 50 feet. Datum mean sea level. Names on tracts are those of fee owners when wells were drilled. Numbers at left of well symbols are those assigned by lease owners. Italic numbers adjacent to the well symbols show depth below sea level of the top of the Upper Hartshorne coal or equivalent bed. The letter C following the italic number indicates that the Upper Hartshorne coal was recorded in the well log.

drawal divided by the total pressure drop gives a yield per pound of drop in pressure of 37,600,000 cubic feet. The production prior to 1926 and subsequent to 1933 can be computed by the use of this recovery factor as follows:

Estimates of recovered and recoverable gas from the Bassett group of wells

Year	Pressure (pounds per square inch)		Recovery factor (cubic feet per pound of drop in pressure)	Gas yield (billions of cubic feet)
	Average for year	Drop during period		
1916 1926	580 395	185	37, 600, 000	[1] 7.0
1926 1933	395 302	93	[1] 37, 600, 000	3.5
1934 (?)	302 0	302	37, 600, 000	[1] 11.4
Total				21.9

[1] Computed.

The relatively large figure of 11.4 billion cubic feet, which represents the reserves of gas for this group of wells, is due to the fact that this group is the only one in the field from which substantial amounts of gas have been withdrawn. Although the extent of the reservoir from which these wells are drawing is not known, it may be that they are being supplied by a relatively large area, which would permit large production with only a small drop in pressure. The computed recovery of 11.4 billions cannot be attained, however, because the wells are operated against a line pressure. The decrease in recovery due to this factor will be proportional to the pressure maintained in the line.

The decline in pressure of the McGaha well, half a mile east of the Bassett group, and of the L. C. Featherston well, half a mile east of the McGaha well, is greatly out of proportion to the small yield that has been recorded. In the McGaha well the total pressure drop since 1927 has been 150 pounds; in the L. C. Featherston well, 125 pounds. Such a decline would represent a yield of approximately 5 billion cubic feet for each well, if the recovery factor for the Bassett group were applied. This yield is more than 50 times the recorded production and suggests either withdrawal of gas from the area beneath the McGaha and Featherston wells as a result of the continuous and large withdrawals from the Bassett group of wells or escape of the gas through leaks in the equipment or through low-pressure sands that have not been completely cased off. The withdrawal of gas from the Bassett, McGaha, and L. C. Featherston wells in the western part of the field has had little effect on pressures in the eastern part

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of the field, although the L. C. Featherston well is only five-eighths of a mile west of the most westerly well in the eastern part of the field.

No estimate of the reserves of gas for this field is attempted in this report, because the limits of the reservoir are too conjectural.

ADDITIONAL GAS AND OIL POSSIBILITIES OF THE KINTA ANTICLINE

There are possible gas-producing sands below the Hartshorne sandstone, in the Atoka and Morrow formations, although the Atoka was not productive on the terrace east and northeast of the town of Canadian, nor on the west end of the Enterprise anticline. The nearest Atoka gas occurs in the vicinity of Wilburton, 12 miles south of Quinton, where gas has been obtained at depths of 3,000 to 4,000 feet below the Hartshorne sandstone. The porous beds of the Morrow formation offer a chance of additional production in this district, for they contain gas on anticlines and elsewhere.

The possibility of oil and gas in the older rocks, chiefly in the Simpson formation, of the Ordovician system, depends on many unknown factors. The least conjectural of these factors are the kind and degree of metamorphism of the rocks and the relation of the known structure in the younger rocks to the structure of the earlier Paleozoic rocks. The metamorphism is intimately connected with the history of the Ouachita Mountains. The most definite statement that can be made is that the degree of metamorphism of the surface rocks does not necessarily indicate a similar degree of alteration in the Ordovician rocks. The second factor is complicated by the presence of unconformities between the sedimentary systems, but the fact that the surface structure of the Kinta, Burning Springs, Flowery Mound, and Lilypad Creek anticlines and the terrace north and northeast of Canadian is duplicated in the underlying sedimentary rocks at least to a depth of 2,500 feet suggests that similar folds may also be found in the still deeper beds. The steepening of the dip of the subsurface beds away from the anticlinal axis and also along the axis away from the highest parts of the anticlines lends credence to this theory. On the other hand, the northwestward thinning of the lower Pennsylvanian beds may reduce the northwest dip by such an amount that the folds will have insufficient closure to retain oil.

As oil is present in the Simpson formation in the counties adjoining the Quinton-Scipio district on the north and west, and as the existence of subsurface folds in this district to depths of at least 2,500 feet is known, it would seem that a deep test of the Kinta anticline would be warranted. The depth at which the Simpson formation would be encountered on the Kinta anticline cannot be computed with any degree of accuracy. If there is no major unconformity in the lower Pennsylvanian beds that would tend to thin the interval and if the interval between the Morrow formation and the Simpson formation is the same as the interval encountered in well 11, then the Simpson should be found at 6,500 to 7,000 feet in the Carney field.

BURNING SPRINGS ANTICLINE

Location and drilling.—The Burning Springs anticline extends into this district in the northern part of T. 6 N., R. 17 E. Attention was first directed to it by gas seepages in the beds of some of the creeks traversing the anticline. Two shallow test wells (nos. 65 and 66) were drilled shortly after 1900 in sec. 9, T. 6 N., R. 17 E. According to D. C. Acosta, the first of these wells obtained gas at a depth of 1,298 feet, the flow amounting to 500,000 to 750,000 cubic feet daily. Both drilling and fishing tools were lost in the hole, which was abandoned without plugging. Considerable amounts of gas are still escaping from the hole. The second well found no gas whatever at the 1,300-foot horizon and was abandoned as a dry hole at a depth of 1,876 feet, which must have been only a short distance above the Hartshorne sandstone.

About the time of these operations a well (no. 64) was drilled on the north flank of the Burning Springs anticline, 2 miles northeast of its crest. It was abandoned as a dry hole at a depth of 2,112 feet.

In 1930 the Cities Service Gas Co. drilled two wells (nos. 67 and 68) through the Hartshorne sandstone. The first well (no. 67), on the crest of the anticline in sec. 9, was dry. The second well (no. 68), on the south flank of the surface fold in sec. 16, reported a small amount of gas. Both wells were plugged and abandoned. No further development has taken place on this portion of the anticline.

Stratigraphy and structure of rocks not exposed.—The axis of the subsurface structure appears to be coincident with the axis of the surface anticline (pl. 13), but the rate of dip of the beds is accentuated with depth. This is shown by the sea-level altitudes of the tops of the formations in wells 64, 67, and 68 (table on p. 209). If the record of well 64 is taken at its face value, it gives very striking evidence of the steepening of the structure in depth, for the position of the Stigler coal in wells 64 and 67 reveals a difference of altitude of 987 feet, as compared to one of 350± feet in the surface beds.

An interesting stratigraphic feature of the Burning Springs anticline is the fact that the McAlester shale is 200 feet thicker than on the Kinta anticline, 4 miles north, and 300 feet thicker than on the Flowery Mound anticline, 8 miles west. The increase in interval appears to take place in the lower shale part of the formation.

The absence of commercial amounts of gas on a fold so pronounced as the Burning Springs anticline is difficult to explain, except by the assumption of unfavorable sand conditions such as low porosity or lenticularity. The Hartshorne sandstone averages 215 feet in thickness, but much of it is shaly and hence unsatisfactory for a gas reservoir. The character of the sandstone is well illustrated by the following description of the samples taken from the Cities Service wells, furnished through the courtesy of that company.

Partial log of Cities Service Gas Co. No. 1 Featherston well, 1,975 feet west and 668 feet south from the northeast corner of sec. 9, T. 6 N., R. 17 E.

	Feet
Top of Hartshorne sandstone.	
Gray micaceous sand	1, 980–2, 020
Gray and black shale	2, 020–2, 030
Coal	2, 030–2, 040
Dark-gray micaecous fine sandy shale	2, 040–2, 070
Gray-white micaceous fine sand; effervesces slowly when heated	2, 070–2, 160
Sand as above, 50 percent; gray micaceous fine sandy shale, 50 percent	2, 160–2, 170
Top of Atoka formation	2, 170
Gray micaceous fine sandy shale	2, 170–2, 320

Partial log of Cities Service Gas Co. No. 1 Hughes well, 660 feet south and 664 feet east from northwest corner of sec. 16, T. 6 N., R. 17 E.

	Feet
Top of Hartshorne sandstone.	
Fine white angular sandstone, dolomitic cement, 50 percent; gray sandy shale, 50 percent	1, 975–1, 985
Gray sandy shale	1, 985–2, 000
Light-gray fine sandstone and medium-gray shale	2, 000–2, 025
Light-gray sandstone and sandy shale, 80 percent; coal 20 percent	2, 025–2, 027±
Light-gray micaceous sandstone	2, 027–2, 032±
Medium-gray shale	2, 032–2, 055
Medium-gray shale 70 percent; coal 30 percent	2, 055–2, 068±
Medium-gray pyritic sandy shale	2, 068–2, 078±
Medium-gray very sandy shale	2, 078–2, 085
Fine white angular sandstone slightly dolomitic	2, 085–2, 115
Light-gray to white fine sandstone and gray sandy shale	2, 115–2, 180
Red sandstone and red shale, some sandy	2, 180–2, 195
Top of Atoka formation	2, 195
Gray sandy shale	2, 195–2, 245

Gas possibilities.—Although additional drilling may reveal more favorable sand bodies and larger amounts of gas, the chances of obtaining a large gas field from the Hartshorne sandstone on the Burning Springs anticline do not appear very promising. Well 69, drilled 6 miles northeast on this same structural trend, was also dry. No beds of pure sand in the Hartshorne formation were logged in this well. The formation is recorded as consisting of 220 feet of shale, including only 90 feet of sandy shale.

The possibility of finding gas and oil at deeper horizons is discussed in connection with the description of the Flowery Mound anticline.

FLOWERY MOUND ANTICLINE

The Flowery Mound anticline, the top of which is situated in sec. 1, T. 6 N., R. 16 E., and sec. 6, T. 6 N., R. 17 E., furnished the city of McAlester with fuel for several years from the Fish Creek well (no. 45). The gas came from the Hartshorne sandstone, found between depths of 1,920 and 2,120 feet. The initial flow was estimated to be about 1,000,000 cubic feet. The well was plugged and abandoned several years ago, but gas is still escaping from the ground for a radius of 15 feet about the well. It is not known, however, whether this gas is coming from the Hartshorne sandstone or from sands in the middle part of the McAlester shale, which are also gas-bearing in this locality.

In 1931 Joe Perrine and others tested these McAlester sands in a shallow well drilled as an east offset to the Fish Creek well. Estimates of the initial volume of gas obtained in this well vary from 500,000 to 5,000,000 cubic feet. The well was shut in pending the development of a market. An accurate log of the well was not kept, but the gas is said to have come from a sand found at a depth of about 1,100 feet.

Three other wells were drilled near the axis of the Flowery Mound anticline. One of these (no. 44) was drilled southwest of its top, and the other two (nos. 47 and 48) east and northeast of the top. Two different logs of well 44 are available, neither of which is very good. Their composite record indicates that the Stigler coal was found at 1,240 to 1,248 feet and "gas rock" at 2,700 to 2,710 feet. The "gas rock" was the Hartshorne sandstone, but it was apparently barren. The record shows that the well was abandoned after having drilled but 10 feet of the sand, a depth which ordinarily would be inadequate to test its gas possibilities. Well 47 recorded 185 feet of continuous Hartshorne sandstone, and well 48 showed 151 feet, but the formation produced gas in neither well.

As in the Burning Springs anticline, the axis of the Flowery Mound anticline at depth is nearly coincident with the axis at the surface, but the dips are higher in the deeper beds. This is shown on plate 13 and also by the following table:

Differences of altitude of successively deeper stratigraphic horizons on the Flowery Mound anticline, in feet

	Observed at surface in beds of Boggy shale (approximate)	Recorded in well records		
		Top of McAlester shale	Top of Hartshorne sandstone	Top of Atoka formation
Between wells 45 and 44	400	564?	729	----------
Between wells 45 and 47	250	219	274	196
Between wells 45 and 48	300	492	614	499

Although no large gas field can be developed in the Hartshorne sandstone on the Flowery Mound anticline, wells similar to the Fish Creek well may be obtained on the west end of the anticline. However, gas has been marketed or has leaked from the sands in this well since 1915, and it is probable that a large area has been drained of its gas content. The amount of gas that can be obtained from the sands in the McAlester shale is open to question, but well 45 is probably typical of such wells as may be found. The possibility of finding oil and gas at horizons below the Hartshorne sandstone on the Burning Springs and Flowery Mound anticlines is uncertain, as on the Kinta anticline. However, these anticlines are smaller in lateral extent than the Kinta anticline and they are more intensely folded, hence accumulation would tend to be more localized, and the subsurface structure would be affected less by convergence of overlying beds.

LAKE McALESTER ANTICLINE

Only one test well (no. 41) has been drilled on the Lake McAlester anticline. It was located close to the surface axis but west of the top of the structure. This well passed through 65 feet of sand, sandy shale, and shale correlated with the Hartshorne sandstone, but gas in commercial quantities was not found. The well was abandoned at a total depth of 2,975 feet in the Hartshorne sandstone. The east end of the anticline, however, cannot be considered as having been adequately tested by this well.

The possibility of obtaining production from deeper beds on this anticline appears to be limited to the Pennsylvanian rocks. The interval between the Boggy shale and the Hartshorne sandstone shows a thinning of about 300 feet between well 41 and well 34, 5 miles to the northwest. Therefore, the chance of finding oil in the Simpson formation is considered to be unpromising, because the west component of the convergence of the Pennsylvanian sedimentary rocks is greater than the westward closure of the anticline.

LILYPAD CREEK ANTICLINE

The Lilypad Creek anticline, at the west end of Lake McAlester, has not produced commercial quantities of gas, although six wells (nos. 35 to 40) have been drilled at or near its top. One of these wells (no. 38) reached a total depth of 4,303 feet, at which it was 1,558 feet below the base of the Hartshorne sandstone. A thickness of 123 feet of Hartshorne sandstone was recorded in this well, but it contained no gas. The well was plugged back in order to save a flow of 2 million cubic feet of gas from a sand between 600 and 655 feet. The gas has been used for additional drilling and for domestic purposes, and the well is still active. The other wells on the top of the anticline were abandoned before they reached the Hartshorne sandstone.

A deep test well (no. 34), was drilled on the northwest flank of the Lilypad Creek anticline, 3 miles from the group of wells on the top of the fold. It was abandoned at a total depth of 4,307 feet in the Atoka formation. Beds definitely referable to the Hartshorne sandstone were not recorded in this well, but a 20-foot limestone, which occurred at a depth of 3,190 feet, may represent the Hartshorne.

The failure of the test that was located on the top of the anticline and the apparent absence of sand on the northwest flank indicate that the chances of finding a prolific gas field in the Hartshorne sandstone on this anticline are small. Although the shallow sand at 600 feet yielded gas in one well, gas was not found in five other wells drilled through it.

The possibilities of finding oil or gas in the rocks below the Pennsylvanian on this anticline are lessened by the fact that the rate of northwestward dip, both in the surface rocks and in the Hartshorne sandstone, differs so little from the rate of northwestward thinning of the underlying Pennsylvanian that in the deeper rocks the anticline may be converted into a terrace. The Lake McAlester anticline at depth may be an anticline plunging eastward from this terrace. As previously noted, however, the computed effect of the known convergence may be canceled by the presence of unconformities. Such unconformities are more likely to be present in the western part of the district, which lies somewhat nearer to the margin of the basin of deposition, than in the eastern part. As the Atoka formation is probably much thinner over the area of the Lilypad Creek anticline, a well here could test the possibilities of the rocks below the Pennsylvanian at lesser depths than a well in the eastern part of the district. (See footnote 37a, p. 205.)

TERRACE NORTHEAST OF THE TOWN OF CANADIAN

Development.—In the vicinity of the town of Canadian 21 wells have been drilled in the search for gas and oil. They may be divided into two groups—one in secs 25, 26, and 36, T. 9 N., R. 16 E., and the other in sec. 32, T. 9 N., R.16 E., and secs. 4 and 5, T. 8 N., R. 16 E. Shows of gas have been obtained at various depths in most of the wells, but only three zones have yielded gas in commercial quantities. The shallowest of these is a coal bed in the Boggy shale, which is found at a depth of 400 feet in the western group of wells and at about 650 feet in the eastern group. A thin limestone is usually recorded a short distance above the coal. This succession suggests that the coal is the same as the one which, in the surface outcrops, occurs about 200 feet above the Secor coal. In well 13, however, there is an interval of only 88 feet between the limestone-capped coal at a depth of 418 feet and an underlying coal bed at a depth of 506 feet. The lower coal can reasonably be correlated with the Secor coal, for the decrease of the interval above it from 200 feet on the surface outcrops to 88 feet in this well would not be unusual in view of the general northward thinning of the beds. The gas found at the horizon of the upper coal comes from the top portion of the coal bed. The initial output of these wells is small, usually less than half a million cubic feet, and the pressure is low. The accumulation of gas in the coal is very irregular, as witnessed by the dry hole (well 18) that was drilled about 20 feet from the producer (well 17). The coal is 12 feet lower in well 18 than in well 17. The difference in altitude of the coal is not a satisfactory explanation of this anomalous production, because in well 15, which is a producer, the coal is lower than in well 18. It is possible that there is a fault between wells 17 and 18 and that its southward projection would account for well 19, a dry hole, in which the coal is 46 feet lower than in well 17.

Another coal bed at a depth of 1,400 feet yielded half a million cubic feet of gas in well 13 and 2 million cubic feet in well 12. The pressure was recorded as being 200 pounds.

The next deeper bed from which gas has been produced occurs at a depth of 1,900 feet in well 3. This bed is probably one of the sands in the McAlester shale.

The sand that is thought to represent the Hartshorne sandstone, which occurred at a depth of 1,000 feet in well 13, yielded 1 million cubic feet of gas. The gas was cased off, and the well was drilled to the Cromwell (?) sand, found at about 4,500 feet, where a flow of 3 million cubic feet of gas was reported to have been obtained. This well was begun as a deep test, but the tools were lost in the hole, and another test (well 12) was started 550 feet north of it.

The drilling of well 12 was carried on over a period of 5 years, and it reached a total depth of 5,902 feet.[48] This is the only well in the district to test the Viola limestone, the Simpson formation, and the top of the Arbuckle limestone, which is the oldest producing zone in the State. A partial log of the well is given on page 213. Numerous shows of gas were found during the course of drilling. An oil show was reported from a sand at a depth of 5,340 to 5,420 feet, in the upper part of the Simpson formation. The sand was shot with 240 quarts of explosive, but commercial production was not obtained. Another oil show was said to have been found at a depth of 5,730 feet. The temperature of the well at a depth of 5,280 feet was reported to be 193° F., which would give the unusually high thermal gradient of 27 feet per degree of temperature.

Structure.—As shown on plate 13, the wells in this vicinity have been drilled on the northern and northwestern edge of a broad, gently sloping structural terrace developed in the rocks of the upper part of the Boggy shale. On the Upper Hartshorne coal, however, the structure as deduced from the study of the well records shows an

[48] Oil Weekly, March 11, 1932, pp. 59-60.

anticline extending east-northeastward in the northwestern part of T. 8 N., R. 16 E., and the southern part of T. 9 N., R. 16 E. The interval between the Boggy shale and the top of the Atoka formation is very thin. This interval in well 11 is 720 feet thinner than it is in well 26, which is 11 miles to the east, on the Enterprise anticline, and 694 feet thinner than in well 48, which is 10 miles to the south-southeast, near the west end of the Kinta anticline. The thinning may be due to the presence of one or more unconformities between formations, or more likely it is intraformational, for the sequence recorded in the wells near Canadian contains numerous coals that can be correlated with the coals of the thicker sections. As there is, however, a possibility that the gas-bearing coal and sandstone sequence that has been here correlated with the Hartshorne sandstone may in fact be McAlester beds overlapping an inlier of Atoka, a question mark has been added in the table on page 208 to such figures as only doubtfully represent altitudes on the Upper Hartshorne coal in this vicinity. Numerous occurrences of gas in the beds above the Atoka formation and the gas found in the Cromwell (?) sand accord with the anticlinal structure in depth.

Oil and gas possibilities.—The presence of gas in the Pennsylvanian formations on this anticline, in volumes which are probably representative of those which may be obtained by future drilling, has been demonstrated. The oil possibilities in the formations above the Cromwell (?) sand are small and in the Cromwell (?) sand itself are probably unfavorable, to judge from the dryness of the gas that occurred in this sand in wells 11 and 12. The lack of commercial production in well 12, although it appears to have been located near the top of the anticline, the quartzitic nature of the sands in the Simpson formation, and the possibility that the northwestward thinning of the Atoka may in depth neutralize the northwest dip on the Upper Hartshorne coal greatly reduce the chances of finding oil in the Simpson formation. However, the considerable size of the anticline, as shown by the subsurface altitudes of the Upper Hartshorne coal, the thinning of the Pennsylvanian formations over the anticline, and the shows of gas and oil in well 12 may warrant another test of the Ordovician rocks.

SUMMARY OF STRUCTURAL RELATIONS

In general, it may be said that the anticlines shown by contours on the Upper Hartshorne coal conform to those in the formations exposed at the surface in shape and position but not in the amount of relief. So far as information is available, the axial planes of the anticlines are vertical, even in those which are asymmetric in form. This is true at least to a depth of 2,500 feet, or to the Atoka formation. It is reasonable to suppose, but not necessarily true, that the same relation exists at greater depths, and that the most favorable places to drill deep test wells in this district would be close to the axes of the surface anticlines.

The dips in the buried rocks that have been revealed by drilling are steeper than the dips at the surface. Such a condition might be the result of concentric folding, differential compaction, or the repetition of folding at several periods separated by erosion. The steepening of the dips on the Upper Hartshorne coal seems to be too great and too irregular to be attributed to concentric folding. Differential compaction has probably played a part in reducing the amount of dip upward in the section, but the variations in thickness of the Hartshorne sandstone and overlying formation seem too great to attribute to compaction alone. That there has been repetition of folding at several periods is indicated by numerous data. The marked range in the thickness of the Atoka formation from 950 to 5,000 feet (p. 212), the local variations amounting to over 240 feet in the thickness of the Hartshorne sandstone (pp. 211–212), and similar variations in the thickness of the McAlester shale (pp. 210–211) indicate instability of the earth's crust during the deposition of the Pennsylvanian sediments. The subsurface faulting of pre-Savanna and post-Hartshorne age on the Kinta anticline suggests that the formation of this anticline began at least as early as Hartshorne time and that it had several increments of growth during McAlester time. Such a structural history would evolve steeper dips in the older rocks than in the younger ones. Recurrent movements of this kind along structural trends would favor the possibility of finding oil and gas in the deeper beds, because such movements tend to increase the steepness of the older folds, and the erosional unconformities developed across buried porous strata may form favorable seals for reservoirs in which oil or gas may accumulate.

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