Geology of the Fort Smith District Arkansas

GEOLOGICAL SURVEY PROFESSIONAL PAPER 221-E

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By T. A. HENDRICKS *and* BRYAN PARKS

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY, 1949, PAGES 67–93

GEOLOGICAL SURVEY PROFESSIONAL PAPER 221–E

A description of the stratigraphy, structure, and geomorphology

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1950

UNITED STATES DEPARTMENT OF THE INTERIOR

Oscar L. Chapman, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

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Washington 25, D. C. - Price $1.00 (paper cover)

CONTENTS

ILLUSTRATIONS

GEOLOGY OF THE FORT SMITH DISTRICT, ARKANSAS

By T. A. Hendricks and Bryan Parks

ABSTRACT

The Fort Smith district embraces an area of about 1,100 square miles in Scott, Sebastian, Crawford, Franklin, and Logan Counties, Ark. It lies entirely within the Arkansas Valley region (fig. 4).

The exposed stratified rocks of the district belong to the Atoka, Hartshorne, McAlester, Savanna, and Boggy formations, of Pennsylvanian age, or, more specifically, upper Pottsville and lower Allegheny. They consist mainly of alternating beds of shale and sandstone, but they include some coal beds, and there is a lenticular bed of limestone in the upper part of the Savanna sandstone. Unconformities are present at the base of the Hartshorne and Savanna sandstones, and many small unconformities probably occur within the formations.

The correlation of the Pennsylvanian formations in the district with those of the type formations in Oklahoma have been checked by means of plant fossils which were collected from a number of localities.

The thickness of the Pennsylvanian strata exposed in the southern part of the district is about 13,000 feet, but the strata thin so rapidly northward that they are only about half as thick at the north side of the district. The major source of the sediments appear to have been to the south, in and beyond the Ouachita Mountains, though some of the older sediments probably came from the east. The sediments were deposited in a basin that was warped downward progressively while its northern margin, which lay across the central part of the Fort Smith district during most of early Atoka time, migrated northward across the area. While the sediments were being deposited the basin underwent minor deformation by lateral pressure from the south. It stood close to sea level during most of the period of deposition, and received no invasion of marine waters of sufficient depth or duration to leave a widespread perceptible record in the stratigraphic column, the bulk of the sediments having been deposited under fluviatile conditions. The stratigraphy of the district has several noteworthy general features. There is a northward thinning of the strata, the rate of which appears to be most rapid along an east-west line at which there is a sharp change in structural pattern. The lithologic units are of limited lateral extent, and there does not appear to be any rhythmic recurrence of lithologic types in the stratigraphic column.

The geologic structure is of two types. South of the structural boundary just mentioned, long, steep-sided, narrow anticlines are separated by broader synclines and are broken at a few places by reverse faults, the structure there being closely related to that of the Ouachita Mountains to the south. In the northern part of the district, gentle folds are broken by many normal faults, as in the Boston Mountains to the north. There is evidence that the folds and the faults were formed at the same time, and that all the structural features were formed by thrust pressures exerted from the south.

The location and development of the topographic features of the district have been controlled almost entirely by the character and attitude of the strata. Where the strata lie nearly horizontal, the most characteristic features of the relief are large, broad-topped mountains and flat-topped or conical hills. Where the strata are tilted, long, curving ridges have been formed along the outcropping edges of resistant sandstone beds, and curving valleys follow the outcrops of the softer shales. Normal faults have determined the present course of the Arkansas River for considerable distances and also those of several smaller streams in the northern part of the district. Gravel-capped terraces were formed by the Arkansas River and some of its tributaries during the time when the river flowed at a level about 50 feet higher than its present level. Alluvium has been deposited in wide areas along the Arkansas River and its major tributaries, and in narrower areas along the smaller streams.

INTRODUCTION

PRESENT INVESTIGATION

From March 4 to October 1, 1934, a geologic party under the direction of T. A. Hendricks investigated the geologic features of the Fort Smith district, Arkansas. The investigation consisted principally in detailed mapping of the various rock formations and in assembling the many subsurface data made available by companies, mining engineers, and State agencies. The mapping was done by C. B. Read, Bryan Parks, J. N. Payne, W. M. Plaster, C. J. Finger, Jr., C. O. Hansard, and P. A. Shaw. The investigation was financed by an allotment of funds to the Geological Survey from the Public Works Administration.

The present report, prepared from the data thus accumulated, describes the stratigraphy, structure, and geomorphology of the Fort Smith district. It is supplementary to an earlier report [1] in which the mineral resources of the district were described. The district (fig. 4) is an irregularly shaped area of about 1,100 square miles containing parts of Scott, Sebastian, Crawford, Franklin, and Logan Counties, in west-central Arkansas. It comprises roughly the western two-thirds of the Arkansas coal field and lies entirely within the geomorphic province of the Arkansas Valley.

[1] Hendricks, T. A., and Parks, Bryan: Geology and mineral resources of the western part of the Arkansas coal field: U. S. Geol. Survey Bull. 847–E, 1937.

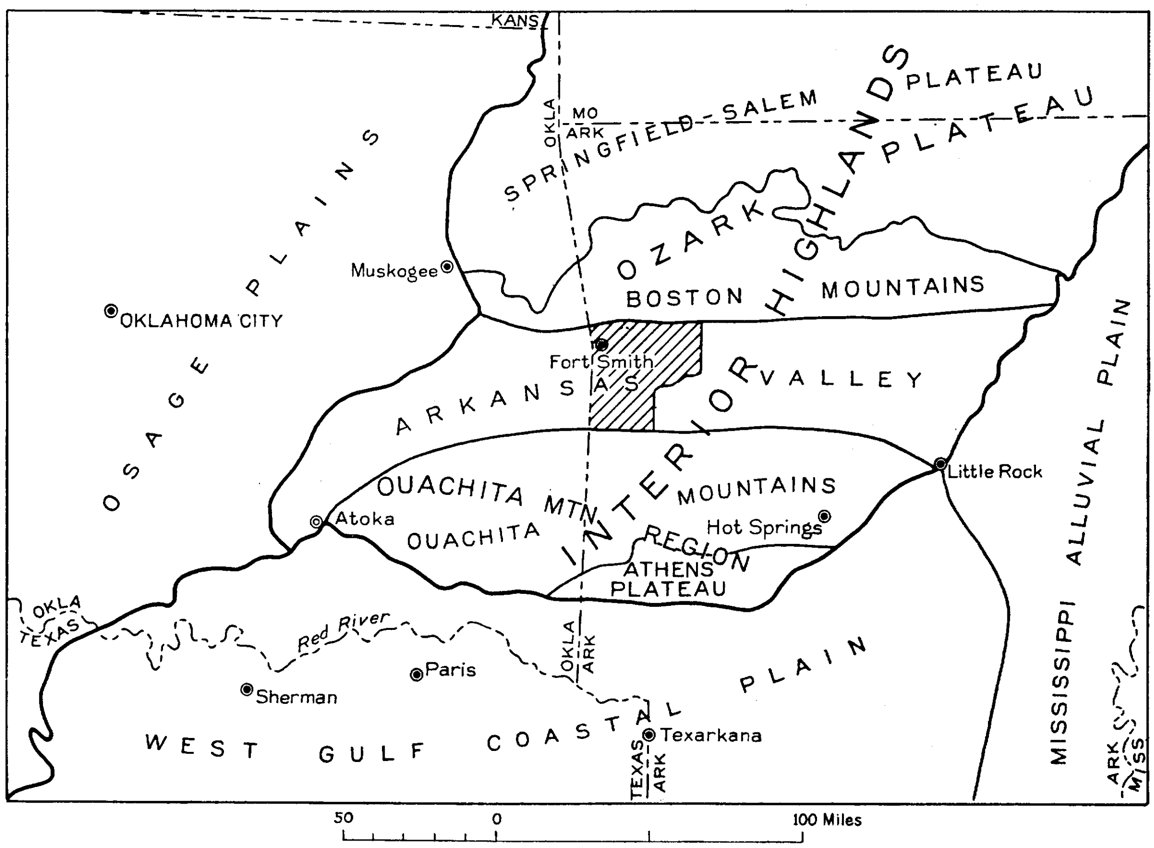

FIGURE 4.—Map showing location of the Fort Smith district (shaded area) in relation to geomorphic provinces of parts of Arkansas and adjacent States.

PREVIOUS PUBLICATIONS

A brief account of the geology of the Arkansas coal field, which is a large area that includes the Fort Smith district, was given in a report by Winslow,[2] published in 1888. In a later paper, Winslow[3] described the structure and physiography of the Arkansas coal field more fully.

Collier,[4] in a report on the geology of the Arkansas coal field that was published in 1907, discussed all phases of the geology of the region.

The geologic structure of a small part of the Fort Smith district was described by Smith[5] in a brief report, published in 1914, on the Fort Smith-Poteau gas field of western Arkansas and eastern Oklahoma.

Croneis,[6] in 1927, compiled the data then available on the Paleozoic of Arkansas, and supplemented his compilation by field work in some parts of the area where these data were few. Croneis's views regarding the geology of the Fort Smith district agree very closely with those advanced in the earlier report by Collier except for a few parts of the district where later information, largely derived from logs of gas wells, was available.

Correlation of strata from Oklahoma to the Arkansas coal field was discussed in a paper by Hendricks and Read[7] published in 1934. The conclusions presented in that paper were based on field mapping in a part of Oklahoma that is adjacent to Arkansas and on numerous collections of plant fossils from both States.

A more comprehensive discussion of the stratigraphy of the Arkansas-Oklahoma coal field, by Hendricks, Dane, and Knechtel,[8] was published in 1936.

Two papers by Hendricks, bearing on this region[9] were published in 1937. One of these, dealt with the conditions under which the Pennsylvanian strata of the

[2] Winslow, Arthur, The geology of the coal regions; a preliminary report upon a portion of the coal regions of Arkansas; Arkansas Geol. Survey Ann. Rept. for 1888, vol. 3.

[3] Winslow, Arthur, The geotectonic and physiographic geology of western Arkansas: Geol. Soc. America Bull., vol. 2, pp. 225–242, 1891.

[4] Collier, A. J., The Arkansas coal field: U. S. Geol. Survey Bull. 326, 1907.

[5] Smith, C. D., Structure of the Fort Smith-Poteau gas field, Arkansas and Oklahoma: U. S. Geol. Survey Bull. 541, pp. 23–33, 1914.

[6] Croneis, Carey, Geology of the Arkansas Paleozoic area: Arkansas Geol. Survey Bull. 3, 1927.

[7] Hendricks, T. A., and Read, C. B., Correlations of Pennsylvanian strata in Arkansas and Oklahoma coal fields: Am. Assoc. Petroleum Geologists Bull., vol. 18, no. 8, pp. 1050–1058, 1934.

[8] Hendricks, T. A., Dane, C. H., and Knechtel, M. M., Stratigraphy of Arkansas-Oklahoma coal basin: Am. Assoc. Petroleum Geologists Bull., vol. 20, no. 10, pp. 1342–1356, 1936.

[9] Hendricks, T. A., Pennsylvanian sedimentation in Arkansas coal field: Am. Assoc. Petroleum Geologists Bull., vol. 21, no. 11, pp. 1493–1421, 1937.

Arkansas coal field were deposited. The other by Hendricks and Parks,[10] described the geology and mineral resources of the western part of the Arkansas coal field. This report contained a detailed account of the coal and natural-gas resources of the Fort Smith district and a brief description of the general geology. The present report describes the geology of the district in far greater detail, and unlike the earlier report it contains an areal geologic map (pl. 13).

ACKNOWLEDGMENTS

Many companies and individuals supplied the authors with logs of gas wells and diamond-drill holes, which have been invaluable in preparing this report. Particular thanks are due to Messrs. A. B. Harper, of the Fort Smith Gas Co., Leigh Kelly, of the Kelly Trust Co., and Cecil Robinson, of the Arkansas Natural Gas Co., and to the Western Coal and Mining Co., the Central Coal and Coke Co., and the Charleston Coal Co.

STRATIGRAPHY

GENERAL DESCRIPTION

All of the bedded rocks in the Fort Smith district belong to the Pennsylvanian series of the Carboniferous system (pl. 13). The most abundant kind of rock is shale, which is interbedded with thinner layers of sandstone. Some of the shale beds contain coals and underclays. Individual layers of sandstone have no distinctive lithologic features by which they can be identified from place to place, and that is true regarding individual layers of shale, though the shales of the Atoka formation can in general be distinguished from those of the younger formations. Individual coal beds, on the other hand, can be identified with reasonable certainty from their own special characteristics and the sequence of overlying and underlying beds; at most places, moreover, the shales associated with the coals in formations younger than the Atoka contain plant fossils that are characteristic of each horizon over a large area. Where plant fossils are abundant the stratigraphic position of the beds can be definitely determined.

The stratified rocks in the Fort Smith district extend westward into Oklahoma, where they were originally divided by Taff and Adams into formations,[11] five of which are recognizable in Arkansas. These are, from oldest to youngest, the Atoka formation, the Hartshorne sandstone, the McAlester shale, the Savanna sandstone, and the Boggy shale. Not only these formations, but all units within them that could be traced laterally, were mapped by the field party working under the direction of Mr. Hendricks. In plate 13, the lithologic features of the formations and their smaller subdivisions, and their thicknesses for the southwestern and northeastern parts of the district, are given in two columnar sections. The areal distribution of all the units mapped is shown on a geologic map.

Some of the formation names mentioned above were used by Collier [12] in his report on the entire Arkansas coal field, but Collier's placing of boundaries differed considerably from that of Taff and Adams.[13]

In the course of the field work on which the present report is based, Hendricks [14] traced the formation boundaries eastward from their type localities in Oklahoma to the Arkansas-Oklahoma State line, and from there into Arkansas. The Atoka and Hartshorne formations of Collier are identical with the Atoka and Hartshorne formations of the present report. But Collier used the name McAlester group instead of McAlester shale, and he subdivided the McAlester group into the (†) Spadra [15] shale, the Fort Smith formation, and the (†) Paris shale. He also mapped an overlying sandstone as the Savanna sandstone. The correlation between Collier's divisions and those used in this report are given in the table below.

Correlation of formation divisions used by Collier and those used in this report

Collier (U. S. Geol. Survey Bull. 326)	This report
Savanna sandstone	Boggy shale
Paris shale	Savanna sandstone
Fort Smith formation	
Spadra shale	McAlester shale
Hartshorne sandstone	Hartshorne sandstone
Atoka formation	Atoka formation

[10] Hendricks, T. A., and Parks, Bryan, op. cit.

[11] Taff, J. A., Geology of the McAlester-Lehigh coal fields, Indian Territory: U. S. Geol. Survey 19th Ann. Rept., pt. 3, p. 441, 1899. Taff, J. A., and Adams, G. I., Geology of the Eastern Choctaw coal field, Indian Territory: U. S. Geol. Survey 21st Ann. Rept., pt. 2, p. 273, 1900.

[12] Collier, A. J., op. cit.

[13] Taff, J. A., op. cit., p. 441; Taff, J. A. and Adams, G. I., op. cit., p. 273.

[13] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 1. The McAlester district, Pittsburg, Atoka, and Latimer Counties: U. S. Geol. Survey Bull. 874–A, 1937; Part 4, The Howe-Wilburton district, Latimer and Le Flore Counties: U. S. Geol. Survey Bull. 874–D, 1939.

[15] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the Geological Survey.

Surficial unconsolidated sands, gravels, and clay a few feet to about 50 feet thick occur at many places in the district. These materials are alluvial deposits laid down by streams in Pleistocene (?) and Recent time.

CARBONIFEROUS SYSTEM

PENNSYLVANIAN SERIES

ATOKA FORMATION

Rocks of the Atoka formation are exposed in five parts of the district. Their largest area of outcrop is in the southern part of the district. A somewhat smaller area lies south of Backbone Mountain between Greenwood and the Arkansas-Oklahoma State line. There is a small outcrop of the formation southeast of Fort Smith, and a long belt south of Mill Creek, in the north-central part of the district. The formation also crops out along the north side of the district.

South of Backbone Mountain about 6,900 feet of beds in the Atoka formation are exposed, and near Mansfield, in the southern part of the district, about 3,300 feet of strata crop out and 2,700 feet of lower strata have been penetrated in wells drilled for gas. Along the north side of the district, from Little Mulberry River westward to the Oklahoma State line, strata about 2,000 feet below the top of the Atoka are exposed. Elsewhere in the district only the uppermost beds of the Atoka formation are exposed.

The Atoka formation consists chiefly of alternating beds of sandstone and shale, the shale being the more abundant, and it locally contains a few discontinuous streaks of coal and coaly shale. The sandstones vary greatly in thickness and character, both from bed to bed and from place to place in a single bed. In general the sandy zones continue for considerable distances, although a thick, massive, coarse-grained bed of sandstone within such a zone may grade laterally into a sandy shale that is considerably thinner. Some of the sandstone is coarse-grained and almost white; some fine-grained, brownish, and very shaly; all is very micaceous. In some belts half a mile to a mile wide the average thickness of the sandstone beds increases from 10 to 15 feet at the sides of the belt to as much as 150 feet along its middle part. The base of the sandstone cuts across the bedding of the underlying shale in the direction of thickening, and the beds become thicker and more irregularly bedded. These very thick sandstones were deposited in stream channels cut into the underlying shale. A good example of such a channel sandstone is exposed in the bluff on the north bank of the Arkansas River immediately west of Ozark.

The most abundant rock of the formation is black, slightly gritty, splintery shale that contains some coarse mica and abundant macerated plant material. Contacts between this black shale and sandstone are commonly gradational, the two being separated in most places by a transitional zone of brownish sandy micaceous shale. At some horizons, however, there is a sharp contact between black shale and underlying or overlying sandstone. Marine fossils and well-preserved plant fossils have been found at only a few localities, and none of the fossiliferous zones can be traced laterally beyond a single exposure.

The lithologic character of the formation indicates that the sediments were mostly deposited on wide, comparatively level surfaces that stood close to sea level. Where the surface lay close to sea level but below it the shallow water was subjected to almost continuous agitation, and the resulting turbidity did not permit the existence of a large fauna. Where the surface lay above sea level it must in general have been comparatively well drained, as otherwise accumulation of plant materials in stagnant marshes would almost certainly have resulted in the formation of lenticular coal beds. The very few lenticular streaks of coaly shale in the formation indicate that locally the drainage was not perfect, so that some slight accumulation of plant debris was possible. It is probable that in a given area each of these conditions obtained at one time or another, and it is certain that different conditions existed simultaneously in different parts of the district. The rate of deposition must have been rapid, as the available faunal and floral evidence indicates that the formation, though thousands of feet thick, was deposited within a relatively short time. Such rapid deposition of clastic materials would provide an inhospitable environment for the growth of either plants or invertebrates, and would thus account for the scarcity of fossiliferous beds in the section.

A complete section of the Atoka formation has been obtained at only one place in the district. It is supplied by the drill cuttings from the R. A. Maraz Stewart No. 1 well, northeast of Mulberry, at the northern boundary of the district. This well starts in the basal part of the Hartshorne sandstone, penetrates all of the Atoka formation, and ends in the Fayetteville shale, of Mississippian age. The base of the Atoka formation is difficult to identify exactly from the drill cuttings; it probably lies at the base of a sandstone at a depth of 4,465 feet, though it is possibly slightly higher. If the base is at 4,465 feet the total thickness of the formation in this section is 4,450 feet.

The formation is about 9,000 feet thick in two areas that lie, respectively, about 20 miles east and 25 miles west of the Mansfield gas field, in the southern part of the district (fig. 5). As lines of equal thickness of the formation trend east and west, the Atoka formation is

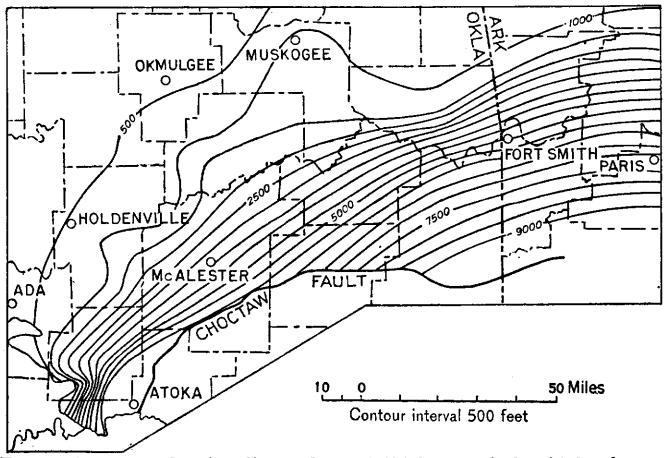

FIGURE 5.—Map showing lines of equal thickness of the Atoka formation in parts of Arkansas and Oklahoma.

probably about 9,000 feet thick in the Mansfield gas field itself, which lies about 35 miles south of the Maraz well. In 35 miles, then, the Atoka formation thickens southward about 4,550 feet—an average of 130 feet per mile.

The thickening between the highest and lowest continuous sandstone beds of the formation is gradual (fig. 6): the uppermost 3,750 feet of the Atoka strata in the Maraz well thickens to 4,925 feet in the Mansfield gas field, or at an average rate of 0.82 percent per mile. Below the lowest continuous sandstone bed the rate of southward thickening is much greater; the top of that bed is 700 feet above the base of the Atoka formation in the Maraz well, and it correlates with the top of a zone of sandstone and sandy shale 4,075 feet above the base of the formation in the Mansfield gas field. The lower part of the formation thus thickens 3,375 feet from north to south in the width of the district, or at an average of 13.8 percent per mile, about 17 times as rapidly as the upper part of the formation. This great thickening in the lower part of the formation may be due to progressive overlap on a surface that had an initial southward slope of about 96 feet per mile, to a greatly increased rate of thickening of individual units in the lower part of the formation, or to deposition in a progressively downwarped basin whose northern margin either lay within the district or migrated northward across it.

If progressive overlap occurred on a surface that had an initial slope of about 96 feet per mile, either the southern part of that slope was far below sea level or the northern part high above sea level when deposition of the Atoka sediments began. The absence of any marked change of character of the Atoka sediments seems to eliminate the possibility that the Atoka sea was ever deep. Nor does it seem possible that the region north of the Fort Smith district could have been far above sea level in early Atoka time, for the Atoka formation lies on a relatively even surface and wherever its base is exposed it is underlain by the thin Morrow group.

If the gross thickening were due to a greatly increased rate of thickening of individual units, the basal 700 feet of strata in the Atoka formation in the Maraz well would contain the thinned equivalents of all the strata in the basal 4,075 feet of the formation in the Mansfield gas field. If this were true, all parts of the basin would have been receiving sediments throughout early Atoka time while the bottom of the basin steadily sank, slowly at the site of the Maraz well and at a rate that became progressively more rapid southward to Mansfield. In the upper part of the formation (fig. 6) the rate of thickening is variable but in general decreases downward. The great southward thickening of individual units in the lower part of the formation would therefore show, on this hypothesis, that the southern part of the basin moved downward rapidly in early Atoka time, very slowly in middle Atoka time, and at an intermediate rate in late Atoka time.

It appears more probable, however, that in early Atoka time the southern part of a comparatively level surface was warped downward into a basin, and that the part of the surface north of the margin of downwarping stood so near sea level that it neither received appreciable quantities of sediment nor underwent appreciable erosion of that time. The bottom of the basin thus formed probably subsided gradually throughout early Atoka time, and received sediments about as fast as it subsided. In middle Atoka time the north margin of the downwarped basin moved northward progressively and younger Atoka strata spread progressively farther to the north. That sequence of events would result in northward overlap at the base of the Atoka formation north of the margin of the original basin; and such a northward overlap has in fact been observed in the Muskogee-Porum district, Oklahoma,[16] near the latitude of the northern part of the Fort Smith district.

The rate of thickening of the upper part of the Atoka formation is most rapid near the Backbone anticline (fig. 6), as if the Backbone anticline lay in a zone of weakness in which downwarping occurred throughout Atoka time. The suggestion is strengthened by the change in structural pattern from the north to the south side of the Backbone anticline. The anticlines to the north are open, while those to the south are tightly folded (fig. 4). As a gradual transition from

[16] Wilson, C. W., Jr., and Newell, N. D., Geology of the Muskogee-Porum district, Muskogee and McIntosh Counties, Okla.: Oklahoma Geol. Survey Bull. 57, p. 26, 1937.

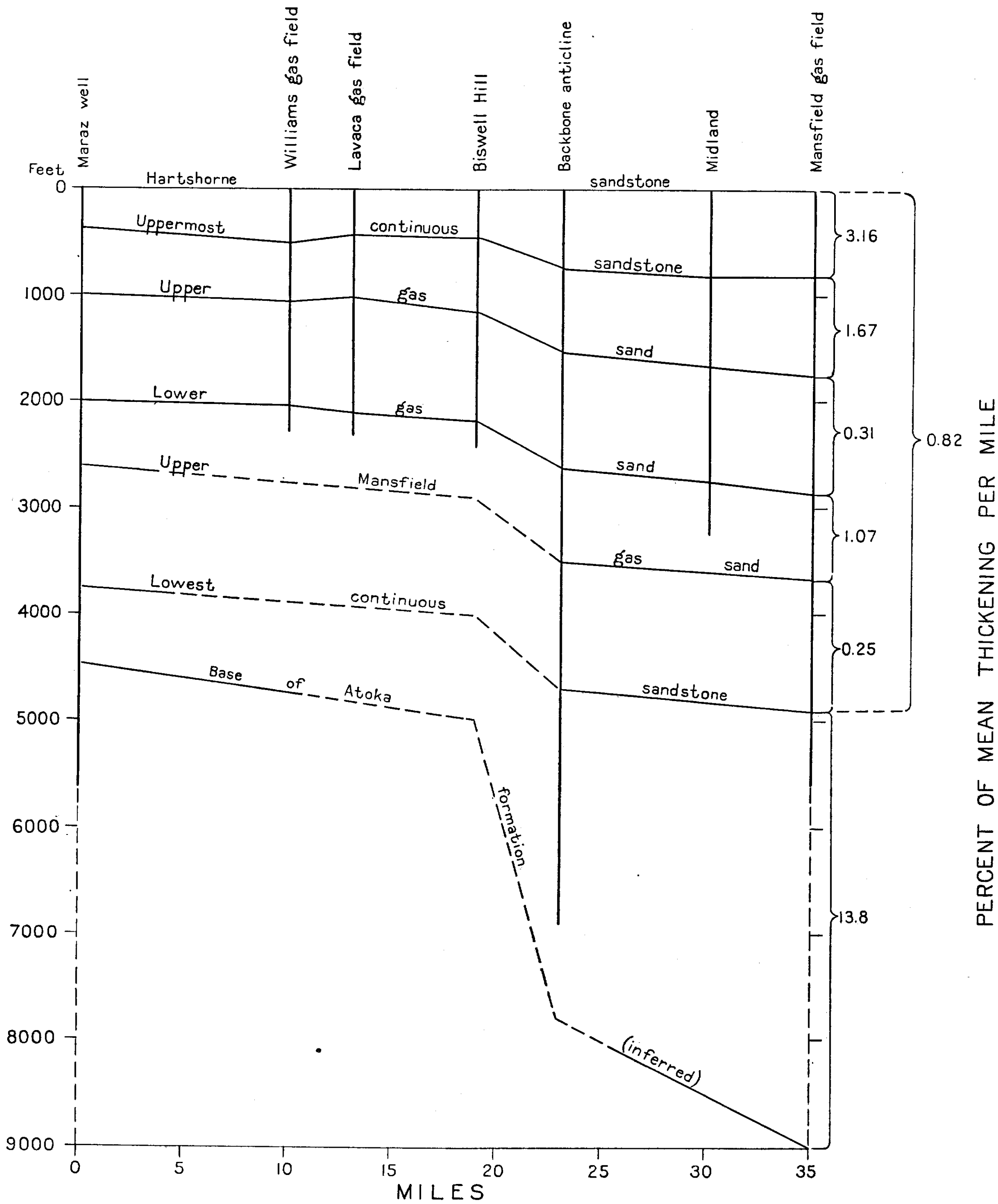

FIGURE 6.—Diagram showing correlations of several horizons in the Atoka formation from north to south across the Fort Smith district.

closely compressed to slightly compressed anticlines would be expected in materials of comparatively uniform character, the abruptness of the change in the character of the folds suggests a pronounced change in the character of the strata, such as would have been effected by the deposition of a great thickness of Atoka sediments south of that zone and of a small thickness to the north.

The thickening of the part of the Atoka formation above the highest continuous sandstone is variable rather than progressive (fig. 6). The zone thickens northward from the Lavaca gas field to the Williams gas field, but between Biswell Hill and the Backbone anticline it thickens southward at the very high rate of 19.44 percent per mile. These deviations from the normal southward thickening are probably due to structural movements that occurred after the deposition of the highest Atoka sandstone and before the deposition of the Hartshorne sandstone. As a minor unconformity is present at the base of the Hartshorne sandstone, it appears probable that the area between Backbone Mountain and the Williams gas field was warped upward at the end of Atoka time, and that erosion of the pre-Hartshorne surface removed some of the uppermost strata from the uplifted area. All of the lower horizons (fig. 6) were affected by the uplift, which therefore appears to have been deep-seated.

In many exposures on the flanks of the Hartford anticline and in a few exposures on the flanks of the Washburn anticline, some of the sandstone beds in the Atoka formation contain plates of shale as much as 3 inches long and half an inch thick, which lie at various angles to the bedding. The shale in these plates resembles that of the Atoka formation, so that presence of the plates in the sandstone appears to show that previously deposited shale of the Atoka was being eroded while the sandstone was being deposited. The large size of the plates of shale indicates that they were transported only a short distance before being deposited in the including sandstone. The occurrence of these plates, together with the existence of channels in which some of the sandstones were deposited, indicates that, at least locally, breaks occurred in the deposition of the Atoka sediments, causing minor unconformities or diastems.

The Atoka formation of the Fort Smith district is identical with the Atoka formation of the Oklahoma coal field. North of the Fort Smith district, however, all of the Atoka formation was included by Purdue [17] in the (†) Winslow formation. The base of the Winslow formation of Purdue coincides with the base of the Atoka formation, but locally, in the extreme southeast corner of the Winslow quadrangle, Purdue included in the upper part of the Winslow formation strata belonging to the Hartshorne sandstone and McAlester shale.

The geologic map of the State published by the Arkansas Geological Survey in 1929, shows a large area of Hartshorne sandstone north of Van Buren, but this sandstone is actually in the middle part of the Atoka formation, about 2,000 feet below the top. All of the strata above the Morrow group north of Van Buren belong in the Atoka formation.

HARTSHORNE SANDSTONE

The Hartshorne sandstone rests upon an irregular surface of the Atoka formation, from which it is separated by a minor unconformity. It ranges in thickness from about 10 to about 300 feet in exposures in the Fort Smith district. Where it is thick it is generally coarse-grained, clean, and thick-bedded or massive; where it is thin it is fine-grained, thin-bedded, and shaly. In all exposures, however, fresh surfaces of the sandstone have an ashy white color that serves to distinguish the Hartshorne from other sandstones in the district, except that in some outcrops the next two sandstones above the Hartshorne resemble it for short distances.

The Hartshorne sandstone has been defined in earlier work in Arkansas as the first continuous sandstone underlying the Lower Hartshorne coal, and that definition is adopted in the present report. Taff and Adams,[18] on the other hand defined the Hartshorne sandstone in Oklahoma as extending from the top of the first sandstone below the Upper Hartshorne coal to the base of the first continuous sandstone below the Lower Hartshorne coal. It is thus evident that the sandstone lying between the Upper and Lower Hartshorne coals in Oklahoma is not a part of the Hartshorne sandstone as mapped in Arkansas. In the Fort Smith district the sandstone between the Hartshorne coals occurs only at a few places in the extreme southwestern part of the area, and even there it is so discontinuous that its top can hardly be used as a formation boundary.

The remains of invertebrate animals in the Hartshorne sandstone comprise only a few poorly preserved brackish-water forms. Plant fossils, however, are very abundant in the formation. Most of the plant remains in the sandstone proper are fragments of stems and twigs that probably were transported from nearby land areas, though some are of types that grow in shallow water and may have lived either in fresh water or in the sea.

Its lithologic character, widespread occurrence, and continuity, together with its fossil content, indicate that the Hartshorne sandstone was deposited in an extensive body of shallow water. The top of the sandstone lies only a few feet below and practically parallel with the Lower Hartshorne coal, which indicates that the top of the sandstone was almost level at the time of deposition. The thick masses of sandstone, 3 to 10 miles wide, therefore have the shape of broad shallow channel deposits, such as would be expected to form in front of the mouths of large streams. The fact that the sandstone in the thicker channeloid parts of the formation is relatively coarse-grained likewise suggests the existence there of stronger currents, such as might be expected near the mouths of large streams. It appears probable, therefore, that the thick parts of the Hartshorne sandstone

[17] Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), 1907.

[18] Taff, J. A., and Adams, G. I., op. cit., pp. 274–275.

were deposited in submarine channels in front of the mouths of streams, and that the thin parts which are fine-grained and shaly were widely distributed by offshore currents and deposited in the less-agitated waters away from the streams.

McALESTER SHALE

The McAlester shale, which overlies the Hartshorne sandstone conformably, consists mainly of dark gritty shale but contains several beds of sandstone and coal. It ranges in thickness from about 1,820 feet in the southwest corner of the district to about 500 feet near Fort Smith, in the northwestern part (fig. 7).

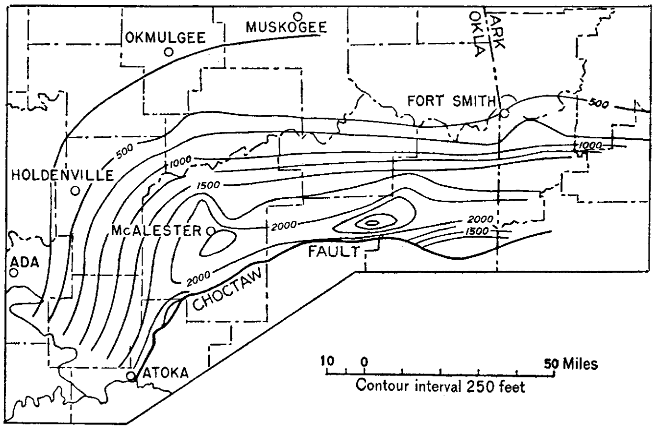

FIGURE 7.—Map showing lines of equal thickness of the McAlester shale in parts of Arkansas and Oklahoma.

No single sandstone bed in the McAlester shale is continuous over the entire district, though several of the beds continue for 30 or 40 miles before pinching out. Other beds locally attain a thickness of as much as 50 feet but disappear entirely within a few miles. As the sandstones constitute the only mappable horizons in the McAlester shale it is impossible to subdivide the formation into members.

Most of the sandstone is fine-grained, thin-bedded, ripple-marked, micaceous, and of a pale buff color, but the lenticular sandstone near the base of the formation in Tps. 4 and 5 N. is generally coarse-grained and massive. The sandstone in the middle part, east of Caulksville in the southeastern part of the district, is white, pure, coarse-grained, and massive, being remarkably similar to the underlying Hartshorne sandstone. At some places south of Greenwood and west of Caulksville, sandstone beds in the McAlester shale contain flat plates of shale, several inches in diameter, that lie at at various angles to the bedding.

Most of the shale is gray, sandy, and micaceous. In the northern part of the district, however, the shale in the lower part of the formation is very dark gray, blocky, and free from sand.

Eight coal beds are known to be present in the McAlester shale. They are, from oldest to youngest, a thin unnamed coal; the Lower Hartshorne coal, the Upper Hartshorne coal; three thin unnamed beds; the McAlester coal; and the Stigler coal. Coal has been mined from only three of these beds: from the thin unnamed bed below the Lower Hartshorne at two mines near Excelsior, in the west-central part of the district; from the Lower Hartshorne bed at many mines, especially where it is thick and lies near the surface; and from the lowest of the three unnamed beds in the middle part of the formation at Moores Rock, north of Lavaca, where the coal is exposed in the bed of the Arkansas River. The Upper Hartshorne coal and the two unnamed beds in the middle part of the formation were not seen in outcrops at any place in the district, but each was encountered in many drill holes.

In other regions, coal bearing strata of Pennsylvania age contain several lithologic types that tend to recur many times in a regular sequence.[19] The possibility that similar repetitive sequence might exist in the McAlester shale led the authors to examine very carefully several hundred diamond-drill records of strata in the McAlester shale of the Fort Smith district.

With the help of observations made in the field, several stratigraphic horizons can be identified in five deep diamond-drill holes that penetrate about 1,100 feet of strata in the lowest part of the formation in secs. 3, 5, 7, 27, and 32, T. 4 N., R. 32 W. Although four coal beds were penetrated by these drill holes (fig. 8), no semblance of recurring lithologic sequence could be recognized. The only consistent recurrence lies in the alternation of coal beds with clastic sediments. Individual clastic beds vary greatly in both lithology and thickness within short horizontal distances, although the thickness of clastic rocks between coal beds tend to remain fairly constant over distances as of 5 or 10 miles. If the coal beds are absent or not exposed in any two or more given sections, the measuring and matching of clastic beds is of little or no value for correlation.

A detailed composite section of the McAlester shale, compiled from diamond drill records and from a large number of measured sections in T. 5 N., R. 32 W., also was studied carefully in order to ascertain whether or not any lithologic sequences were repeated. The various partial sections were tied together by detailed

[19] Udden, J. A., Geology and mineral resources of the Peoria quadrangle, Illinois; U. S. Geol. Survey Bull. no. 506, pp. 26–5, 1912. Wanless, H. R., Pennsylvania cycles in western Illinois: Illinois Geol. Survey Bull. 60, pp. 179–193, 1931. Weller, J. M., Cyclic sedimentation in the Pennsylvanian and its significance: Jour. Geology, vol. 38, No. 2, pp. 97–135, 1930. Stout, Wilbur, Pennsylvanian cycles in Ohio: Illinois Geol. Survey Bull. 60, pp. 195–216, 1931. Moore, R. C., Pennsylvanian cycles in the northern Mid-Continent region: Illinois Geol. Survey Bull. 60, p. 247–257, 1931.

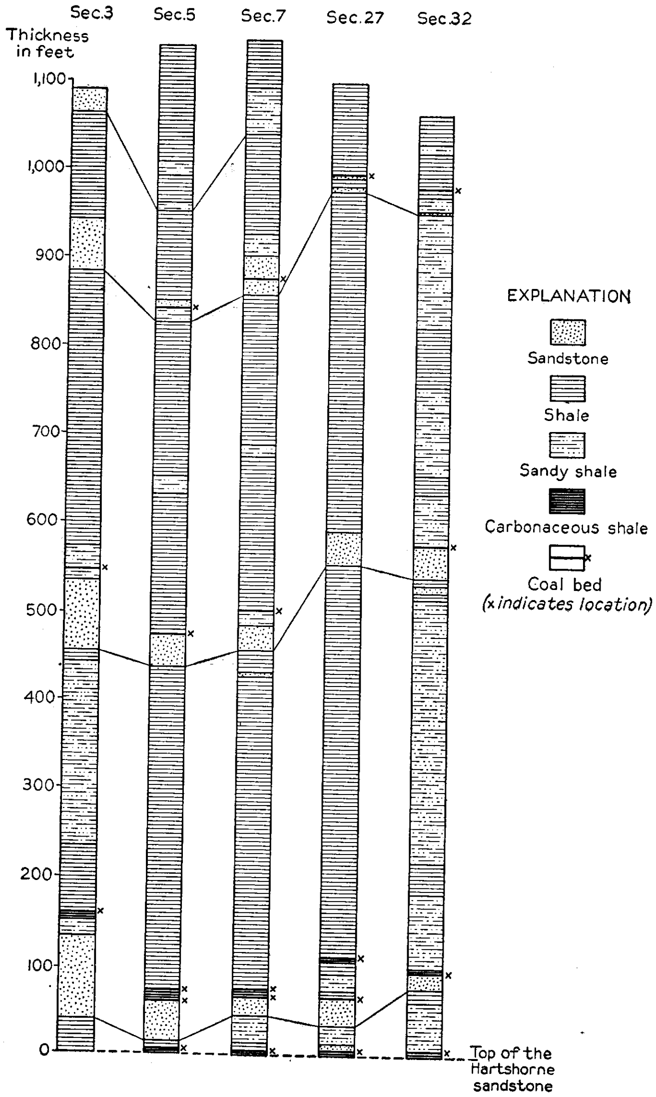

FIGURE 8.—Sections of the lower part of the McAlester shale encountered in five diamond-drill holes in T. 4 N., R. 32 W., in the Fort Smith district, Ark.

plane-table mapping on a scale of 2 inches to 1 mile. The section is given below.

Composite section of the McAlester shale on the east end of Sugarloaf Mountains, T. 5 N., R. 32 W.

[Beds 1-13 inclusive are repeated, together with three partial sections from the Savanna sandstone, on page 77]

	Ft.	in.
1. Shale, gray, sandy, micaceous	250	0
2. Shale, black, carbonaceous; contains ostracods	4	0
3. Coal	------	3
4. Shale, black, carbonaceous	1	2
5. Coal	------	4
6. Underclay, hard	2	0
7. Shale, gray, sandy, micaceous	170	0
8. Shale, gray, clayey, fissile	5	0
9. Coal, very impure, mostly carbonaceous shale	------	8
10. Underclay	1	0
11. Sandstone, hard, dense, dark, stigmarian	------	8

Composite section of the McAlester shale on the east end of Sugarloaf Mountains, T. 5 N., R. 32 W.—Continued

	Ft.	in.
12. Sandstone, shaly, olive, soft, micaceous	------	8
13. Sandstone, ripple-marked, micaceous, gray; thickness of beds one-eighth inch to 1 inch thick in lower part, increasing progressively to about 3 feet in upper part	80	0
14. Shale, dark gray, micaceous, sandy; grades upward into the overlying sandstone	480	0
15. Sandstone, gray, ripple-marked, micaceous, in beds 1 inch to 2 inches thick; grades laterally into sandy shale	13	0
16. Shale, dark gray, micaceous, sandy	112	0
17. Shale, very sandy; locally grades into shaly sandstone, buff to gray, micaceous	25	0
18. Coal	1	0
19. Shale, black, carbonaceous	3	0
20. Sandstone, fine-grained, gray, micaceous, ripple-marked, in beds about 1 inch thick; grades downward into sandy shale	30	0
21. Shale, dark, micaceous, somewhat sandy	170	0
22. Shale, gray, micaceous, very sandy	13	0
23. Shale, dark gray, micaceous, slightly sandy	175	0
24. Coal	1	0
25. Shale, black, carbonaceous	3	0
26. Sandstone, gray to buff, micaceous, fine-grained, ripple-marked, thin-bedded; locally grades laterally into sandy shale	47	0
27. Shale, very sandy, micaceous, gray	16	0
28. Sandstone, similar to 26	7	0
29. Shale, similar to 27	6	0
30. Sandstone, similar to 26	9	0
31. Shale, dark gray, micaceous, somewhat sandy	92	0
32. Shale, gray to buff, very sandy, micaceous	124	0
33. Shale, dark gray	27	0
34. Shale, very sandy, micaceous, gray to buff	13	0
35. Shale, dark gray, micaceous	48	0
36. Coal and carbonaceous shale	5	0
37. Shale, black, carbonaceous	3	0
38. Sandstone, buff, fine-grained, micaceous, ripple-marked	17	0
39. Shale, very sandy, gray, micaceous	12	0
40. Coal, impure	2	0
41. Sandstone, coarse-grained, irregularly bedded, gray to white; lenticular, with irregular base; ranges in thickness from a knife edge to 54 feet	20	0
42. Shale, sandy, micaceous, gray	30	0
43. Shale, dark, carbonaceous; contains plant fossils and brackish-water invertebrates	7	0
44. Coal (Lower Hartshorne)	4	0
45. Shale, carbonaceous, with coaly streaks, basal beds of the McAlester shale	3	0
	2,034	9

Although this section does not appear to be composed of a series of similar lithologic sequences, the group of beds from 1 to 13, at the top of the formation, is somewhat similar to sequences at three horizons in the Savanna sandstone, and it will be considered further in describing that formation.

Invertebrate fossils are sparingly present, at least locally, at several horizons in the McAlester shale, but no one fossiliferous horizon could be identified in all parts of the area. The fossils are mostly pelecypods, too poorly preserved to be accurately identified. Plant fossils are abundant and well preserved at several horizons, and have served as a useful check on their correlation.

SAVANNA SANDSTONE

The Savanna sandstone rests on the McAlester shale with a somewhat irregular contact, and near the Arkansas State line, on the part of Sugarloaf Mountains that extends into Oklahoma, the basal sandstone of the formation cuts downward to the east across the beds in the upper part of the McAlester shale at an angle of 1° or 2°. These features suggest that there is at least a minor unconformity at the base of the Savanna sandstone.

Complete sections of the Savanna sandstone are exposed at three localities in the district—the Paris basin, the basin south of Charleston, and Poteau Mountain. The thickness of the formation at those localities ranges from 1,140 to 1,610 feet.

The formation consists predominantly of shale and sandstone, but it contains at least six coal beds and one lenticular bed of limestone. The shale is mostly buff to brown and sandy, though there is some gray clay shale and several thin beds of black carbonaceous shale. The sandstone beds are generally thin-bedded, ripple-marked, fine-grained, and buff to brown in color. Locally, however, they are coarse-grained and irregularly bedded, as if deposited in channels. About ten mappable sandstone beds occur in most of the sections of Savanna sandstone, but they are lenticular and cannot be correlated with certainty from one section to another. The lower, upper middle, and upper parts of the formation contain zones of sandstone and sandy shale.

Eight coal beds are known to occur in the formation. Five of them are only a few inches thick, but the other three—the Charleston, Cavanal, and Paris coals—attain thicknesses of 18 inches or more. In the eastern part of the district, all these coal beds are present and represent fairly continuous identifiable horizons. The Charleston coal of this part of the district is probably equivalent to a thin coal bed found in the lower part of the Savanna in the southwestern part of the district where the only other coal bed is the Cavanal coal, probably represented in the eastern part of the district by a thin bed of coal in the middle part of the formation.

The only limestone in the Savanna sandstone lies in the upper part of the formation. It is exposed only in the basin south of Charleston, where 2 feet 4 inches of calcareous shale, containing limestone streaks, is overlain by a 6-inch layer of limestone composed almost entirely of pelecypods bound together by a calcareous cement. A careful search in the Paris basin and in the extreme southwestern part of the district failed to reveal any limestone at that horizon.

Apparently, therefore, the limestone bed is a lens of brackish or fresh-water origin.

Many partial sections of the Savanna sandstone were measured in the basin south of Charleston. These were tied together by plane-table mapping and were compiled into the following composite section on page 77.

No definitely recognizable sequence of lithologic units appears to be repeated in this section or in the section of the McAlester shale given on page 75. Lithologic sequences that are somewhat similar occur, however, at three horizons on the Savanna sandstone and at one horizon in the upper part of the McAlester shale. They are in table on page 77. The four sequences of strata have a total thickness of only about 790 feet, as compared with a thickness of about 3,275 feet for the entire section, and, though all but one of them contains a bed of coal, they are separated from one another by sequences of sandstone, sandy shale, and shale that are very dissimilar. As the tendency for lithologic types to recur in similar sequences in the McAlester and Savanna formations of the Fort Smith district thus appears to be slight, it is not feasible to use lithologic sequences for purposes of correlation or as a basis for subdividing the formations.

Plant fossils are abundant at several horizons in the Savanna sandstone, and they are of great service in correlating horizons in the formation, not only between one section and another within the Fort Smith district but between sections in the district and those in adjoining areas.

BOGGY SHALE

The Boggy shale, which overlies the Savanna sandstone conformably, is exposed at only a few places in the district. Less than 100 feet of Boggy shale occurs on the top of Poteau Mountain, in the southwestern part of the district, about 500 feet in the Bloomer syncline south of Charleston, and about 900 feet in the Paris syncline, on Short and Horeshoe Mountains in the eastern part of the district.

The part of the formation that is present in the district consists of dark clay shale and gritty shale, with three sandstone beds about 760 to 900 feet above the base. The shales are poorly exposed, and it is possible that they contain some coal beds that were not seen. The sandstone is coarse-grained, medium-bedded, and buff to brown in color.

Composite section of the Savanna sandstone south of Charleston, T. 7 N., Rs. 28 and 29 W.

Beds 11-16; 19-22; and 32-36 are repeated in the section below]

		Ft.	*in.*
1.	Sandstone, buff, in thick even beds, medium-grained, aud micaceous; uppermost unit of the Savanna sandstone	20	0
2.	Shale, gray, sandy	6	0
3.	Sandstone, buff, shaly	5	0
4.	Shale, gray	5	0
5.	Limestone, sandy, with abundant fresh-water fossils	1	0
6.	Shale, black, calcareous	2	0
7.	Limestone, dark gray, very fossiliferous, hard, silicified	1	0
8.	Coal	---	6
9.	Shale, gray, sandy	6	0
10.	Sandstone, brown, to shaly, thin-bedded	8	0
10a.	Shale, gray and black, sandy in part	27	0
10b.	Sandstone, marine fossils	2	0
11.	Shale, gray in upper part; grades downward into black shale that contains abundant plant fossils	30	0
12.	Coal	1	6
13.	Shale, gray and black, with abundant plant fossils in lower part	110	0
14.	Coal	---	2
15.	Shale, black and gray, with some plant fossils in upper part	70	0
16.	Sandstone, brown, fine-grained, and shaly	7	0
17.	Shale, sandy, gray and black	90	0
18.	Sandstone, medium-grained, soft, brown, thin-bedded	5	0
19.	Coal	------	4
20.	Shale, gray	100	0
21.	Coal	------	4
22.	Sandstone, gray, hard, fine-grained, even-bedded in beds 1 inch to 8 inches thick; used locally for structural stone	20	0
23.	Shale, gray and black, and some sandy shale	200	0
24.	Sandstone, gray, brown, shaly, even-bedded	8	0
25.	Shale, gray and black, and some sandy shale	80	0
26.	Sandstone	10	0
27.	Shale, gray and black, and some sandy shale	50	0
28.	Sandstone	10	0
29.	Coal	------	11
30.	Shale, gray and black, and some sandy shale; contains two lenticular sandstone beds	160	0
31.	Sandstone, brown, even-bedded, shaly, lower 1 to 2 feet very hard	10	0
32.	Shale, sandy, brown, micaceous	15	0
33.	Coal	------	6
34.	Shale, sandy, banded in gray and black, in quarter-inch to half-inch beds resembling varves; contains plant fossils, especially in lower part	70	0
35.	Coal	1	6
36.	Sandstone, gray to buff, medium-grained to shaly	10	0
37.	Shale, gray, and some brown sandy shale	200	0
38.	Sandstone, brown, fine-grained, thin-bedded, hard; breaks into long, narrow, rectangular fragments; basal units of the davanna sandstone	15	0
		1, 359	9

Similar lithologic sequences at four horizons in the McAlester shale and Savanna sandstone

McAlester shale [1]	Savanna sandstone [2]		
	A	B	C
Shale, gray, sandy.	Shale, sandy.		Shale.
Shale, black, carbonaceous; contains ostracodes.			Sandstone, marine.
Coal.			
Shale, black, carbonaceous.	Coal.	Coal.	Coal.
Coal.			
Underclay, hard.			
Shale, clayey, with plant fossils.	Shale with plant fossils.	Shale.	Shale with plant fossils.
Coal, impure.	Coal.	Coal.	Coal.
Underclay.			Shale with plant fossils.
Sandstone, stigmarian.			
Sandstone.	Sandstone.	Sandstone.	Sandstone.

[1] For stratigraphic position and thickness of McAlester shale see p. 75, beds 1-13.
[2] For stratigraphic position and thickness of beds see parts of section of Savanna sandstone above, A, beds 32-36; B, beds 19-22; and C, beds 11-16.

No fossils of any kind were noted in this formation, but fossils may nevertheless be present and might have been found if the exposures of the formation were better and more numerous. Correlation with the Boggy shale of Oklahoma is based on similarity of stratigraphic position and of lithologic character.

SOURCE OF THE SEDIMENTS

Evidence as to the source of the Pennsylvanian sediments is less abundant within the Fort Smith district than in other parts of the Arkansas-Oklahoma coal basin.

West of Black Knob Ridge, in Oklahoma, at the southwest end of the coal basin, conglomerates at horizons ranging from the lower part of the Atoka formation to the top of the Savanna sandstone were derived from strata that lay southeast of that part of the basin.[20]

Near Heavener, Okla., about 10 miles west of the Arkansas coal field, a buried forest in the Hartshorne sandstone has been exposed in the Pine Mountain strip pit.[21] Many of the trees of that buried forest have tilted or overturned, with their tops pointing northward and their bases southward. They probably were pushed over by northward-flowing streams that carried some of the sediment of the Hartshorne sandstone.

In the southwestern part of the Fort Smith district the Lower Hartshorne coal is overlain by lenticular beds of sandstone (pl. 13). The bases of the sandstone lenses are convex downward, and the lenses appear to have been deposited in channels. They contain some remains of plants and brackish-water invertebrates. The lenses are numerous in T. 4 and 5 S., but farther north they are absent, although the horizon at which they should occur is widely exposed. If they were deposited in streams that flowed southward they should continue to the north in the stream channels, and the abrupt termination at the north suggests that they were deposited in northward-flowing streams that entered a sea or lake somewhere near the north side of T. 5 N. Some evidence that this occurred is afforded by the fact that the shales which, to the north, lie at the horizon of the sandstone lenses contain a few poorly preserved brackish-water or marine invertebrate fossils.

In the northern part of the Boston Mountains, which lie north of the coal basin, there are conglomerates, containing small quartz pebbles, in the lower part of the Atoka formation that have been described by Simonds,[22] Miser and Purdue,[23] and others. Those conglomerates are similar to others that occur in rocks of about the same age farther east and are believed to have been derived from sources that lay east of the present Appalachian Mountain. The horizons at which these conglomerates in the Boston Mountains lie are not exposed in the Fort Smith district, so that their presence or absence there cannot be determined.

In the Oklahoma portion of the coal basin there is a gradual change toward the northwest from continental to marine strata, which suggests that the Pennsylvanian sea lay to the northwest and the land area to the southeast. On the basis of the limited available data, therefore, it appears probable that the Pennsylvanian sediments of the Arkansas-Oklahoma coal basin came predominantly from the south or southeast but in minor part from the east. According to Miser,[24] the source of most of the Pennsylvanian sediments of the Ouachita Mountains and Arkansas Valley was Llanoria, an extensive land area of crystalline rocks that stood south of the Ouachita Mountains in Pennsylvanian time and was later lowered and covered with sediments of the Gulf Coastal Plain. The Atoka formation contains the youngest rocks in the Ouachita Mountains; the Hartshorne sandstone and overlying formations are not present in those mountains and may not have been deposited there. It seems possible, therefore, that the previously deposited Pennsylvanian strata of the Ouachita Mountains, as well as the crystalline rocks of Llanoria, supplied sediments to the coal basin in post-Atoka time.

QUATERNARY SYSTEM

STREAM TERRACES

Extensive deposits of gravel, sand, silt, and clay occur about 50 feet above the Arkansas River and on both sides of it in the northern part of the district. They have a maximum thickness of about 50 feet and are made up of quartz, chert, quartzite, sandstone, and other siliceous materials. Although some of the sand is probably of local origin, most of the material is unlike any of that in the bedrock of the Fort Smith district.

In addition to the terraces developed along the course of the Arkansas River, there are extensive terraces near the same level along the lower courses of the major tributaries that enter the Arkansas River from the north. The coarser material in each of those terraces is chiefly sandstone of a type native to the drainage basin of the associated stream.

In the extreme southern part of the district, south of Mansfield and Hartford, several large terraces covered with cobbles and gravels lie about 50 feet above the streams that flow in the large valley north of Poteau Mountain. The pebbles and boulders in those terraces consist of rock like those now exposed on Poteau Mountain, from which the terraces slope northward.

All the terraces are believed to be contemporaneous, and they are tentatively correlated with the Gerty sand of Oklahoma, which is believed to be Pleistocene but which may be as old as Pliocene. The terrace deposits throw much light on the development of the present topography of the Fort Smith district, and they will

[20] Knechtel, M. M., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 2, The Lehigh district coal, Atoka, and Pittsburg Counties: U. S. Geol. Survey Bull. 874–B, pp. 124–126, 1937.

[21] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 4, The Howe-Wilburton district Latimer and LeFlore Counties: U. S. Geol. Survey Bull. 874–D, 1939.

[22] Simonds, F. W., The geology of Washington County; Arkansas Geol. Survey Ann. Rept. for 1888, p. 1, pp. 106–112, 1891.

[23] Miser, H. D., and Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 15, 1916.

[24] Miser, H. D., Llanoria, the Paleozoic land area in Louisiana and Texas; Am. Jour. Sci., 5th ser., vol. 2, pp. 61–89, 1921.

be discussed further in connection with the geomorphology of the district (pp. 88 to 92).

ALLUVIUM

Alluvium covers the broad valley bottoms along the Arkansas River and its major tributaries, and narrower strips of alluvium border the smaller streams. The visible alluvium along the Arkansas River is mostly silt. Its exposed thickness ranges from a feather edge at the sides of the flood plains to about 20 feet in the stream banks, but many gas wells that have been drilled through the alluvium of the Arkansas River southeast of Van Buren have passed through 30 to 50 feet of silt of a kind that might well accumulate to such thickness on the flood plain of the river. Two wells passed through 255 and 260 feet, respectively, of sand and gravel. Both the coarseness and the thickness of these materials suggest that they were deposited in abandoned channels of the river, and that they represent approximately the maximum thickness of alluvium that may be expected.

PALEONTOLOGY

PLANT FOSSILS

Seventeen collections of plant fossils from the Arkansas coal field have been studied by C. B. Read. Most of the collections came from the Fort Smith district, but several came from other parts of the coal field. Some of the collections were made by A. J. Collier in 1907, some by members of the field party working in the area in 1934, and others by T. A. Hendricks and C. B. Read in 1930 and 1931. A check list of the flora is given below.

Check list of plant fossils

[Collections studied by C. B. Read]

Genus and species	Collection No.																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Alethopteris sevlii (Brongniart) Goeppert				×	×			×	×	×	×		×				
Annulata stellata (Schlotheim) Wood							×						×				
Annulata sphenophylloides (Zenker) Gutbier			×				×	×	×	×	×	×					
Aphlebia hirsuta (Lesquereux) D. White									×								
Asterophyllites equisetaeformis (Schlotheim) Brongniart								×			×				×		
Asterophyllites sp											×						
Asterophyllites sp. cf. *A. equisetaeformis* (Schlotheim) Brongnairt													×				
Calamites suckowii Brongnairt					×			×									
Calamostachys sp													×				
Callipteridium sullivantii Lesquereux				×									×				
Cordaites communis Lesquereux					×	×											
Desmopteris n. sp													×				
Eremopteris n. sp									×			×					
Lepidocarpon sp					×												
Lepidodendron sp					×												
Lepidophyllum sp					×			×									
Lepidophyllum missouriensis D. White											×						
Lepidophyllum lanceolatum Lindley and Hutton																×	
Lepidostrobus variablis Lindley and Hutton			×														
Lepidostrobus sp									×								
Linopteris n. sp. (cf. species from Illinois Pottsville)	×																
Linopteris gilkersonensis D. White					×	×											
Linopteris rubella Lesquereux											?	×	×	×	×	×	
Linopteris squarrosa (Ettingshausen) D. White									×								
Mariopteris neruosa (Brongniart) Zeiller				×		×	×	×									
Mariopteris occidentalis D. White			×	×	×		×										×
Mariopteris cf. *M. latifolia* (Brongniart) Zeiller					×												
Mariopteris sp. cf. *M. nervosa* (Brongniart) Zeiller											×						
Mariopteris sp. cf. *M. sphenopteroides* (Lesquereux) Zeiller											×		×				
Neuropteris sp. cf. *N. rarinervis* Bunbury	×				×			×									
Neuropteris scheuchzeri Hoffman		×		×	×	×	×	×	×		×	×	×		×		
Neuropteris capitata Lesquereux				×			×	×									
Neuropteris missouriensis Lesquereux				×	×	×		×			?	×					×
Neuropteris rarinervis Bunbury						×							×				×
Neuropteris harrisi D. White						×		×									
Neuropteris ovata Hoffman						×	×	×		×			×				
Neuropteris sp. cf. *N. tenuifolia* Scholtheim												×					

880807—50——2

Check list of plant fossils—Continued

[Collections studied by C. B. Read]

Genus and species	Collection No.																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Neuropteris sp													×	×			
Neuropteris ienneyi D. White									×	×							
Odontopteris cf. *O. wortheni* Lesquereux								×									
Pachytesta sp			×														
Pecopteris vestita Lesquereux		×	×	×	×		×		×	×	×		×		×		
Pecopteris sp. cf. *P. arborescens* (Schlothein) Brongniart				×									×				
Pecopteris dentata Brongniart					×												
Pecopteris richardsoni D. White			×														
Pecopteris unita Brongniart									×								
Sigillaria sp					×											×	
Sigillariostrobus quadrangularis (Lesquereux) D. White						×											
Sigillariostrobus sp									×								
Sphenophyllum cuneifolium (Sternberg) Zeiller		×					×										
Sphenophyllum emarginatum Brongniart		×						×					×				
Sphenophyllum majus Bronn												×					
Sphenophyllum suspectum D. White							×										
Sphenopteris cristata (Brongniart) Presl				?						×							
Sphenopteris sp. cf. *S. mixta* Schimper				×													
Sphenopteris obtusiloba Brongniart					×	×							×		×	×	
Sphenopteris macilenta Lindley and Hutton					×					×					×		
Sphenopteris sp							×	×									

1. Atoka formation, 2,500 feet (±) below the top, on road, 2½ miles west of Barber, Ark., SE¼SW¼ sec. 4, T. 5 N., R. 29 W. East of the Fort Smith district.
2. Atoka formation, 500 feet below the top, at road junction on Highway U. S. No. 71, center west sid , sec. 13, T. 5 N., R. 31 W.
3. Atoka formation, shale in the upper few feet, on a road, three-quarters of a mile east of Huntington, Ark., SE¼NW¼ sec. 30, T. 5 N., R. 30 W.
4. McAlester shale, in roof of the Lower Hartshorne coal at abandoned mine, E½SE¼ sec. 9, T. 9 N., R. 31 W.
5. McAlester shale, roof of the Lower Hartshorne coal, Ouita basin, Pope County, Ark. East of the Fort Smith district.
6. McAlester shale, roof of the Lower Hartshorne coal, Skinner mine, Ouita basin, Pope County, Ark. East of the Fort Smith district.
7. McAlester shale, roof of the Lower Hartshorne coal, SE¼ sec. 22, T. 9 N., R. 26 W. East of the Fort Smith district.
8. McAlester shale, shale below the Lower Hartshorne coal, NE¼NE¼ sec. 23, T. 9 N., R. 27 W.
9. McAlester shale, shale 3 feet below the Lower Hartshorne coal, SE¼ sec. 24, T. 10 N., R. 25 W. East of the Fort Smith district.
10. McAlester shale, shale 4 feet below the Lower Hartshorne coal, NE¼ sec. 13, T. 9 N., R. 25 W. East of the Fort Smith district.
11. Savanna sandstone, roof of the Charleston coal at the Coleman mine, SW¼NE¼ sec. 17, T. 7 N., R. 28 W.
12. Savanna sandstone, near the horizon of the Charleston coal, 50 paces south of iron bridge half a mile east of Caulksville, Ark., center south line sec. 3, T. 7 N., R. 27 W.
13. Savanna sandstone, roof of the Charleston coal, dump of abandoned mine, center NE¼ sec. 10, T. 7 N., R. 27 W.
14. Savanna sandstone, roof of the Charleston coal, west end of strip pit, center west side SW¼ sec. 32, T. 8 N., R. 28 W.
15. Savanna sandstone, shale near the horizon of the Charleston coal, NE¼ sec. 6, T. 7 N., R. 28 W.
16. Savanna sandstone, roof of the Paris coal, NE¼NE¼ sec. 10, T. 7 N., R. 26 W.
17. Savanna sandstone, shale 300 feet below the horizon of the Paris coal, in ditch beside road NE¼SW¼ sec. 32, T. 7 N., R. 28 W.

Four general stratigraphic zones are represented by the collections. Collections 1 and 2 are too small to be critical, but collection 1 is suggestive of upper Pottsville age, as would be expected. Collection 3 (from the top of the Atoka formation), and collections 4 to 10, inclusive (near the horizon of the Lower Hartshorne coal), all show marked similarity with collections from near the horizon of the Lower Hartshorne coal in Oklahoma. On the basis of the Oklahoma flora at that horizon Read [25] has expressed the opinion that the Hartshorne sandstone is of about the same age as the lower part of the Allegheny of Pennsylvania.

Collections 11 to 15, inclusive, from the horizon of the Charleston coal, lie in a zone characterized by an abundance of *Linopteris rubella*, which correlates with the lower part of the Savanna sandstone of Oklahoma. According to Read, the rarity of *L. rubella* and the presence of *Mariopteris* sp. (cf. *M. sphenopteroides*) in collections 11 and 13 suggest that they are from strata as old as the upper part of the McAlester shale of Oklahoma. The fact that both of these collections come from the same horizon as collections 12 and 14, which Read believes to be definitely lower Savanna, indicates that the suggested affinity to the upper part of the McAlester shale is not a sufficient basis for correlation.

Collections 16 and 17 come from the upper part of the Savanna sandstone. Collection 17 is not diagnostic, and according to Read collection 16 seems to be from a horizon near that of the Cavanal coal in the Oklahoma coal field. On the basis of field mapping, however, the Paris coal, from which collection 16 was obtained, appears to be considerably higher in the Savanna sandstone than the horizon of the Cavanal coal.

The plant fossils in collections 11 to 17, inclusive, indicate that the Savanna sandstone correlates with the strata in the Allegheny formation of Pennsylvania.

[25] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 1, The McAlester district, Pittsburg, Atoka, and Latimer Counties: U. S. Geol. Survey Bull. 874–A, p. 13, 1937.

INVERTEBRATE FOSSILS

Several collections of invertebrate fossils were made by the field party working in the western part of the Arkansas coal field in 1934, but a casual examination of the fossils by G. H. Girty and P. V. Roundy indicated that they had little stratigraphic significance. A number of collections made by Collier and others were examined by Girty and discussed by him [26] in the report on the Arkansas coal field prepared by Collier in 1907. The faunal lists in that report are not repeated here.

Girty found that the faunas have only a general stratigraphic significance, which he stated as follows:

> All of these fossils are of Pennsylvanian age, and all show closely related faunal facies. I regard them as rather low in the Pennsylvanian. Very little discrimination can be made between these collections on the strength of their invertebrate faunas.

STRUCTURE

GENERAL DESCRIPTION

The Fort Smith district lies in a long, comparatively narrow synclinal trough that extends eastward along the Arkansas Valley from the Oklahoma State line, lying between the Boston Mountains on the north and the Ouachita Mountains on the south. The geologic structure is very different in these two mountain areas. The rocks of the Ouachita Mountains have been folded and locally faulted by intense pressures exerted from the south; in the folds and along the faults the beds are now steeply inclined, and in many places they are vertical or even overturned. The rocks of the Boston Mountains, on the other hand, have been only slightly tilted to the south and gently folded, but they are broken by steep faults, along most of which the downthrow is on the south.

The geologic structure of the Fort Smith district is essentially a combination of the structure of the Ouachita Mountains and that of the Boston Mountains. Structually the district is roughly divisible into two parts, the boundary being along the south side of the Backbone anticline. In the southern part of the district where the rocks have been strongly folded and are broken by a few reverse faults, the structure is similar to that of the Ouachita Mountains, and is characterized by folding and faulting only slightly less intense. The strata in the northern part of the district, like those of the Boston Mountains, are deformed only by gentle folds and normal faults.

Each of the anticlines, synclines, and faults is described below, and on plate 1 the depths of the strata in the folds are shown by structure contours and the fault traces by heavy lines. Plate 2 consists of three sections across the district.

DESCRIPTION OF INDIVIDUAL STRUCTURAL FEATURES

Hartford anticline.—The Hartford anticline crosses the Fort Smith district from west to east about 5 miles north of the south boundary. Its axis passes through Hartford and about a mile south of Mansfield. The anticline dies out a short distance east of the district, but it continues for about 15 miles westward to Oklahoma. It is a symmetrical fold, with maximum observed dips of 26° on the north flank and 32° on the south flank. At the Oklahoma State line the anticline plunges gently eastward, but about a mile east of the border the direction of plunge is reversed, and the axis of the fold plunges westward to the central part of Coops Prairie, about 2 miles southeast of Mansfield. There the direction of plunge is again reversed, and the anticline plunges eastward to the east side of the district. The Hartford anticline has a structural closure of about 1,600 feet, and the Mansfield gas field lies in the central part of the area of closure.

The field is on Coops Prairie, the floor of an elliptical valley, which is about 4 miles long and is developed on shale. The prairie is surrounded by a scarp formed by a standstone bed. The strata exposed in the Hartford anticline comprise the lower 300 feet of the McAlester shale, the whole of the Hartshorne sandstone, and the upper 3,500 feet of the Atoka formation.

Sugarloaf syncline.—The broad, shallow Sugarloaf syncline lies about 3 miles north of and parallel to the Hartford anticline. Its axis crosses the Fort Smith district from west to east just north of Huntington and the highest part of Sugarloaf Mountains. The axis of the syncline plunges westward throughout its course within the district, and from east to west successively younger beds of the Atoka formation. Hartshorne sandstone, McAlester shale, and Savanna sandstone cross its axis. The erosion of this westward plunging syncline has resulted in the formation of a series of horseshoe-shaped ridges and valleys, whose sides lie roughly parallel to the axis of the syncline and whose open ends point westward. In the extreme western part of the fold, however, where the degree of plunge is low, the gently dipping beds near the axis of the fold have withstood erosion better than the surrounding more steeply dipping beds. They form Sugarloaf Mountains, an excellent example of a mountain with synclinal structure.

Midland anticline.—The Midland anticline, which lies 2 to 4 miles north of the Sugarloaf syncline, extends eastward from a point near Slatonville, at the west side of the Fort Smith district, to a point about 3 miles

[26] See Collier, A. J., The Arkansas coal field: U. S. Geol. Survey Bull. 326, 1907, pp. 31–35.

north of Huntington—a distance of about 10 miles. In the part of the anticline that lies within the district the axis plunges westward, and progressively younger strata of the Atoka, Hartshorne, and McAlester formations cross it in succession from east to west. Erosion on alternating hard and soft strata in those formations has produced a series of horseshoe-shaped ridges and valleys with their open ends to the east. Near its eastern end, where it dies out on the south flank of the larger Washburn anticline, the anticline is poorly defined, the ridges that cross its axis being but slightly curved.

James Fork syncline.—The James Fork syncline lies about 2 miles north of and parallel to the Midland anticline. In its eastern part, the syncline plunges westward rather sharply, so that beds of the Atoka formation and Hartshorne sandstone cross it nearly at right angles. In its western part, gently dipping beds in the McAlester cover large areas in the syncline. About 2½ miles south of Hackett there are two small normal faults in the McAlester shale near the axis of the syncline.

Greenwood syncline.—The southwest end of the Greenwood syncline is on the north flank of the James Fork syncline, at a point about 3 miles southeast of Hackett. From there it extends, with a curving northeasterly course, for about 15 miles to a point about a mile east of Auburn, where it dies out on the south flank of the Bloomer syncline. This syncline is narrower than any other syncline in the Fort Smith district, and has steeper dips on its flanks. The average dip of the beds on both flanks being a little greater than 10°. The syncline plunges southwestward from its southwest end to a point just south of Excelsior, where the direction of plunge reverses. The plunge is northeastward to the vicinity of State Highway No. 10, then southwestward again for about a mile northeast of the highway, and finally reverses direction once more, remaining northeastward to the end of the fold.

Washburn anticline.—The broad Washburn anticline lies south of the Greenwood syncline. From a point about 1½ miles southeast of Excelsior, it extends eastward across the east side of the Fort Smith district, and it is known to continue eastward for many miles farther. The beds on the north flank of this anticline dip steeply and are locally overturned, while those on the south flank dip gently at angles not exceeding 30° (pl. 15). Within the Fort Smith district the anticline everywhere plunges westward, and from east to west progressively younger beds of the Atoka formation cross its axis. The outcrops of several sandstone beds can be traced where they dip gently on the south flank, but as they approach the axis of the anticline they cannot be recognized. This may be due to any one of several causes. One sandstone can be traced westward to within about a mile of the point where it should cross the axis, but it cannot be found beyond that point. As there is no change in the degree of dip at or near the point where the sandstone disappears, it may be that the axis of the anticline stood above sea level when the sandstone was being deposited, so that the sand layer feathered out at some distance from the axis. The same explanation probably applies to another sandstone bed that pinches out half a mile from the anticlinal axis. A third bed of sandstone crosses the axis of the anticline but can be traced for only a short distance on the north flank. When that bed was being deposited the axis of the anticline may have been farther north, in which case the explanation given above might apply to it also. It seems more probable, however, that the bed is actually present, and that the change from gentle dips on the south flank to steep dips on the north flank has resulted in the concealment of the thin sandstone bed north of the fold. In the northeast corner of sec. 20, T. 6 N., R. 30 W., the beds on the north flank of the fold are displaced by a small reverse fault. The fault may extend for a considerable distance eastward or westward parallel to the strike of the beds, but that could not be proved.

Backbone anticline and fault.—The Backbone anticline extends from a point about 1½ miles northeast of Greenwood almost due west for about 4 miles to the vicinity of Jenny Lind, where its axis passes beneath the Backbone fault. West of Jenny Lind the Backbone fault is flanked on the north by a narrow belt of strata that dip in general, steeply to the north but are locally overturned, and on the south by strata that dip in general about 65° S., though about a mile west of Jenny Lind there are also vertical and overturned dips on the south side of the fault. The folding involves the Atoka formation, the Hartshorne sandstone, and the McAlester shale.

The Backbone fault extends north-northwestward from a point about half a mile west of Greenwood to a point about half a mile west of Jenny Lind; from there it runs westward beyond the state line, which it crosses about a mile south of Bonanza. The beds along the south side of the fault, which are in the Atoka formation, have moved upward and northward relative to those on the north side, which are in the Atoka, Hartshorne, and McAlester formations. Near the east end of the fault, two smaller faults branch off from its south side and extend for distances of half a mile and 1½ miles, respectively. The displacement along the fault reaches a maximum of about 6,500 feet near the Oklahoma State line.

Jenny Lind syncline.—The Jenny Lind syncline is a shallow westward plunging trough in Hartshorne and lower McAlester beds. It extends eastward for about 3¼ miles from a point about a mile east of New Jenny Lind, between the overlapping ends of the eastward-plunging Backbone anticline on the south and the westward-plunging Biswell Hill anticline on the north.

Biswell Hill anticline.—The Biswell Hill anticline, which begins about a mile east of New Jenny Lind, trends about N. 70° E. for about 5 miles to the northern part of sec. 20, T. 7 N., R. 30 W., and then follows a curve trending slightly south of east to a point about a mile east of Auburn, a distance of approximately 6 miles. It is a broad flat arch, with dips generally less than 6° on the south flank and from 6° to 14° on the north flank. In general it plunges eastward at the east end and westward at the west end, and in its middle part there is an area of structural closure about 6 miles long, but within that large area of closure there are two smaller ones, separated by a small saddle on the axis of the anticline. The Hartshorne sandstone is the only formation exposed in the fold except at the east end, where beds in the McAlester shale and Savanna sandstone also cross the axis.

Central syncline.—The Central syncline enters the Fort Smith district from Oklahoma about three-quarters of a mile north of Bonanza, and follows a curve trending about N. 70° E. for a distance of 20 miles, dying out about a mile northeast of Lavaca. At the State line the axis of the syncline plunges westward; but throughout the remainder of the fold the plunge of the axis is toward the part of the syncline near Barling where the synclinal basin is widest. Beds in the McAlester shale and Savanna sandstone dip into the syncline from each side at a low angle.

Massard Prairie anticline and Massard fault.—The Massard Prairie anticline enters Arkansas from Oklahoma about midway between Cavanaugh and Bonanza, and continues in a northeasterly direction for about 12 miles to the northern part of sec. 25, T. 8 N., R. 31 W. In its middle part, on which the Massard Prairie gas field is located, the anticline is interrupted by the Massard fault, and at the east end it is cut off by that fault. The anticlinal axis plunges in both directions from the gas field, in which the fold is broadest. Gently dipping beds in the Atoka formation, the Hartshorne sandstone, and the McAlester shale are exposed on the flanks of the anticline.

The Massard fault extends from the southwest corner of sec. 11, T. 7 N., R. 32 W., northeastward to the southwest corner of sec. 21, T. 8 N., R. 30 W. It is a normal fault with the downthrow on the south. Its maximum throw, in the Massard Prairie gas field, is about 450 feet. A small fault branches off the northwest side of the Massard fault in sec. 31, T. 8 N., R. 31 W., and extends southwestward, approximately parallel to the main fault, for about 1½ miles. The beds on the south side of this branch fault also have moved relatively downward, but probably were no more than 50 feet. The exposed strata broken by the two faults lie in the upper part of the Atoka formation, the Hartshorne sandstone, and the lower part of the McAlester shale.

Lavaca anticline.—The Lavaca anticline begins at the Massard fault, in sec. 30, T. 8 N., R. 30 W., and extends eastward for about 8 miles to the southern part of sec. 16, T. 8 N., R. 29 W., where it dies out. Throughout its length it plunges westward. The strata exposed in the fold belongs to the McAlester shale. In most of the western part of the anticline, where the Lavaca gas field is located, the shale is covered with terrace gravels, but further east, where older beds are exposed, the dips on the flanks of the anticline nowhere exceed 4°.

Barling syncline.—The Barling syncline extends from sec. 32, T. 8 N., R. 31 W., eastward to sec. 30, T. 8 N., R. 30 W. It is a small syncline that plunges westward in the extreme eastern part and eastward throughout the remainder of its length. Beds in the McAlester shale dip into the syncline from each flank at angles not exceeding 5°. The north flank of the syncline ends against the Massard fault, which lies a quarter of a mile to half a mile north of the axis.

Vache Grasse anticline.—The Vache Grasse anticline is a small fold that lies a quarter to three-quarters of a mile south of the Barling syncline. Its axis plunges eastward except at the extreme east end, where it plunges westward. The exposed beds in the fold all lie in the lower part of the McAlester shale. The highest dips on the flanks are 6°.

Fort Smith syncline.—The Fort Smith syncline enters the western part of the district in sec. 32, T. 9 N., R. 32 W., extends almost due east for 3½ miles to the southern part of sec. 35 of the same township, and then runs southeastward for about 9 miles to the north side of sec. 19, T. 8 N., R. 30 W. It continues in an easterly direction for about 9 miles, at a distance of half a mile to 2 miles north of the Lavaca anticline. The plunge of the axis reverses three times producing a broad, shallow basin in the eastern part and a higher zone in the middle part, west of which the axis plunges westward to the State line. In the eastern and middle parts of the syncline the exposed beds in the lower part of the McAlester shale dip into the syncline from each flank at very low angles (3° or less), but near the State line the dips increase to as much as 10° on the south flank and 35° on the north flank. In the more steep-sided western part of the syncline, beds in the lower part of the Savanna sandstone are exposed along the axis.

Kibler anticline.—The Kibler anticline extends eastward along a curving course from sec. 31, T. 9 N., R. 31 W., about 1½ miles southeast of Van Buren, through the Kibler gas field to sec. 35, T. 7 N., R. 30 W.

It is about 9 miles long and attains a maximum relief of about 200 feet near the east end. Beds in the McAlester shale lie at or near the surface along the axis of the Kibler anticline but they are largely concealed by alluvium of the Arkansas Valley and by terrace gravels. Where beds in the McAlester shale are exposed they dip away from the axis of the anticline at angles of 1° to 10°, the average dip being about 3°.

Kibler syncline.—The Kibler syncline begins near the Arkansas River in sec. 31, T. 9 N., R. 31 W., and trends about N. 10° E. to sec. 16, T. 9 N., R. 30 W., where it ends against the River Ridge fault. The syncline is structurally highest in its middle part. Beds in the McAlester shale, dipping at angles of 2° to 10°, are exposed near the axis at many places but in most of the area of the syncline the bed rock is concealed by alluvium and terrace gravels.

Shibley anticline.—The Shibley anticline is a small fold entirely within T. 9 N., R. 31 W., trending northward from the western part of section 26 to the northeastern part of section 15. The axis of the anticline plunges toward each end from the central part, where there is a structural closure of about 50 feet. Terrace gravels cover the surface throughout the extent of the anticline, the position of which was determined from information obtained from wells drilled into the underlying beds of the McAlester shale.

Mulberry fault.—The Mulberry fault enters the Fort Smith district at the west in sec. 19, T. 9 N., R. 32 W. It runs about S. 80° E. to a point near Van Buren, where its course curves to east-northeast; it follows this course to the north line of sec. 21, T. 10 N., R. 29 W., north of Mulberry, and there leaves the district. Near Van Buren and farther west, and also near Alma in the valley of Clear Creek, the fault is covered with alluvium. Its downthrow is on the south. The rocks exposed on the north side of the fault belong to the Atoka formation and lie about 2,000 feet below the Hartshorne sandstone. On the south side of the fault for most of its length the exposed rocks are in the McAlester shale; but in a belt about 3 miles long, extending eastward from sec. 8 to sec. 10, T. 9 N., R. 31 W., they are near the top of the Atoka formation, and still farther east they are in the Hartshorne sandstone and the upper part of the Atoka formation. The vertical displacement of the fault is thus about 2,000 to 2,500 feet. The fault is known to dip southward in places, and it probably does so everywhere for wells drilled as much as a quarter of a mile south of the fault trace in the Alma gas field have passed through the fault plane at depths of 2,000 feet or less. Its exact dip cannot be determined, because the depth at which the fault plane was encountered in the wells is not known.

Minor faults associated with the Mulberry fault.—Three minor faults branch off from the Mulberry fault within the district. One of them, about 3 miles northeast of Van Buren, extends southeastward from the Mulberry fault for about 2 miles. Beds in the lower part of the McAlester shale are exposed on the southwest side of this branch fault; but on the northeast side the upper part of the Atoka formation, the Hartshorne sandstone, and the lower part of the McAlester shale are exposed successively from northwest to southeast. The displacement on the fault at its northwest end is thus about 500 feet, and it diminishes southeastward. North of Alma another branch extends northwest from the Mulberry fault.

About midway between Mulberry and Dyer a fault along which the beds have been dropped on the southwest side appears to extend southeastward from the Mulberry fault for about 3 miles. The fault is not indicated by surface exposures; it has been inferred from differences between the logs of two wells, close together, one of them northeast of the fault and the other southwest of it.

Small faults east of Mulberry.—A small fault extends northeastward for about 3½ miles from the southeast corner of the town of Mulberry. The downthrow of the fault is on the southeast, and its maximum displacement, near the middle, is about 200 feet. The rocks exposed along the fault comprise, from west to east, the lower part of the McAlester shale, all of the Hartshorne sandstone, and the upper part of the Atoka formation.

A small fault about a mile long, striking N. 10° W., has broken beds in the Atoka formation in secs. 20, 28, and 29, T. 10 N., R. 28 W. Its downthrow is on the south.

In secs. 22 and 27, T. 10 N., R. 28 W., there is a fault about a mile long, trending northwestward, with the downthrow of the southwest. It displaces beds in the upper part of the Atoka formation.

Bectum Hill syncline.—The Bectum Hill syncline begins at the Mulberry fault near Alma, trends about S. 15° E. for about 3 miles, turns eastward, and continues, on a course approximately parallel to the Arkansas River, for about 12 miles to sec. 4, T. 10 N., R. 28 W., where it dies out. The syncline plunges toward the central part from each end. The beds affected by the fold at the surface belong to the McAlester shale, but through most of the extent of the syncline they are concealed beneath alluvium and terrace gravels.

River Ridge fault.—The River Ridge fault branches from the Mulberry fault about 2½ miles west of Alma. It trends about S. 60° E. for 5 miles, nearly due east for about 15 miles, S. 60° E. for 5 miles and finally northeastward for about 2 miles to sec. 13, T. 9 N., R. 27 W., where it passes beneath alluvium at the west side of the Arkansas Valley. Through most of its middle part the fault lies in the bed of the Arkansas River or a short distance north of it. West of the center of sec. 20, T. 9 N., R. 27 W., where it is joined by the Bee Bluff fault, its downthrow is on the north, but east of the junction its downthrow is on the south. The downthrow of the Bee Bluff fault is on the west. The exposed strata broken by the River Ridge fault are in the upper part of the Atoka formation, the Hartshorne sandstone, and the McAlester shale. The fault attains its maximum displacement, about 1,300 feet, in the western part of T. 9 N., R. 29 W.

Ozark fault.—The Ozark fault branches from the River Ridge fault in sec. 13, T. 9 N., R. 28 W., and continues in an east-northeasterly direction for about 6 miles to the east boundary of the district, which it crosses a short distance southeast of Ozark. Its downthrow is on the south. The exposed strata broken by the fault are all in the upper part of the Atoka formation except in a small area near the west end, where the hanging wall of the fault consists of the lower part of the Hartshorne sandstone.

Manitou anticline.—The Manitou anticline begins at the Ozark fault in sec. 4, T. 9 N., R. 27 W., and runs northward and westward on a curve for about 4 miles to sec. 36, T. 10 N., R. 28 W., where it dies out. It is a broad domelike fold with dips of about 1° outward from the center in all directions. The rocks exposed at the surface in the anticline belong to the Hartshorne sandstone and the upper part of the Atoka formation.

Bee Bluff fault.—The Bee Bluff fault extends from the River Ridge fault to the Ozark fault along a northward-flowing stretch of the Arkansas River about 3 miles southwest of Ozark. The fault is concealed beneath alluvium in the Arkansas Valley throughout its length, and its presence is inferred solely from the fact that the same strata stand at a much lower level on the west side of the river than on the east side.

Cecil anticline and Mill Creek fault.—The Cecil anticline is terminated at the west by River Ridge fault near the Arkansas River, in sec. 36, T. 9 N., R. 30 W., to sec. 20, T. 9 N., R. 27 W. From here it runs eastward, and through most of its length it runs parallel to the Arkansas River and about 2 miles south of it. The strata exposed in the anticline include the Hartshorne sandstone and the upper part of the Atoka formation, and they dip away from the axis at angles of 2° to 5°. About 2 miles west of Cecil the anticline is broken by the northeastward-trending Cecil fault, which is about 2 miles long and has a downthrow on the northwest of about 50 feet.

The Mill Creek fault lies about a mile south of the axis of the Cecil anticline. It begins about a mile west of the Arkansas River, in sec. 35, T. 9 W., R. 30 W., and extends into sec. 30, T. 9 N., R. 27 W., having a known length of 14 miles. Its downthrow is on the north; its maximum displacement, along its central part, is about 350 feet. The exposed rocks along the south side of the fault belong to the upper part of the Atoka formation except near the east end, where the Hartshorne sandstone is exposed for about half a mile, and those on the north side belong to the Hartshorne sandstone except in a small area in the central part in sec. 29, T. 9 N., R. 28 W., where beds in the upper part of the Atoka formation are exposed. A small fault branches from the Mill Creek fault near its east end and extends southwestward for about 2 miles. In the middle part of the small fault there is a downthrow on the northwest of about 130 feet. Beds in the upper part of the Atoka formation are exposed on the southeast, and beds in the Hartshorne sandstone and the upper part of the Atoka formation on the northwest side.

Smith Creek syncline.—The Smith Creek syncline begins in sec. 5, T. 8 N., R. 27 W., continues northwestward for about 4 miles, and then passes beneath the alluvium of the Arkansas Valley. The syncline plunges northeastward, and from the southwest to northeast successively younger beds in the Hartshorne sandstone and McAlester shale cross its axis.

Etna anticline.—From Roseville, on the Arkansas River, the Etna anticline extends slighly south of west for about 8 miles to the west side of T. 8 N., R. 27 W., and then southwestward for about 5 miles. Throughout its length it plunges southwestward, and in that direction successively younger beds in the Hartshorne sandstone, McAlester shale, and Savanna sandstone cross its axis. The strata on the flanks of the anticline dip at angles of 2° to 8°.

Etna fault.—The Etna fault extends westward from sec. 12, T. 8 N., R. 27 W., for 7 miles to sec. 11, T. 8 N., R. 28 W. The east half of the fault cuts the north flank of the Etna anticline, but its western part lies between two small westward-plunging synclines, which dies out near the west end of the fault. The fault has a downthrow on the south of about 50 feet. The rocks exposed on the north side belong to the Hartshorne sandstone except at the extreme west end, where they lie near the base of the McAlester shale. On the south side, the exposed rocks along the east half of the fault belong to the Hartshorne sandstone except in a small area in sec. 10, T. 8 N., R. 27 W., where beds near the base of the McAlester shale appear; along the west half of the fault the south wall consists of the lower part of the McAlester shale.

Paris syncline.—The Paris syncline enters the district from the east about a mile east of Paris, and follows a curving westerly course for about 15 miles to sec. 4, T. 7 N., R. 28 W., where it dies out. The syncline plunges eastward from its west end to Horseshoe Mountain, and westward from the east side of the district to Short Mountain. Between those two mountains the axis rises slightly, so that each mountain lies in a shallow structural depression. Strata in the Boggy shale are exposed in the central part of the syncline, and strata in the Savanna sandstone at both ends and on the flanks. The strata on both flanks dip at angles of 4° to 8° at most places, but about 2 miles west of Paris the beds on the south flank dip at angles as great as 45°.

Pine Ridge anticline.—Only the west end and a part of the north flank of the Pine Ridge anticline lie within the Fort Smith district. The anticline extends westward along the south side of the district from the east boundary to sec. 30, T. 7 N., R. 27 W., where it dies out. It plunges westward in the westernmost 5 miles; it was not studied in detail farther east. The strata exposed in the anticline within the district belong to the upper part of the Atoka formation, the Hartshorne sandstone, and the McAlester shale. The dips on the north flank of the anticline are steep at most places and are locally vertical or overturned.

Fault on the north flank of the Pine Ridge anticline.—A reverse fault extends westward along the north flank of the Pine Ridge anticline from sec. 15, T. 7 N., R. 26 W., to sec. 14, T. 7 N., R. 27 W. Its upthrow is on the south side. The strata exposed on the south side of the fault belong to the lower part of the Savanna sandstone and the upper part of the McAlester shale; those on the north all belong to the Savanna sandstone except for a short distance at the west end, where beds near the top of the McAlester shale are exposed. The displacement on the fault is greatest near the middle where it is about 300 feet and decreases progressively toward each end.

Chismville syncline.—The Chismville syncline enters the east side of the Fort Smith district in sec. 29, T. 7 N., R. 26 W., and extends westward for 7½ miles to sec. 30, T. 7 N., R. 27 W., where it dies out. It plunges westward throughout its course within the district, and from east to west successively younger strata in the Atoka formation, the Hartshorne sandstone, and the McAlester shale cross its axis (pl. 16). The strata exposed on the flanks of the syncline dip at angles of 6° to 35°.

Bloomer syncline.—The Bloomer syncline trends southwestward from sec. 9, T. 7 N., R. 27 W., for 6 miles to sec. 34, T. 7 N., R. 28 W., and then about N. 20° W. for about 13 miles to a point 2 miles west of Bloomer. The central part of the syncline is a structural basin, into which the axis plunges from each end; but the strata rise slightly in the middle of the basin and divide it into two smaller basins separated by a low structural divide. Beds in the lower part of the Boggy shale are exposed in the middle of the western basin and are surrounded by beds of Savanna sandstone, which in turn are surrounded, in the outer parts of the syncline, by McAlester shale. The strata dip into the syncline at angles of 2° to 10° except in the middle part of the south flank, where the dips increase to as much as 45°.

Game Hill anticline and associated faults.—The Game Hill anticline begins in sec. 3, T. 7 N., R. 30 W., about half a mile north of the west end of the Bloomer syncline, and pursues a smoothly curving course eastward for about 16 miles to sec. 5, T. 7 N., R. 27 W., where it ends against a fault. From its west end, the anticline rises for about 2½ miles, then plunges until it passes northeast of Charleston, then rises again, and finally, from a point about 2 miles east of Branch, plunges to its east end. It thus comprises two zones of structural closure near the ends, separated by a structural saddle in the middle part. The Savanna sandstone is exposed in the central part of the anticline, and the McAlester shale in both the eastern and the western parts. The dips on the flanks are mostly between 3° and 5°.

In the eastern part of the anticline two normal faults, each about a mile long, break the strata on the south flank. One of them trends about S. 60° W. through secs. 10 and 11, T. 7 N., R. 28 W.; the other branches off from the first in sec. 10 and trends about S. 30° W. into sec. 15, where it dies out. Both faults cut beds in the McAlester shale and in the lower part of the Savanna sandstone. The downthrow on both is to the south. The maximum displacement, which is at the junction of the two faults, is about 125 feet. Near its east end, the north flank of the Game Hill anticline is cut by a fault zone consisting of three faults. One of these extends eastward from Branch for about 2½ miles; the other two branch from it near its east end and extend southeastward about 2 miles to the SE¼ sec. 5, T. 7 N., R. 27 W., where they join. From this junction a single fault extends eastward for about a mile and then dies out. The strata cut by this fault zone at the surface are in the McAlester shale. The

AERIAL PHOTOGRAPH OF THE WEST END OF THE WASHBURN ANTICLINE

Note the strong asymmetry of the fold and that the prominent ridge in the center disappears in the belt of steep dips in the northeast corner. Photograph supplied by the Agricultural Adjustment Administration.

AERIAL PHOTOGRAPH SHOWING HAIRPIN RIDGE IN THE CHISMVILLE SYNCLINE

Outward-facing scarp is formed by the closure of a sandstone bed in the McAlester shale across the axis of the westward-plunging Chismville syncline about 10 miles southwest of Paris, Ark. Photograph supplied by the Agricultural Adjustment Administration.

AERIAL PHOTOGRAPH OF NED AND HOLLIS LAKES

The two lakes are parts of an old ox-bow lake in a cut-off meander of the Arkansas River, 4 miles southeast of Van Buren. Note meander scars on the flood plain of the Arkansas River and the fairly straight line of separation of the flood plain from high-level terrace deposits in the upper right corner. Photograph supplied by the Agricultural Adjustment Administration.

downthrow on each fault is on the north. The displacement reaches a maximum of about 100 feet in the middle part of the fault zone.

Charleston syncline.—The Charleston syncline begins in sec. 25, T. 8 N., R. 30 W., and follows a curving course eastward for about 11 miles to sec. 27, T. 8 N., R. 28 W. The syncline plunges westward from its east end for about 2 miles, and eastward throughout the remainder of its extent, so that near its east end there is a structural basin. The strata exposed in the western half of the syncline lie in the McAlester shale, and those exposed in the eastern half lie in the lower part of the Savanna sandstone. The dips on the flanks range from 2° to 6°.

ORIGIN OF STRUCTURAL FEATURES

The nature of the structural features of the Fort Smith district and their relation to the structure of the adjacent Ouachita and Boston Mountains show that the dominant force in the production of those features was horizontal pressure exerted from the south. This is indicated by the gradational change in structure from the Ouachita Mountains northward into the coal field. The rocks of the Ouachita Mountains have been compressed into closely spaced, tight folds and broken by thrust faults through the agency of strong compressive forces exerted from the south.[27] Those forces were only partly relieved by the folding and faulting in the Ouachita Mountains, and the unrelieved forces were transmitted northward to the Arkansas coal field, of which the Fort Smith district is a part. The Hartford, Washburn, Backbone, and Pine Ridge anticlines, in the southern part of the district, are large and rather tightly folded, and with the exception of the Hartford anticline they are strongly asymmetrical, with the steeper dips on the north flank. The Backbone anticline, moreover, is broken along the crest by a southward-dipping reverse fault. With the development of each successive fold or reverse fault in the coal field the compressive forces exerted northward were diminished, being so feeble north of the Backbone anticline that they produced only gentle undulations bearing little resemblance to the folds in the Ouachita Mountains. This area of gentle folding contains many normal faults.

The mode of origin of these normal faults cannot be determined from existing evidence. They may have been formed by a downward movement of one side as a result of tension after the compression that formed the folds had ceased.

However, there is evidence that some of the faults and folds of the northern part of the district were formed within a single stage of deformation rather than in separate and independent stages. The Game Hill anticline terminates at its east end against a fault; the Massard Prairie anticline is both interrupted in its middle part and terminated at its east end by the Massard fault. In each instance, the angle of junction between the anticline and the associated fault is about 15° and the fault does not continue into the adjoining syncline. The termination of the anticlinal axes at the faults indicates that the faults were formed either before or during the folding of the anticlines. Both the anticlines lie on the upthrown side of the faults, so the vertical component of movement was in the same direction within the anticline as on the fault at the termination of the anticline. This fact indicates that at the junction of an anticline and a fault the vertical component of movement produced by folding in the anticline was translated into vertical movement on the fault. If the folding along the afore-mentioned two faults, which was produced by compressive forces from the south, is merely a translation of the vertical component of folding into movement on a fault plane, the movement along the faults must also have occurred in response to those same forces.

The Manitou and Cecil anticlines are terminated—not merely shifted or displaced—by faults, which indicates that these anticlines were formed either contemporaneously with or later than the faults; but in those instances it cannot be shown conclusively that the movement along the fault plane and the movement in the process of folding were produced by a single set of forces. The River Ridge, Mill Creek, and Etna faults, also, lie near and parallel to anticlinal or synclinal axes, and it seems reasonable to infer, in the absence of evidence to the contrary, that the faults and adjacent folds were produced by the same set of structural movements. Thus several examples point more or less clearly to the same conclusion, namely, that the movement on most of the normal faults in the western part of the Arkansas coal field, even though it had a vertical component, occurred in response to compressive forces from the south, and that it was contemporaneous with the development of the anticlines and synclines in the same area. The examples are not sufficiently numerous, however, to preclude the possibility that many of the faults were formed by downward movement of the downthrown side as a result of tension developed after the period of folding by compression.

The Mulberry fault forms the southern boundary of the Boston Mountains, which lie on the south limb of the broad Ozark dome. The upthrow of this fault is on the north, or in the direction of upwarping in

[27] Miser, H. D., Structure of the Ouachita Mountains of Oklahoma and Arkansas: Oklahoma Geol. Survey Bull. 50, p. 24, 1929.

the Ozark dome. Many gently folded anticlines and synclines with east-northeasterly trends, parallel to the Mulberry fault, occur in the Boston Mountains, and they suggest that the Ozark-Boston Mountain area was subject to compressive forces exerted from a direction slightly east of south, which probably established the Mulberry fault along a zone of weakness. The present stratigraphic displacement of the fault, which is about 2,000 feet, might have resulted either from upward movement on the north side, during the uplift of the Ozark dome, or from downward movement on the south side, caused by tension developed after the uplift of the dome.

GEOMORPHOLOGY

The physiographic features of the Fort Smith district have been developed by stream erosion on a series of alternating hard and soft strata that have been greatly deformed. In most parts of the area the strata have been folded into anticlines and synclines of different magnitudes, and locally they have been broken by faults. The erosion of strata so diverse in attitude and resistance has produced a corresponding diversity of topographic forms.

Winslow's [28] excellent account of the geomorphology of the Fort Smith district was very useful to the writers in the preparation of the following discussion.

If one could see the whole of the Fort Smith district in a birds-eye view, the heights that would stand out most prominently would be Poteau Mountain and Sugarloaf Mountains, in the southern part of the district. These two elongate mountains, which trend nearly east-west and rise about 2,000 feet above the surrounding valleys, are made up of nearly horizontal strata that lie in the central parts of the Poteau Mountain and Sugarloaf synclines. They are typical examples of synclinal mountains, which are common in areas where folded strata have been subjected to erosion. They owe their existence primarily to the gentle dips of the strata in them as contrasted with the steeper dips in the surrounding areas. The resistant strata have a greater horizontal extent in such areas of gentle dips than in the surrounding areas of steeper dips. Where the dips are steep, the resistant strata cannot protect the weaker strata; they present, also, a relatively small surface to erosion, and are consequently eroded at a relatively rapid rate. The contrary is true in the bottoms of broad, open synclines, and the gently dipping strata in these, held up by the soft beds which they protect from erosion, remain to form hills or mountains, such as Poteau Mountain and Sugarloaf Mountains.

[28] Winslow, Arthur. The geotectonic and physiographic geology of western Arkansas: Geol. Soc. America Bull., vol. 2, 225–242, 1891.

In the extreme eastern part of the district two smaller, flat-topped, mealike mountains — Short Mountain and Horseshoe Mountain—stand above the central part of the Paris basin, a topographic depression developed on soft shales that lie in the central part of the Paris syncline. The two mountains rise more than 500 feet above the surrounding valleys. They are capped by about 100 feet of horizontal resistant sandstone beds, and they probably are remnants of a mountain that was once as large as Sugarloaf.

South of Charleston, in the south-central part of the district, a long hill about 200 feet high rises from the central part of the Bloomer syncline. In the structurally deepest part of the syncline, toward its west end, a sharp conical peak rises about 330 feet above the remainder of the hill. That peak consists of soft shale, but it is a remnant of a once-extensive mesalike hill, similar to Short Mountain and Horseshoe Mountain, from which the resistant sandstone cap has been removed.

Elsewhere in the district there are similar but smaller hills that probably were formed in the same way. Two of the anticlines in the Fort Smith district contain well-developed canoe-shaped valleys. The better-developed of the two is Coops Prairie, which lies south of Mansfield and occupies the highest part, structurally, of the Hartford anticline (pl. 17*A*). Coops Prairie is about 4 miles long and a mile wide and is surrounded by a steep scarp about 150 feet high, held up by the outcropping edge of a resistant sandstone bed that dips away from the valley on all sides. It is drained by a tributary of the James Fork of the Poteau River, which cuts through the scarp in the middle of the north side. The other well-developed anticlinal valley lies in the central part of the Washburn anticline, but, as the anticline continues for many miles beyond the east side of the area, only the western end of the valley is within the Fort Smith district. Outside the scarps that form the rims of these two valleys there are a series of hogbacks, held up by the outcropping edges of resistant sandstone beds, roughly parallel to the axes of the anticlines. The axes of the anticlines plunge at varying angles, but the crests of the hogbacks vary but little in height. In each valley the ridges approach progressively closer to the anticlinal axis in the direction of its plunge, and finally the two ridges that are held up by the same resistant bed on the opposite sides of the anticline join across the axis. If the anticline plunges toward only one end, a series of horseshoe ridges with the closed ends in the direction of plunge is formed (pl. 15). If the anticline plunges toward both ends and away from a central structurally high part, the individual ridges close across the axes at both ends and form elongate, flattened ovals. The profiles of most of the hogbacks are asymmetrical, with a steep scarp face on the side toward the axis and a gentle slope on the opposite side. The degree of asymmetry of their profiles depends largely on the dip of the resistant beds that form their crests—the lower the dip of the strata the more marked is the asymmetry of the ridge, and the higher the dip the more nearly symmetrical is the ridge. The ridges in which the strata dip 45° or more are normally almost symmetrical. The height of the ridges depends on five factors, namely: unit resistance of the ridge-forming sandstone to erosion; thickness of the sandstone; dip of the strata; thickness of the underlying nonresistant bed; and distance from major streams.

The conditions most favorable for the formation of a high ridge are supplied by a thick bed of hard sandstone that overlies a thick shale bed, dips at a low angle, and is near a major stream. If four of the five factors enumerated above remain constant along an individual ridge, the height of the ridge varies directly with the remaining factor. If two or more of the factors vary along an individual ridge, the relative heights of the ridge at various places are integrally related to the variable factors.

Some of the synclines in the district, such as the Bloomer syncline, plunge sharply toward the center near their ends. At such a plunging end of a syncline, ridges that lie between the axis of the syncline and an adjoining anticline curve toward the synclinal axis and cross it (pl. 16). A horseshoe ridge thus formed will differ from those on the plunging ends of the anticlines, in that the scarp face is on the outer side of the curve and the gentle slope of the ridge faces the deeper part of the syncline (pl. 17 *A*).

Long ridges similar to those described above are the most common topographic forms in the Fort Smith district. The ridges differ in height and profile, and the height and profile of a single ridge vary from place to place, in accordance with the controlling factors described above. But the district also contains anticlinal ridges and hills, whose surface nearly conforms with the bedding. One of these is Biswell Hill, which rises about 400 feet above the surrounding valleys in the west-central part of the district. Biswell Hill is smoothly rounded and is elongate, being about 9 miles long and 4 miles wide. Its crest coincides approximately with the axis of the Biswell Hill anticline, and both its crest and its flanks consist of the Hartshorne sandstone, which has been warped into an anticline. The hill has been formed by the erosion of the soft lower part of the McAlester from the resistant Hartshorne sandstone where it was anticlinally arched.

The surface of the crests of River Ridge and of the associated hills that lie immediately south of the Arkansas River in the eastern part of the district likewise conforms closely to the shape of the top of the Hartshorne sandstone, there warped upward on the Cecil anticline (fig. 9). Along the abrupt bluff of River Ridge that faces the Arkansas River, the river has cut through the Hartshorne sandstone, which forms the top of the ridge, and through several hundred feet of strata in the upper part of the Atoka formation. An abrupt scarp lies south of Mill Creek, on the south flank of the Cecil anticline. The gentle slope north of Mill Creek is essentially a dip slope on the top of the Hartshorne sandstone; the scarp south of the creek also is capped with Hartshorne sandstone; and the rounded southward slope south of the scarp is essentially a dip slope developed on the top of the Hartshorne sandstone (fig. 9). Thus in River Ridge and the associated hills the development of the topography has been largely controlled by the erosion of soft shales from the deformed top of the underlying resistant Hartshorne sandstone.

Similar but smaller hills, such as the small one immediately north of Barling, which lies south of the Arkansas River in the western part of the district, have likewise been developed by the removal of soft overlying strata from the surface of an arched bed of sandstone along the axis of an anticline.

North of the Arkansas River, in the parts of the district that lie northwest of Van Buren and east of Mulberry, there are broad uplands broken by deep, narrow valleys. In general the surface of this area is underlain by gently dipping beds of sandstone and shale. The uplands are underlain by resistant sandstone beds, through which the streams have cut valleys in shale.

Several areas of low relief, the most extensive of which is Massard Prairie, southeast of Fort Smith, lie a short distance south of the Arkansas River. They stand about 50 feet above the present level of the river, having been developed by planation of soft strata at a time when the river flowed at a level about 50 feet higher.

There are stream-terrace deposits at considerable distances both north and south of the Arkansas River in the western part of the district (pl. 17*B*), and thin veneers of sand and gravel cover the tops of several level benches near Etna, south of the Arkansas River and in the eastern part of the district. These terrace deposits, also, lie about 50 feet above the present base level. Several of the terrace deposits contain cobbles and gravel of Boone chert. The nearest exposures of the Boone chert are in the Ozark Plateau region, which lies about 50 miles north of the Arkansas coal field and beyond the drainage basin of any of the tributaries

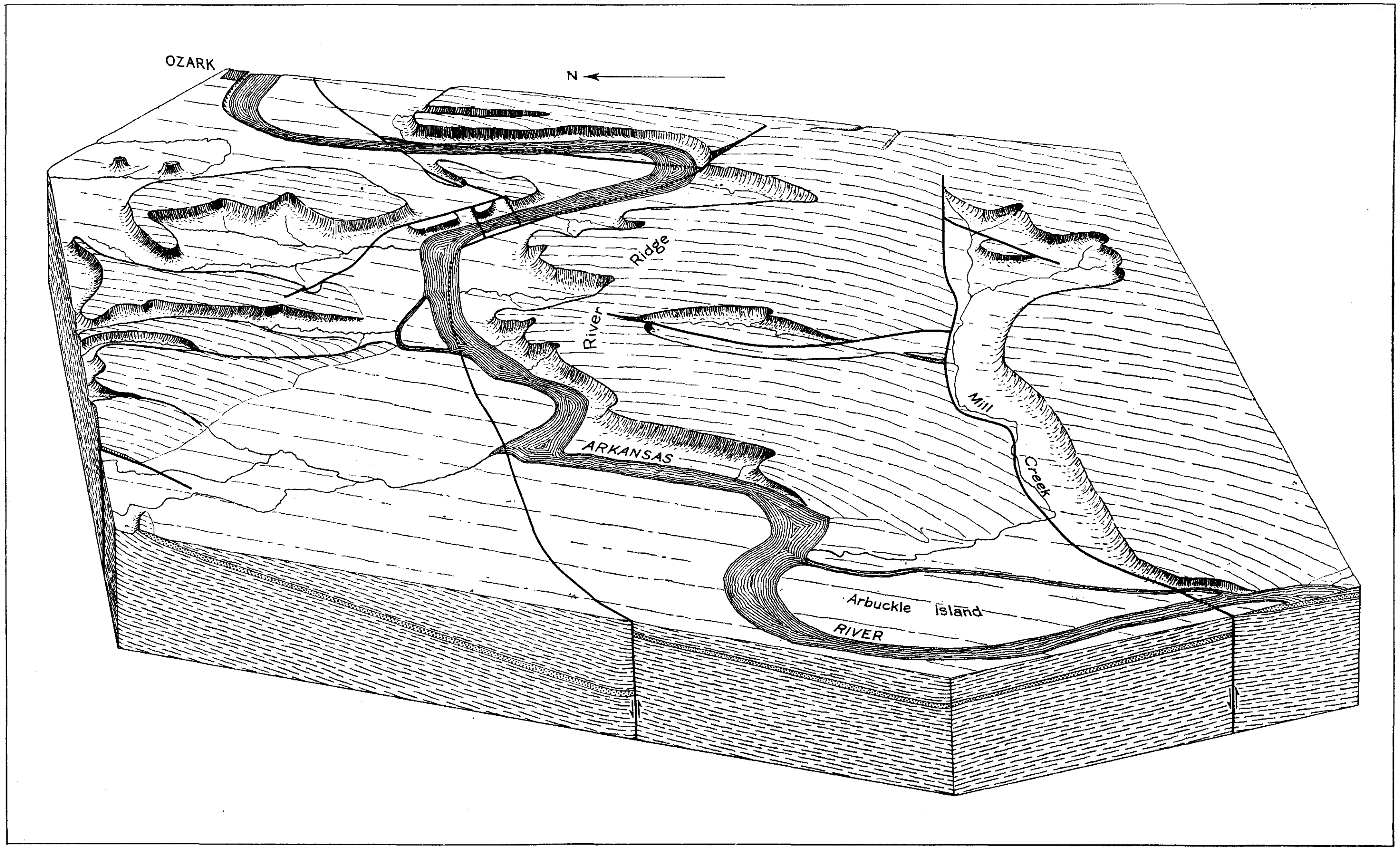

FIGURE 9.—Block diagram of an area in the northeastern part of the Fort Smith district showing broad, gently sloping hills formed from the gently dipping Hartshorne sandstone and the close relation between drainage lines and faults.

that join the Arkansas River within the Fort Smith district. This rock is exposed, however, in the drainage basins of several tributaries of the Arkansas in Oklahoma, notably the Illinois and Neosho Rivers. Much of the material in the terrace deposits thus appears to have been laid down by the Arkansas River itself, rather than by tributary streams. In the Boston Mountains, north of the coal field, some terrace deposits extend along the courses of major streams, such as Lee and Clear Creeks and the Mulberry River. It is probable, therefore, that some of the terrace deposits in the Arkansas Valley and near the mouth of the tributaries were laid down by the tributaries.

In the extreme southern part of the district south of Mansfield and Hartford, several large terraces covered with cobbles and gravel stand about 50 feet above the streams in the large valley north of Poteau Mountain. Those terraces contain materials that are similar to the rocks now exposed on Poteau Mountain, from which the terraces slope gently northward.

The terrace deposits indicate that at one time base level for the Arkansas River was about 50 feet higher than it is at present. It remained so for a sufficiently long period to permit the development of the extensive terraces in the northern part of the district (pl. 17*B*). The material in the terrace deposits is much coarser than that in the modern deposits of the Arkansas River, which suggests that the volume of water then carried by the river was much greater than that carried today.

The Arkansas River controls the base level of its tributaries and some terraces probably were formed along the lower courses of its tributaries at the time when it was forming extensive terraces. The terraces north of Poteau Mountain probably were formed at the same time as those farther north. The great extent of the terraces in the valley immediately north of Poteau Mountain suggests that the deposits in them were laid down by streams that took up a heavy load in flowing down the steep slope of the mountain, and then dropped their coarser sediments in the valley because of the abrupt decrease in gradient.

These terrace deposits lie in a belt that extends westward into Oklahoma, where it joins with terraces that extend northward along the valley of the Poteau River to the Arkansas River. The valley north of Poteau Mountain thus appears to have drained westward to the Poteau River while the terrace gravels were being deposited. Only its western part is drained directly by that river at the present time, its eastern part being drained by headwaters of the James Fork of the Poteau River, which flows northward. Since the time of terrace formation, the James Fork of the Poteau River has probably cut headward and captured a part of the previously existing westward drainage.

Similar terraces, occupying similar positions in regard to the present level of the streams,[29] occur in Oklahoma along streams that enter the Poteau River from the west. There are low passes at the heads of those streams, on the divide between the Poteau River basin and that of the Canadian River, and in these passes lie river-channel deposits (the Gerty sand), the tops of which evidently were once continuous with the terraces along the major streams.[30] The terrace deposits of both the Arkansas River and its tributaries in the Arkansas coal field are therefore probably contemporaneous with the Gerty sand of Oklahoma.

Extensive alluvial flood plains have been developed along the Arkansas River in the northwestern part of the Fort Smith district (pl. 17*B*), and farther east smaller alluvial plains extend along its course and along the lower courses of many of its tributaries. In times of flood, all these alluvial plains are submerged except where protected by levees.

The flood plain of the Arkansas is dotted with lakes and with vestiges of former lakes. Ned and Hollis Lakes, which lie north of the Arkansas River and about 4 miles southeast of Van Buren (center of pl. 17*B*), are oxbow or cut-off lakes formed in an abandoned channel of the river (pl. 18). Both are wide and shallow—hardly anywhere more than ten feet deep—and luxuriant vegetation grows along their shores, even extending outward for several hundred feet into water two or three feet deep. The lakes are bottomed with thick deposits of very soft mud, containing abundant partly decayed plant material. Besides these permanent lakes, there are numerous marshy areas and intermittent lakes. Some of the marshy areas have an oxbow form, and probably represent ox-bow lakes that have been filled up with silt and organic matter.

Near Hollis Lake, Haroldton, and Moores Rock there are a few small, deep lakes (fig. 8) that are locally called "blue holes". These lakes have been formed in recent years, by whirlpool scour at places where the Arkansas River has broken through artificial levees in times of flood. The largest, which is about 1,200 feet long, consists of three interconnected rudely circular scour holes. The depth of the lakes is probably limited by the thickness of the surrounding alluvium which averages between 30 and 40 feet but is locally more than 200

[29] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 4, The Howe-Wilburton district, Latimer and LeFlore Counties: U. S. Geol. Survey Bull. 847–D, map in pocket, 1939.

[30] Hendricks, T. A., Geology and fuel resources of the southern part of the Oklahoma coal field, Part 1, The McAlester district, Pittsburg, Atoka, and Latimer Counties: U. S. Geol. Survey Bull. 874–A, pp. 26–33, 1937.

feet. The lakes receive very little surface-water drainage, being mainly supplied by seepage from the Arkansas River and by normal ground water. Consequently they are almost always clear, and the color of their deep clear water accounts for the name "blue hole".

In several parts of its course across the district the Arkansas River closely follows the traces of faults. From Greenwood Junction eastward to Van Buren it lies close to the Mulberry fault. For about 5 miles from Van Buren it flows southeastward, roughly paralleling the structure contours around the plunging Fort Smith syncline, to the Massard Prairie gas field, and from there it follows rather closely the trend of the Massard fault to the La Vaca gas field. East of there it flows along the axis of the Fort Smith syncline for about 3 miles to Moores Rock, where it turns northward and roughly parallel the strike of the strata around the west end of the Cecil anticline as far as the north side of Arbuckle Island. From Arbuckle Island eastward it follows the trends of the River Ridge, Bee Bluff, and Ozark faults to the city of Ozark (fig. 9). East of Ozark the river forms the northern boundary of the district and for that reason its structural setting there was not fully determined.

The courses of several small streams in the northern part of the district, notably Mill and Clear Creeks, coincide approximately with the trends of faults.

It is evident, from the preceding discussion, that the location and development of most of the topographic features of the Fort Smith district have been controlled almost entirely by the character and attitude of the rock strata. Except for the drop in base level of the Arkansas River from that represented by the terraces to that represented by the present alluvial plains, no change or break in the progressive erosion of the district appears to be recorded.

INDEX