THE UNIVERSITY OF OKLAHOMA

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THE AREAL GEOLOGY OF THE LOCUST GROVE AREA

MAYES COUNTY, OKLAHOMA

A THESIS

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THOMAS J. McBRIDE

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THE AREAL GEOLOGY OF THE LOCUST GROVE AREA

MAYES COUNTY, OKLAHOMA

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THE AREAL GEOLOGY OF THE LOCUST GROVE AREA

MAYES COUNTY, OKLAHOMA

CHAPTER I

INTRODUCTION

Location and Description

The Locust Grove Area, comprising 72 square miles, is located on the southwest edge of the Ozark Plateau, T. 20 N., Rs. 19 and 20E. in Mayes County, Oklahoma. (Figure 1). It is bisected by the south flowing Grand River which separates the dissected Springfield Plateau to the east from the gently sloping Prairie Plains Homocline to the west.

Purpose of Investigation

The mapping of this area was suggested by H. D. Miser to aid in the compilation of a new geologic map of the State of Oklahoma. The immediate mapping of the area was necessary because many of the exposures along the Grand River and its tributaries are soon to be covered by a 10 to 20 foot water rise caused by the construction of the Ft. Gibson dam to the south.

A study of the stratigraphy, structure, tectonics, and faunas of pre-Atoka formations is included.

Method of Investigation

The summer of 1950 was spent in the field examining the

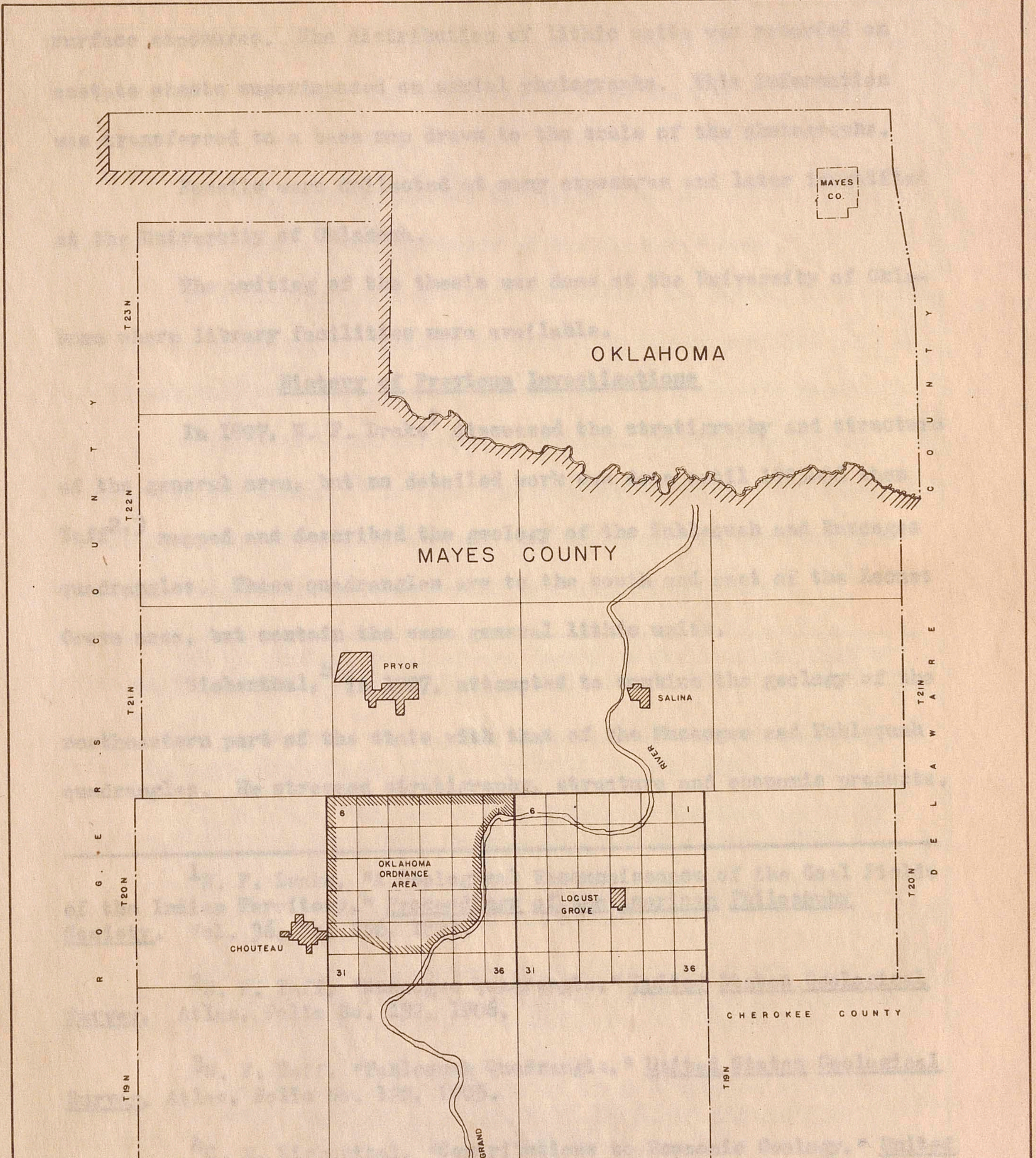

FIG. 1. LOCATION MAP

surface exposures. The distribution of lithic units was recorded on acetate sheets superimposed on aerial photographs. This information was transferred to a base map drawn to the scale of the photographs.

Fossils were collected at many exposures and later identified at the University of Oklahoma.

The writing of the thesis was done at the University of Oklahoma where library facilities were available.

History of Previous Investigations

In 1897, N. F. Drake[1] discussed the stratigraphy and structure of the general area, but no detailed work was done until 1905-06 when Taff[2,3] mapped and described the geology of the Tahlequah and Muscogee quadrangles. These quadrangles are to the south and east of the Locust Grove area, but contain the same general lithic units.

Siebenthal,[4] in 1907, attempted to combine the geology of the northeastern part of the state with that of the Muscogee and Tahlequah quadrangles. He stressed stratigraphy, structure and economic products.

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[1]N. F. Drake, "A Geological Reconnaissance of the Coal Fields of the Indian Territory," Proceedings of the American Philosophy Society. Vol. 36, No. 156, 1897.

[2]N. F. Taff, "Muscogee Quadrangle," United States Geological Survey, Atlas, Folio No. 132, 1906.

[3]N. F. Taff, "Tahlequah Quadrangle," United States Geological Survey, Atlas, Folio No. 122, 1905.

[4]C. E. Siebenthal, "Contributions to Economic Geology," United States Geological Survey, Bulletin 340, 1908, pp. 188-228.

A discussion of the general geology of the Ozark Uplift with a resume on stratigraphy and structure by L. C. Snider[5] was published in 1912.

In 1915, Snider[6] studied the geology of the Mississippian and younger rocks, with special emphasis on the Chester "Group."

In 1930, Cram[7] and Ireland[8] summarized the geology of several counties in northeastern Oklahoma as part of a series entitled "Oil and Gas Investigations." Mayes County was included in Ireland's report.

Cline,[9] in 1934, attempted a regional correlation of the "Osage Group." Laudon,[10] in 1939, measured and described the subdivisions of the Osagean in northeastern Oklahoma. He verified many of Cline's interpretations and added additional information.

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[5] L. C. Snider, "Preliminary Report on the Lead and Zinc of Oklahoma," Oklahoma Geological Survey, Bulletin 9, 1912, pp. 34-44.

[6] L. C. Snider, "Geology of a Portion of Northeastern Oklahoma," Oklahoma Geological Survey, Bulletin No. 24, 1915.

[7] I. H. Cram, "Oil and Gas in Oklahoma, Cherokee and Adair Counties," Oklahoma Geological Survey, Bulletin No. 40-QQ, 1930.

[8] H. A. Ireland, "Oil and Gas in Oklahoma, Mayes, Ottawa, and Delaware Counties," Oklahoma Geological Survey, Bulletin No. 40-NN, 1930.

[9] L. M. Cline, "Osage Formations of Southern Ozark Region, Missouri, Arkansas, and Oklahoma," American Association of Petroleum Geologists, Bulletin, Vol. 18, No. 9, 1934, pp. 1132-1159.

[10] L. R. Laudon, "Stratigraphy of Osage Subseries of Northeastern Oklahoma," American Association of Petroleum Geologists, Bulletin, Vol. 23, No. 3, 1939, pp. 329-338.

Brant[11] mapped the Locust Grove Area, along with several adjoining townships in 1941. He subdivided the Mayes limestone into several lithic units which are discussed on subsequent pages.

In 1947, C. A. Moore[12] published a detailed study of the Morrowan series of northeastern Oklahoma based on insoluble residue studies and measured sections. Subdivisions of the Morrowan, already established in Arkansas were extended into this area.

Laudon[13], in 1948, discussed the Meramec-Osage contact in northeastern Oklahoma with emphasis on unconformities and faunal breaks.

Bollman[14] mapped in detail the two townships to the south of the Locust Grove area in 1949, and the following year, 1950, Hurt[15] mapped two townships along the northern boundary.

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[11] R. A. Brant, "Stratigraphy of the Meramec and Chester Series of Mayes County, Oklahoma," Unpublished Master's Thesis, University of Tulsa, 1941.

[12] C. A. Moore, "The Morrow Series of Northeastern Oklahoma," Oklahoma Geological Survey, Bulletin, No. 66, 1947.

[13] L. R. Laudon, "Osage-Meramec Contact," The Journal of Geology, Vol. 56, No. 4, 1948, pp. 293.

[14] J. F. Bollman, "Areal Geology of the Murphy Area," Unpublished Thesis, University of Oklahoma, 1950.

[15] T. W. Hurt, "Areal Geology of the Pryor Area," Unpublished Thesis, University of Oklahoma, 1951.

CHAPTER II

GEOGRAPHY

Climate

The mean temperature for the Locust Grove Area is 59 degrees F. The average summer temperature is 78 degrees F. and the winter is 38 degrees F. The average rain fall is 43 inches per year.[16]

Principal Cities and Towns

Locust Grove, a small farming town with a population of 500 is located in sec. 22, T. 20 N., R. 20 E. Chouteau is located just outside the western boundary while Pryor and Salina lie a few miles to the northwest and northeast respectively.

Roads and Railroads

Highway 33 runs approximately through the center of the area from east to west. Numerous section line roads form a network which makes the area readily accessible except in the western township where the Oklahoma Ordnance Plant has closed the roads to civilian travel.

The Kansas, Oklahoma and Gulf Railroad serves Locust Grove.

Principal Industries

The principal industry in the Locust Grove Area is agriculture. Several gravel quarries furnish local road building material. The Okla-

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[16] H. M. Layton and O.H. Bensing, "Soil Survey of Mayes County, Oklahoma," United States Department of Agriculture, Bulletin No. 19, Series 1932, p. 3.

homa Ordnance Plant furnished employment to many during the war years and new industries now being developed at that site will offer additional opportunities for the inhabitants.

CHAPTER III

PHYSIOGRAPHY

Relief and Elevations

Greatest relief and elevation are found in the western portion of the area underlain by the Keokuk chert which is most resistive to erosion.

A maximum elevation of 1000 feet is found in sec. 10 T.20N., R.20E. and the lowest elevation of slightly over 500 feet is along the Grand River which runs through the center of the area.

Rugged relief is also found along the cuesta extending north and south in T.20N., R.19E. where an elevation of 700 to 750 feet is attained.

Topography and Drainage

West of Grand River the topography is rolling and the gently dipping beds form a series of cuestas. East of the river the surface on the "Boone" chert is rugged and deeply dissected with a characteristic dendritic drainage pattern.

Tributary streams flow into the Grand River from both the east and west. Pryor and Chouteau Creeks furnish the main drainage from the west whereas the southeast corner of the area is drained by Little Spring Creek.

Vegetation

The gently rolling area to the west is covered with tall prairie grasses. In the more heavily wooded areas, as on hills, are found numerous trees and low vegetation such as dogwood, sumac, wild-grape, persimmon, pecan, cotton wood, willow, sycamore, and black oak.[17]

Exposures

Many excellent exposures are present within the area. The best ones are located along Grand River and its tributaries. In the southcentral portion, where vegetation is not too heavy, outcropping beds form conspicuous bands around the hills and outliers.

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[17] *Ibid.*, p. 2.

CHAPTER IV

STRATIGRAPHY

General Statement

The formations exposed in the Locust Grove Area range in age from Lower Mississippian to Middle Pennsylvanian. Locally these are covered by a thin veneer of terrace gravels and alluvium of Pleistocene and Recent age.

The Mississippian System is represented by the Reeds Spring and Keokuk formations of Osagean age; the "Moorefield," "Hindsville," and "Batesville" assigned to the Meramecian Series; and the "Grand River" and Fayetteville of Chesterian age. Overlying Pennsylvanian beds include the Hale "Morrowan" and Atoka (Atokan) formations.

The generalized stratigraphic sequence is shown in figure 2.

Mississippian System

Reeds Spring Formation

History of nomenclature. Moore, in 1928,[18] defined the Reeds Spring member of the Boone formation. It is named for exposures in the vicinity of Reeds Spring, Missouri. Formational rank was applied by

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[18] R. C. Moore, "Early Mississippian Formations in Missouri," Missouri Bureau of Geology and Mines, Vol. 21, 2nd series, 1928, p. 190.

COMPOSITE SECTION – LOCUST GROVE AREA

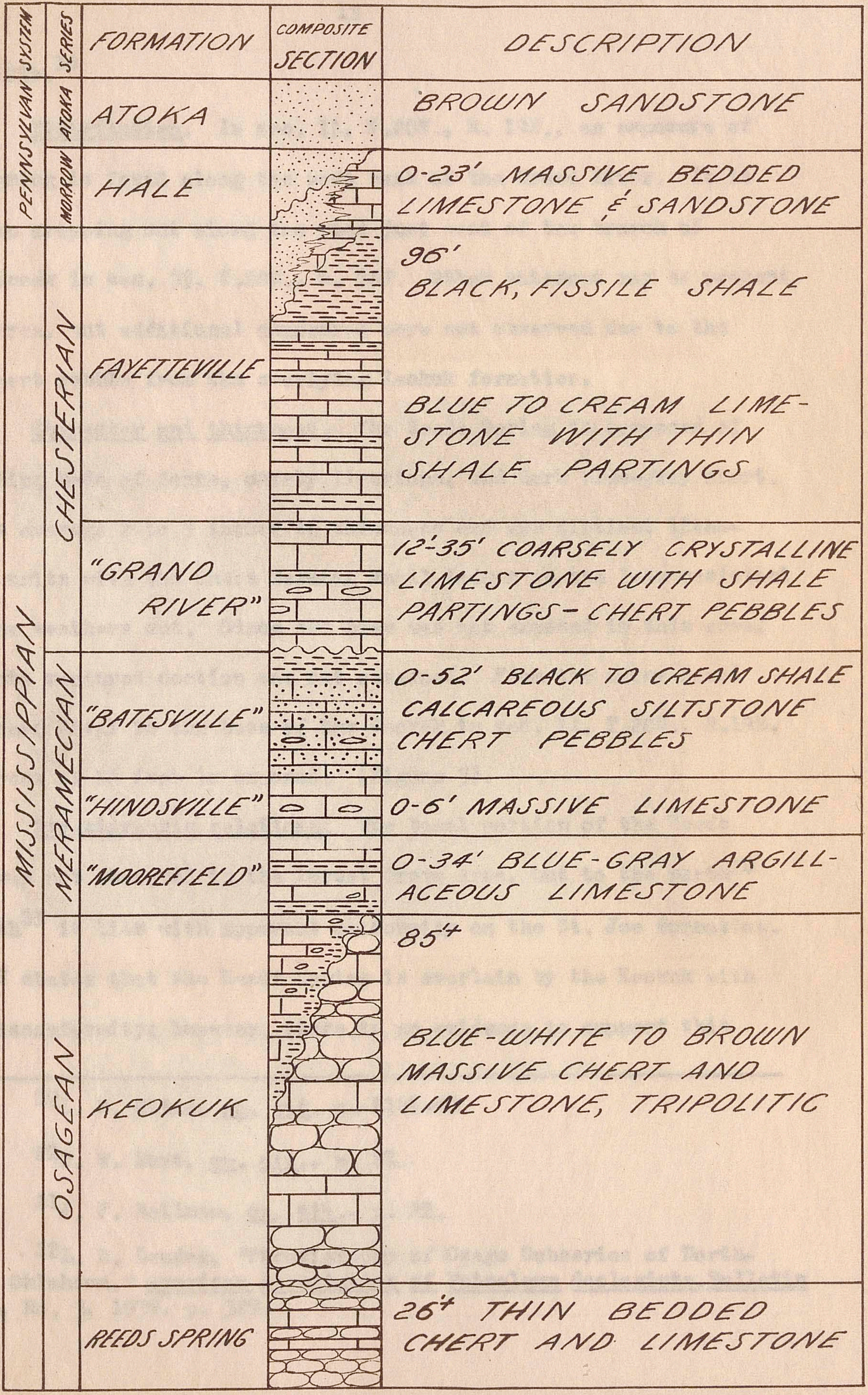

FIG. 2

Cline, 1934.[19]

Distribution. In sec. 11, T.20N., R. 19E., an exposure of Reeds Spring is found along the west bank of the Grand River. It is also seen cropping out along the road just west of the branch of Spring Creek in sec. 35, T.20N., R. 20E. Other outcrops may be present in the area, but additional exposures were not observed due to the heavy chert rubble from the overlying Keokuk formation.

Character and thickness. The Reeds Spring is composed of alternating beds of dense, cherty limestone, and dark blue-gray chert. The beds average 2 to 3 inches in thickness and are distinct lithographic units with the chert forming small ledges as the less resistant limestone weathers out. Since the base was not exposed in this area, a complete measured section was not obtained. From the water level along Grand River to the base of the Keokuk in sec. 11, T.20N., R.19E. a thickness of 26 feet is exposed. (Figure 3).

Stratigraphic relations. The basal portion of the Reeds Spring was not observed in the Locust Grove Area, but to the north[20] and south[21] it lies with apparent conformity on the St. Joe formation. Laudon[22] states that the Reeds Spring is overlain by the Keokuk with sharp disconformity; however, there is no evidence to support this

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[19] L. M. Cline, op. cit. p. 1141-46.

[20] T. W. Hurt, op. cit., p. 21.

[21] J. F. Bollman, op. cit., p. 22.

[22] L. R. Laudon, "Stratigraphy of Osage Subseries of Northeastern Oklahoma," American Association of Petroleum Geologists, Bulletin Vol. 23, No. 3, 1939, p. 329.

Fig. 3. Reeds Spring-Keokuk contact, sec. 11, T.20N., R.19E. in old railroad cut on west river bank.

statement in the Locust Grove Area.

Paleontology. No fossils were found in the Reeds Spring in the Locust Grove Area.

Age and correlation. Laudon[23] states that the Reeds Spring has no correlatives outside of the type area of northeastern Oklahoma, southwest Missouri, and northwest Arkansas. Correlation with the Mississippian type section places the Reeds Spring equal in age to lower Burlington and upper Fern Glen of the Osagean series.[24]

Keokuk Formation

History of nomenclature. Owen,[25] in 1852, named the Keokuk cherty limestone for exposures near Keokuk Landing in southeastern Iowa. Usage of the name has been extended to southwestern Missouri and northeastern Oklahoma where it is applied to the upper, white, massive portion of the "Boone."

Distribution. In T. 20 N., R. 20 E., the Keokuk formation is the most widespread of all units. Along the Grand River in T. 20 N., R. 19 E., there are several exposures with a prominent one located at the bend of the river in sec. 9. West of Grand River it is present only in two localities, secs. 14 and 33, T. 20 N., R. 19 E. Westward, it passes beneath younger formations.

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[23] L. R. Laudon, ibid., p. 328.

[24] G. G. Huffman, Oral Communication, 1950.

[25] D. D. Owen, "Carboniferous Rocks of Southern and Western Iowa," Rept. Geol. Surv. Wis., Iowa, and Minn. 1852, pp. 91-92.

<u>Character</u> <u>and</u> <u>thickness</u>. The Keokuk is a massive, fossiliferous chert that varies in color from white to light gray. Locally a gray, dense limestone is interbedded with the chert. In sec. 34, T. 20 N., R. 20 E. and sec. 24, T. 20 N., R. 19 E., a massive, coarsely crystalline, gray limestone is present in the Keokuk. This limestone is barren of fossils, but locally as in sec. 24, T. 20 N., R. 19 E. it is bounded above and below by chert beds of the Keokuk type.

Along the Grand River the Keokuk forms tall cliffs from 60 to 80 feet in height. Away from the river it forms high rolling hills with deeply eroded, dendritic drainage. Since the Keokuk surface is covered with chert rubble and hence is impractical to cultivate, the hills are usually covered with a heavy growth of scrub oaks and sumac.

In some places the chert has been altered by weathering to tripoli. An excellent example of this may be seen in the stream cut crossing the half-section road in sec. 19, T. 20 N., R. 20 E.

Sink holes, found in sec. 1, T. 20 N., R. 19 E., and sec. 33, T. 20 N., R. 20 E., are believed to be associated with the Keokuk formation. The underground water dissolves the limestone beds from the Keokuk and the overlying chert slumps into the cavities forming sinks in the overlying beds. The sinks in sec. 33, cover approximately one-fourth square mile.

The Keokuk ranges in thickness from 30 feet in sec. 11, T. 20 N., R. 19 E., where the upper and lower boundaries are exposed to 85 feet along the river in secs. 9 and 10, T. 20 N., R. 20 E., where only the upper boundary is seen. This variation in thickness is due to disconformable relationships above and below the Keokuk.

Stratigraphic relations. The Keokuk is bounded above by profound disconformity with beds as young as "Grand River" overlapping its uneven surface. Throughout most of the area, however, the "Moorefield" lies disconformably on the Keokuk. (Figure 4). It is separated from the underlying Reeds Spring by disconformity.

Paleontology. Locally, the Keokuk is fossiliferous, with Dictyoclostus crawfordsvillensis, Neozaphrentis, sp., Spirifer floydensis and other forms preserved as internal molds and casts. (Table I).

Age and correlation. The Keokuk is classed as Osagean in age, and is correlated with the lower part of the Keokuk as developed in the type area.[26]

"Mayes" Group

The term Mayes was defined by Snider,[27] to include the beds between the "Boone" chert and the base of the Fayetteville black shale as developed in Mayes County, Oklahoma. He assigned these units to the Chesterian Series.

In 1941, Brant[28] subdivided the Mayes into four lithic units

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[26] L. R. Laudon, op. cit. 1939, p. 338.

[27] L. C. Snider, "Geology of a Portion of Northeastern Oklahoma," Oklahoma Geological Survey, Bulletin No. 24, 1915, p. 27.

[28] R. A. Brant, op. cit., p. 1.

Fig. 4. Keokuk-"Moorefield" contact, sec. 11, T. 20 N., R. 19 E., 150 feet west of river in old railroad cut.

TABLE I

FAUNULES FROM THE KEOKUK IN THE LOCUST GROVE AREA

	Localities						
	1	2	3	4	5	6	7
Neozaphrentis sp.	.	.	X	X	.	X	.
Allorhynchus heteropsis Winchell	.	.	.	X	.	.	.
Cliothyridina parvirostra (Meek and Worthen)	X	.	.	.	.	.	.
Dictyoclostus crawfordvillensis (Weller)	.	.	X	X	.	X	.
Hamburgia typa Weller	.	.	.	.	X	.	.
Pseudosyrinx gigas Weller	.	X	.	X	.	.	.
Pseudosyrinx keokuk Weller	.	.	.	.	X	.	.
Spirifer carinatus Rowley	.	X	.	.	.	.	X
Spirifer floydensis Weller	.	.	.	.	X	X	.
Spirifer Keokuk Hall	.	.	.	.	.	X	.
Spirifer logani Hall	.	.	.	X	.	.	.
Spirifer montgomeryensis Weller	.	.	.	X	.	X	.
Spirifer mortonanus (Miller)	.	.	.	X	.	.	.
Spirifer rostellatus Hall	.	.	.	.	X	.	.
Teteracamera subtrigona (Meek and Worthen)	.	.	.	X	.	.	.

1. In creek bed 100' north of ford in the NW¼ sec. 1, T. 20 N., R. 19 E.
2. Along west side of river bank in east ½ sec. 11, T. 20 N., R. 19 E.
3. Along west side of river bank in east ½ sec. 14, T. 20 N., R. 19 E.
4. 100' west of house in the NE, SW¼ sec. 24, T. 20 N., R. 19 E.
5. 300' north of Highway 33 in small stream cut in the NW¼ of sec. 25, T. 20 N., R. 19 E.
6. In creek bed under bridge in SW¼ of sec. 2, T. 20 N., R. 20 E.
7. 50' east of ¼ section road in stream bed in the NW¼ of sec. 33, T. 20 N., R. 20 E.

which he called Moorefield, Hindsville, Batesville, and Grand River. He assumed that the lower three were equivalents of units already established in Arkansas, Inasmuch as the validity of his terminology is questionable and since the term Grand River is preoccupied, usage of these names is qualified by enclosure in quotation marks.

"Moorefield" Formation

History of nomenclature. Adams, in 1904,[29] defined the Moorefield shale as overlying Boone limestone and underlying Batesville sandstone of Arkansas. It is named for exposures near Moorefield, Arkansas.

Brant,[30] applied the term "Moorefield" to a sequence of argillaceous limestone beds above the Keokuk in northeastern Oklahoma.

Distribution. The best exposures of "Moorefield" are found along the banks of the Grand River extending from sec. 5, T. 20 N., R. 20 E., to sec. 26, T. 20 N., R. 19 E. In sec. 32, T. 20 N., R. 19 E. the "Moorefield" crops out on the crest of an east-west anticline along Chouteau Creek. Throughout T. 20 N., R. 20 E., it is found in contact with the Keokuk.

Character and thickness. The "Moorefield" is a gray-black, dense, lithographic limestone with occasional gray-black shale streaks. Weathered exposures of the limestone have a platy appearance. (Figure 5). The "Moorefield" is characterized by the occurrance of

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[29] G. I. Adams, A. H. Purdue, and E. O. Ulrich, "Zinc and Lead Deposits of Northern Arkansas," United States Geological Survey, Professional Paper, No. 24, 1904, p. 26.

[30] R. A. Brant, op. cit., pp. 18-22.

Fig. 5. "Moorefield" platy limestone, sec. 26, T. 20 N., R. 19 E. on south river bank west of creek mouth.

black chert nodules near the base of the unit. A 'petroliferous' odor is noticeable on freshly fractured surfaces.

The "Moorefield" varies in thickness from 0 feet in the creek bed in sec. 26, T. 20 N., R. 19 E., to 33 feet 6 inches in sec. 6, T. 20 N., R. 20 E. South of the Shallow Water dam on the west side of the Grand River, in sec. 11, T. 20 N., R. 19 E., one foot of dark, glauconitic shale is present at the base of the "Moorefield." North of the dam, in an old railroad cut this shale is only two inches thick. This unit is not present in all areas of Keokuk-"Moorefield" exposures, for in many instances, gray, lithographic limestone appears to be deposited around the Keokuk chert knobs. An excellent example of this "plastering" effect of "Moorefield" on Keokuk may be seen in the NW$\frac{1}{4}$ of sec. 33, T. 20 N., R. 20 E., where a light gray, lithographic limestone with glauconitic stain is draped around a small Keokuk chert knob. No fossils were collected from the limestone, but due to lithologic similarities, it is considered "Moorefield." (See measured sections, Tables II and III).

Stratigraphic relations. The "Moorefield" underlies the "Hindsville" conformably and overlies the Keokuk with sharp disconformity.

Paleontology. A collection made from the "Moorefield" yielded such common forms as *Leiorhynchus carboniferum*, *Griffithides pustulosus*, and *Spirifer arkansanus*. The faunules collected are listed in Table IV.

Age and correlation. The "Moorefield" is correlated with the lower Moorefield of Arkansas which has been classed as St. Louis,

TABLE II

SECTION EAST OF LINDSEY BRIDGE, SEC. 6, T. 20 N., R. 20 E.

Formational description	Thickness: Of unit	Thickness: To base of formation
"Grand River":		
Limestone, massive, gray, fossiliferous	1' 6"	1' 6"
"Batesville":		
Shale, cream-brown, calcareous	1'	53' 8"
Siltstone, calcareous, alternating massive and platy beds, cream-brown ..	35' 4"	52' 8"
Limestone, silty, alternating massive and platy beds	14' 4"	17' 4"
Siltstone, platy, cream-brown	3'	3'
"Moorefield" - "Hindsville":		
Limestone and shale, massively bedded, gray, dense, with thin beds of gray calcareous shale	8'	45' 4"
Limestone, shaly, black	4"	37' 4"
Limestone, dense, massively bedded, gray, petroliferous	2' 6"	37'
Limestone, platy, gray to black, petroliferous	16' 8"	34' 6"
Limestone, dense, black, petroliferous	1' 3"	17' 10"
Limestone, dense, black, black chert nodules enclosed within, petroliferous	2' 8"	16' 7"
Limestone, dense, dark gray, petroliferous	1' 6"	13' 11"
Limestone, platy, gray, bound at top and bottom by ¼" beds of black chert	11"	12' 5"
Limestone, dense, black, petroliferous	1' 4"	11' 6"
Limestone, shaly, platy, dark gray ...	10"	10' 2"
Limestone, gray, dense, petroliferous with small black chert nodules...	5"	9' 4"
Limestone, gray, dense, petroliferous.	1' 6"	8' 11"
Limestone, thin platy, gray, petroliferous	5"	7' 5"
Limestone, lithographic, gray, petroliferous	3'	7'
Concealed interval	4'	4'

Keokuk:		
Chert, gray and white, alternating thick and thin beds	6'	6'
River level		

TABLE III

SECTION ALONG GRAND RIVER AT SHALLOW WATER DAM SEC. 14, T. 20 N., R. 19 E.

Formational Description	Thickness: Of unit	Thickness: To base of formation
"Batesville":		
Siltstone, weathered to thin platy layers, brown color, blue-gray on fresh break	20' 1"	23' 3"
Limestone, silty, dense, massive, light gray with upper 3 inches containing chert pebbles, weathers brown	1' 4"	3' 2"
Shale, calcareous, platy, weathers gray to brown	1' 10"	1' 10"
"Hindsville":		
Limestone, light gray, massive, coarsely crystalline, slightly petroliferous	5' 10"	5' 10"
"Moorefield":		
Limestone, thin bedded, dense, gray separated by thin shaly limestone streaks, petroliferous odor	3' 5"	20' 1"
Limestone, gray, dense, with black chert nodules, petroliferous odor ..	8"	16' 8"
Covered	15'	16'
Shale, black, glauconitic, unfossiliferous	1'	1'
Keokuk		
Chert, white to gray	4'	4'
River level		

TABLE IV

FAUNULES FROM THE "MOOREFIELD" IN THE LOCUST GROVE AREA

	Localities		
	1	2	3
Triplophyllum sp.	X	.	X
Dictyoclostus manardensis Sutton	X	.	.
Linoproductus ovatus (Hall)	X	X	.
Leiorhynchus carboniferum Girty	.	.	X
Spirifer arkansanus Girty	X	X	X
Spirifer martiniiformis Girty	X	X	.
Torynifera setigera (Hall)	X	.	.
Gastrioceras caneyanum Girty	.	.	X
Griffithides pustulosus Snider	X	.	X

1. In stream cut 50' west of road 2000' north of bridge in sec. 1, T. 20 N., R. 19 E.
2. In creek bed following railroad in center of sec. 8, T. 20 N., R. 20 E.
3. A road cut on the north boundary of sec. 18, T. 20 N., R. 20 E. one half mile from corner of section.

Meramecian in age.[31] Recent work in northeastern Oklahoma suggests partial correlation with the "J" bed of Ottawa County, which is assigned to the Warsaw.[32]

"Hindsville" Formation

History of nomenclature. Purdue and Miser, in 1916,[33] named the Hindsville limestone member at the base of the Batesville sandstone from exposures near Hindsville, Arkansas.

Brant,[34] in bringing the term "Hindsville" to Oklahoma, applied it to the medium-crystalline limestone overlying the "Moorefield" in southern Mayes County.

Distribution. The "Hindsville" crops out in a north-south band extending through the center of the area with limited exposures as far east as sec. 28, T. 20 N., R. 20 E., and as far west as sec. 32, T. 20 N., R. 19 E. The best exposures occur along the Grand River and its immediate tributaries.

Character and thickness. "Hindsville" is a massive, light gray, medium crystalline limestone. A basal chert pebble zone is present where the unit is in close proximity to the Keokuk chert but is typically undeveloped in localities where the "Moorefield" intervenes.

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[31] Mackenzie Gordon, "Moorefield Formation and Ruddell Shale, Batesville District, Arkansas," American Association of Petroleum Geologists, Bulletin, Vol. 28, No. 11, 1944, pp. 1626-1634.

[32] G. G. Huffman, Oral Communication, 1952.

[33] A. H. Purdue and H. D. Miser, "Eureka Springs-Harrison," United States Geological Survey, Folio, Atlas, No. 202, 1916, p. 5.

[34] R. A. Brant, op. cit., pp. 23-25.

In the NE¼ of sec. 26, T. 20 N., R. 19 E., the chert pebble zone is present where the unit is one foot thick. In this instance, however, it is separated from Keokuk by five inches of "Moorefield." In sec. 24, T. 20 N., R. 19 E., where the "Hindsville" is 4 feet thick, the chert pebbles are present; and a Keokuk fossil, Spirifer floydensis, was identified from one of the pebbles. In the measured section in sec. 11, T. 20 N., R. 19 E., at the Shallow Water dam chert pebbles are not present in lower portions. Here the contact with the underlying "Moorefield" is conformable, although marked by a sharp change from sublithographic to medium crystalline limestone. Irregular splotches or masses of "Hindsville" lithology are incorporated in the upper six inches of the dense "Moorefield." (Figure 6). The "Hindsville" grades upward into "Batesville" lithology.

The "Hindsville" varies in thickness from 0 to 5 feet 10 inches. In sec. 6, T. 20 N., R. 20 E., immediately east of the bridge, the "Hindsville" is 5 feet thick; however, approximately 100 yards to the east, a measured section with all the beds exposed, reveals no "Hindsville"-type lithology, but a progressive lateral facies change of "Hindsville" into "Moorefield" lithology which explains the absence of typical "Hindsville" in the north one-half of sec. 6, T. 20 N., R. 20 E. (See Tables II and III for measured sections).

Stratigraphic relations. The "Hindsville" conformably underlies the "Batesville" siltstone, and conformably overlies the "Moorefield"; however it overlaps the "Moorefield" facies and rests on Keokuk at several exposures as in secs. 28 and 33, T. 20 N., R. 20 E.

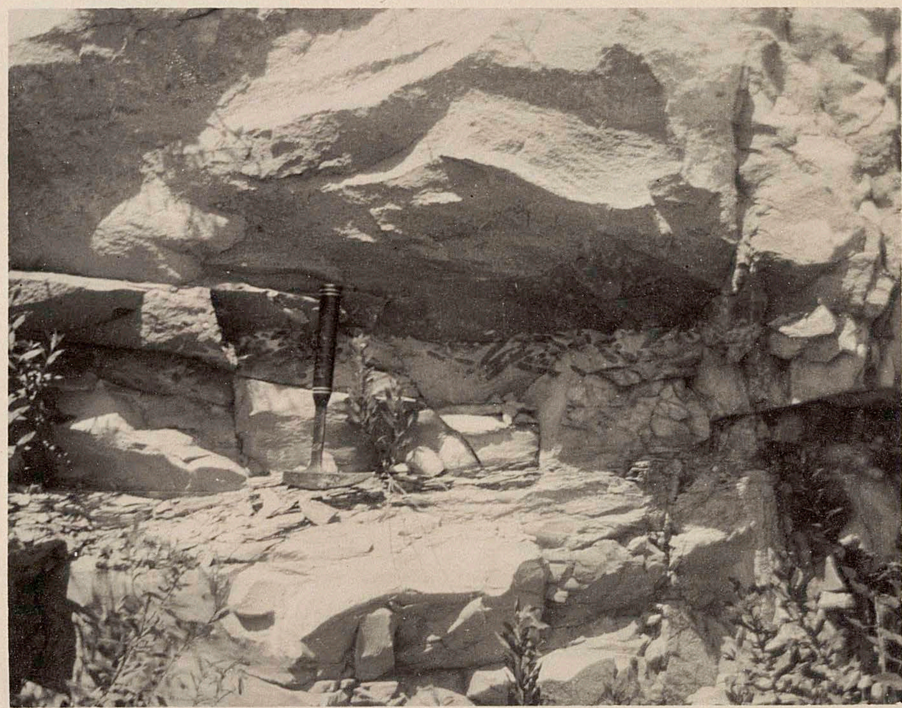

Fig. 6. "Moorefield"-Hindsville" contact,
along river bank west of Shallow Water dam in
sec. 11, T. 20 N., R. 19 E.

Paleontology. No fossils were collected from the "Hindsville" in the Locust Grove Area.

Age and correlation. Brant[35] correlated the "Hindsville" with the type Hindsville limestone of western Arkansas. In the Locust Grove Area the stratigraphic relationship of the "Hindsville" with the "Moorefield" and "Batesville" indicates that it should be correlated with the upper Moorefield of Arkansas.

"Batesville" Formation

History of nomenclature. Banner and Simmonds, in 1888,[36] applied the term Batesville to beds now known to represent the Wedington sandstone in Washington County, Arkansas; it was redefined by Adams and Ulrich[37] as the sandstone immediately overlying the Moorefield shale near Batesville, Arkansas.

Brant[38] extended the term into Oklahoma in 1941 and applied it to the calcareous siltstone above the "Hindsville" and below the "Grand River" limestone.

Distribution. The "Batesville" outcrops occur in a broad north-south band through the central portion of the area with excellent exposures along the west bank of the Grand River.

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[35] R. A. Brant, op. cit., pp. 23-25.

[36] F. W. Simmonds, "Annual Report," Arkansas Geological Survey, Vol. 1, 1888, p. 49.

[37] G. I. Adams, A. H. Purdue, and E. O. Ulrich, "Zinc and Lead Deposits of Northern Arkansas," United States Geological Survey, Professional Paper, No. 24, 1904, p. 27.

[38] R. A. Brant, op. cit., pp. 26-30.

Character and thickness. The "Batesville" is a light blue-gray, silty limestone which weathers with a tan, sandy appearance. On a fresh surface in a quarry, sec. 27, T. 20 N., R. 19 E., the "Batesville is a massive-bedded dense limestone, with no apparent shale partings; however, at the Shallow Water dam, sec. 13, T. 20 N., R. 19 E. the limestone has become leached and weathered to give a platy, sandy shale. At this exposure, a three inch chert pebble zone was found three feet above the main beds of the "Hindsville" in a medium-crystalline limestone which overlies a two foot zone of calcareous siltstone of the "Batesville" type.

The upper "Batesville" is characterized in the Locust Grove Area by an unfossiliferous shale member. In sec. 22, T. 20 N., R. 19 E., approximately ten feet of black fissile shale is exposed while in the SW¼ of sec. 31, T. 20 N., R. 20 E., one foot of cream to gray shale is present. (Figures 7 and 8). The upper shale beds are missing to the north and east where the "Grand River" rest unconformably on the massive middle portion of the "Batesville." (See Tables II, III, and V for measured sections).

Stratigraphic relations. The "Batesville" overlies the "Hindsville" conformably, and is overlain unconformably by the "Grand River". Locally, as in the SW¼ of sec. 31, T. 20 N., R. 20 E., the "Batesville" rests on Keokuk due to onlap.

Paleontology. Few fossils were collected from the "Batesville" in this area. *Leiorhynchus carboniferum* Girty, *Leiorhynchus carboniferum* var. *polypleurum* Girty, *Linoproductus ovatus* (Hall),

Fig. 7. "Batesville"-"Grand River" contact, Center of sec. 22, T. 20 N., R. 19 E.

Fig. 8. "Batesville"-"Grand River" contact, south line of sec. 31, T. 20 N., R. 20 E., 200 feet from the southwest corner.

TABLE V

SECTION AT WEST END OF BRIDGE ACROSS GRAND RIVER ON HIGHWAY 33

Formational description	Thickness	
	Of unit	To base of formation
"Grand River":		
Limestone, gray, finely crystalline with streaks of lithographic limestone	5'	28' 9"
Limestone, lithographic, gray, thin-bedded	2' 6"	23' 9"
Limestone, coarsely crystalline, thick bedded, gray, fossiliferous	4' 4"	21' 3"
Limestone, and shale, alternating, irregularly bedded. Limestone is coarsely crystalline with sub-lithographic limestone streaks. Only coarse limestone is fossiliferous	13'	16' 11"
(Section continued 100 feet north).....		
Limestone, coarsely crystalline, massive, gray, fossiliferous	1' 6"	3' 11"
Shale, gray, thin bedded	6"	2' 5"
Limestone, coarsely crystalline, massive, gray, fossiliferous	10"	1' 11"
Shale, glauconitic, fossiliferous	2"	1' 1"
Limestone, coarsely crystalline, gray, fossiliferous	4"	11"
Shale, glauconitic, green, highly fossiliferous	7"	7"
"Batesville":		
Shale, fissile, brown and black	2' 3"	8' 3"
Shale, black, slightly calcareous, weathers platy	6'	6'
River level		

Spirifer increbescens Hall, and Aviculopecten batesvillensis (Weller) were found in sec. 6, T. 20 N., R. 20 E.; Composita subquadrata (Hall), Dielasma formosum var. whitfieldi Girty, Leiorhynchus carboniferum Girty, and Moorefieldella eurekensis Walcott were collected in sec. 33, T. 20 N., R. 20 E.

Age and correlation. Faunal evidence indicates that the "Batesville" of Locust Grove Area is more closely related to the true Moorefield of Arkansas, and should be considered a member of the Moorefield formation of Oklahoma. Upper shaly portions lithologically resemble the Ruddell shale of Arkansas.[39]

"Grand River" Formation

History of nomenclature. The term Grand River was first used for rocks of Pennsylvanian age in Michigan by Kelly[40] in 1936. The United States Geological Survey adopted this usage in 1944.[41]

Brant,[42] in 1941, unaware of its pre-occupation, applied the term to the upper portion of the "Mayes Group" for exposures along the Grand River in Mayes County, Oklahoma.

Distribution. The "Grand River" crops out both east and west of the Grand River and numerous excellent exposures are present. Beginning in sec. 4, T. 20 N., R. 19 E., and extending south and east,

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[39] G.G. Huffman, Oral Communication, 1952.

[40] W. A. Kelly, Occasional Paper, Michigan Geological Survey, Publication 40, Geological Series 34, 1936, pp. 155-215.

[41] G. V. Cohee, "Geology and Oil and Gas Possibilities of South-Central Michigan," United States Geological Survey, Preliminary Oil and Gas Map 11, 1944.

[42] R. A. Brant, op. cit., pp. 31-36.

the "Grand River" forms a prominent cuesta. In secs. 17 and 20, T. 20 N., R. 19 E., a small dome brings the "Grand River" to the surface.

Character and thickness. The "Grand River" is a gray, medium crystalline limestone which displays a slight petroliferous odor on fresh break. The massive beds near the base are separated by thin gray shale breaks. A bed of glauconitic and shaly coquina is locally present at the contact with the underlying "Batesville." Beneath the bridge over the Grand River on highway 33, the upper beds are composed of gray, lithographic, unfossiliferous limestone, whereas, intermediate beds are of medium crystalline, highly fossiliferous limestone. *Agassizocrinus* is present throughout but forms a conspicuous zone near the base.

Where found in close proximity to the Keokuk the "Grand River" contains chert pebbles, probably derived from a local Keokuk "high." The upper "Grand River," near the Fayetteville contact, weathers to a reddish-brown color and is highly fossiliferous. The "Grand River" varies from 28 to 35 feet in thickness. (Table V).

Stratigraphic relations. The "Grand River" unconformably overlies the "Batesville" and is overlain conformably by the Fayetteville. In several localities the "Grand River" rests directly on the Keokuk.

Paleontology. The "Grand River," a highly fossiliferous formation, yielded a large collection, including *Spirifer increbescens*, *Spirifer leidyi*, *Linoproductus ovatus*, and *Agassizocrinus* sp. cf. *A. conicus*. (See Table VI).

Age and correlation. On faunal evidence and stratigraphic re-

TABLE VI

FAUNULES FROM THE "GRAND RIVER" IN THE LOCUST GROVE AREA

	Localities												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Agassizocrinus sp. cf. A. conicus Owen and Shumard	.	.	.	.	X	.	X	.	.	X	.	.	.
Archimedipora communis (Ulrich)	.	.	.	.	.	X	.	.	.	.	.	.	.
Fenestrellina cestriensis (Ulrich)	.	.	.	.	X	.	.	.	.	.	.	.	.
Camarotoechia sp.	.	.	.	.	.	.	.	.	.	.	X	.	.
Camarotoechia purduei Girty	.	.	.	.	.	.	.	.	.	X	X	.	.
Cliothyridina sublamellosa (Hall)	X	.	.	.	.	X	.	.	.	X	X	.	.
Composita subquadrata (Hall)	X	X	X	.	.	X	.	.	X	.	.	.	.
Dialasmella compressa Weller	.	.	.	.	.	.	.	.	.	X	.	.	.
Diaphragmus cestriensis (Worthen)	.	.	X	X	.	.	.	.	.	X	.	.	.
Diaphragmus fasciculatus McChesney	X	.	X	X	X	.	X	.	.	.	.	.	.
Dictyoclostus inflatus (McChesney)	.	.	.	.	.	.	X	.	.	.	.	.	X
Eumetria vera (Hall)	.	.	.	.	.	.	X	.	.	.	.	.	.
Eumetria verneuiliana (Hall)	.	.	.	X	X	X	X	.	.	X	.	.	.
Girtyella turgida var. elongata	.	.	.	.	.	.	.	.	.	.	X	.	.
Linoproductus ovatus (Hall)	.	.	X	X	.	.	.	.	.	X	.	.	.
Marginifera adairensis (Drake)	.	.	.	.	.	.	X	.	.	.	X	.	X
Orthotetes subglobosus var. batesvillensis Girty	.	.	.	.	.	.	.	.	.	X	X	.	.
Spirifer increbescens Hall	X	.	X	X	.	X	.	X	.	X	X	X	.
Spirifer leidyi Norwood and Pratten	X	.	X	.	.	.	X	.	.	X	.	.	.
Torynifera setigera (Hall)	X	X	X	.	.	.	.	.	.	.	.	.	.
Paladin mucronatus Weller	.	.	.	.	X	.	.	.	.	X	X	.	.

1. Outcrops along the north-south road in the NE¼ of sec. 1, T. 20 N., R. 19 E.
2. 50' southwest of guard tower in sec. 4, T. 20 N., R. 19 E.
3. Hill cut in NW¼ of sec. 15, T. 20 N., R. 19 E.
4. Exposure in road bed 175' north of Oklahoma Ordnance fence in sec. 22, T. 20 N., R. 19 E.
5. At base of hill in the NW¼ of sec. 24, T. 20 N., R. 19 E.
6. 75' southeast of Highway 33, where road makes a curve north to get back on section line in sec. 25, T. 20 N., R. 19 E.
7. At base of Grand View Cabin Site Hill in sec. 26 T. 20 N., R. 19 E.
8. Across the stream from quarry in sec. 27, T. 20 N., R. 19 E.

9. At the intersection of the south and center line of sec. 21, T. 20N., R. 19 E. in a small creek bed.
10. East end of bridge on river bank at Highway 33 in sec. 29, T. 20 N., R. 19 E.
11. On top of hill east of north end of bridge over river in sec. 6, T. 20 N., R. 20 E.
12. In roadcut at intersection of section line road and railroad in the southeast corner of sec. 30, T. 20 N., R. 20 E.
13. 120' east on section line from southwest corner of sec. 31, T. 20 N., R. 20 E.

lations, the "Grand River" is correlated with the Hindsville limestone member of the Batesville formation of Arkansas,[43] and is assigned to the New Design Group of Chesterian age.

Fayetteville Formation

History of nomenclature. In 1891, F. W. Simmonds[44] applied the term Fayetteville to beds now known to belong to the Moorefield formation. In 1904, Adams, Purdue, and Ulrich[45] redefined the Fayetteville as black shale above Batesville sandstone. It is named for Fayetteville, Arkansas.

Distribution. The Fayetteville is confined to the southwestern portion of T. 20 N., R. 20 E., and T. 20 N., R. 19 E. It is found on the slope of hills where it is frequently covered with slump from the overlying Hale and Atoka formations.

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[43] G. G. Huffman, Oral Communication, 1952.

[44] F. W. Simmonds, "Annual Report," Arkansas Geological Survey, Vol. 1, 1891, p. 42.

[45] G. I. Adams, A. H. Purdue and E. O. Ulrich, op. cit., p. 27.

Character and thickness: In the central and southern portions of the area the Fayetteville is composed of a basal sequence of blue-gray sublithographic limestone with cream to gray shale partings and an overlying black fissile shale. The limestone weathers cream to white and in cuboidal blacks, which cover the sloping surfaces. In sec. 15, T. 20 N., R. 19 E., 69 feet of alternating thin beds of cream to yellow limestone and shale are overlain directly by the Atoka sandstone. (Figure 9). South and north along this same outcrop pattern the upper portion of the Fayetteville is not observed because of Atoka and Hale slump. The full significance of local absence of the black shale facies is conjectural, however, since it does appear again in sec. 4, T. 20 N., R. 19 E., it must be assumed that the alternating shale and limestone sequence is a local facies development or that the upper black shale was removed over much of the area by pre-Hale erosion. This does not fully explain the lack of similarity between this limestone development, and other Fayetteville exposures to the north and south. (See measured sections, Tables VII and VIII).

Stratigraphic relations. The Fayetteville conformably overlies the "Grand River" and is overlain unconformably by the Hale formation of Pennsylvanian age.

Paleontology. The upper limestones of the Fayetteville formation are fossiliferous. *Spirifer increbescens*, *Linoproductus ovatus*, *Dictyoclostus inflatus* are among the most common forms. A complete faunal list is included in Table IX.

Age and correlation. The Fayetteville is correlated with the

Fig. 9. Fayetteville limestone section bounded above by Atoka and below by "Grand River," sec. 15, T. 20 N., R. 19 E.

TABLE VII

SECTION ON WEST SIDE OF HILL IN THE SE¼ SEC. 31, T. 20 N., R. 20 E.

Formational Description	Thickness			
	Of unit		To base of formation	
Hale:				
Sandstone, calcareous, medium grained	18'		18'	
Fayetteville:				
Shale, non-calcareous, black, platy, containing occasional black limestone concretions	39'	8"	90'	2"
Limestone, lithographic gray, massively bedded, fossiliferous	2'		50'	6"
Limestone, sub-lithographic, gray, with alternating thin beds of shale, weathers cuboidal	48'	6"	48'	6"
"Grand River":				
Limestone, coarsely crystalline, massively bedded, fossiliferous	28'	4"	28'	4"
"Batesville":				
Shale, cream-brown	1'	6"	1'	6"
Base of exposure:				

TABLE VIII

PARTIAL SECTION AT GRAND VIEW CABIN SITE IN SEC. 26, T. 20 N., R. 19 E.

Formational Description	Thickness: Of unit	Thickness: To base of formation
Hale:		
Sandstone, brown to cream on fresh break, medium grained, non-calcareous	23'	23'
Fayetteville:		
Shale, black, fissile, with occasional limestone concretions ...	26'	65'
Limestone and shale, alternating, with the limestone 2 to 8 inches thick, gray to blue on fresh break and weathering to cream, cuboidal blocks. The shale beds are ½ to 2 inches thick, light green to cream brown in color ..	39'	39'
"Grand River" and base of exposure:		

TABLE IX

FAUNULES FROM THE FAYETTEVILLE IN THE LOCUST GROVE AREA

	Localities							
	1	2	3	4	5	6	7	8
Pleurodictyum meekanum (Girty)	.	.	.	X	.	.	.	.
Fenestrellina cestriensis (Ulrich)	.	.	.	.	.	X	.	.
Athyris cestriensis Snider	.	.	.	.	.	X	X	.
Brachythyris ozarkensis Snider	.	X	.	X	X	X	X	X
Buxtonia arkansana (Girty)	.	.	.	.	X	X	X	.
Camarotoechia purduei var. agrestis Girty	.	.	.	.	.	X	X	.
Camarotoechia purduei var. laxa Girty	.	.	.	.	.	X	X	.
Composita acinus Girty	.	.	.	.	.	X	X	.
Composita subquadrata (Hall)	.	.	X	.	X	X	X	.
Composita trinuclea (Hall)	.	.	.	.	.	.	X	.
Cliothyridina sublamellosa Hall	.	.	X	.	.	X	X	.
Dialasma arkansanum Weller	.	X	.	.	.	X	X	.
Diaphragmus cestriensis (Worthen)	.	.	X	.	.	.	.	.
Diaphragmus fasiculatus McChesney	.	.	.	.	.	X	.	.
Dictyoclostus inflatus (McChesney)	.	.	.	.	.	X	X	.
Echinocoelia levicula (Rowley)	.	.	.	.	.	X	.	.
Eumetria verneuiliana (Hall)	.	X	.	X	.	X	X	.
Linoproductus ovatus (Hall)	.	.	X	.	X	X	X	.
Marginifera adairensis (Drake)	.	.	.	.	.	X	.	.
Orthotetes subglobosus Girty	.	X	.	X	X	X	X	.
Spirifer increbescens (Hall)	.	.	X	.	X	X	X	X
Torynifera setigera (Hall)	X	.	.	.	.	.	.	.

1. Hill cut in NW¼ of sec. 15, T. 20 N., R. 19 E.
2. Outcrop on the north line in the northeast corner of sec. 20, T. 20 N., R. 19 E.
3. At base of hill in the NW¼ of sec. 24, T. 20 N., R. 19 E.
4. In road cut at base of Grand View Cabin Site Hill in sec. 26, T. 20 N., R. 19 E.
5. 75' south of east end of bridge on river bank at Highway 33 in sec. 29, T. 20 N., R. 19 E.
6. In the NW¼ of sec. 32, T. 20 N., R. 19 E. where Chouteau Creek bends southeast go southwest 150' up gully to outcrop.
7. In road cut on hill in NW¼, SW¼ of sec. 34, T. 20 N., R. 19 E.
8. In saddle between the two hills in center of sec. 36, T. 20 N., R. 19 E.

type Fayetteville of Arkansas which is considered Middle Chesterian in age.

Pennsylvanian System

Hale Formation

History of nomenclature. In 1904, Adams and Ulrich[46] used the term Hale to designate the basal portion of the Morrow as developed on Hale Mountain, Washington County, Arkansas.

Distribution. The Hale is limited to T. 20 N., R. 19 E., except for a northeast-southwest trending hill capped by Hale limestone in secs. 31 and 32, T. 20 N., R. 20 E., and a small hill top in sec. 30, T. 20 N., R. 20 E. In the southeast portion of T. 20 N., R. 19 E., the Hale rims the tops of high hills. Through the center of the township it crops out along the crest of north-south cuesta. Down dip from the cuesta, the Hale is exposed around a domal structure, with the outcrop extending up Chouteau Creek and out of the area to the west.

Character and thickness. The Hale is a cream, brown to reddish-brown, cross-bedded, coarse to conglomeratic, leached sandstone. In the areas where the lime is not leached the Hale is a white to brown, massive, medium crystalline limestone that weathers pitted. The most outstanding characteristic of the Hale is its change in lateral extent over a short distance from limestone to sandstone, often within a distance of a few feet. An excellent example of this may be seen on the Grand View Cabin Site hill in the northeast corner of sec. 26,

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[46] G. I. Adams and E. O. Ulrich, op. cit., pp. 28, 109-113.

T. 20 N., R. 19 E., where the Hale caps the hill except for two small overlying patches of Atoka sandstone. Here the Hale is a red-brown, pitted, cross-bedded sandstone except on the southwest side of the hill where the sand changes laterally into a massive limestone. This behavior was noted in scattered spots throughout the outcrop area of the Hale. In many places the Hale is covered with Atoka slump and was not observed. Where exposed, except in secs. 18 and 19, T. 20 N., R. 19 E., where it passes under younger units into subsurface and floors a small valley, the Hale forms a prominent cliff near the crest of the hills. A pronounced vertical ledge from 6 to 25 feet high is common and large slump blocks cover the slope below. In sec. 4, T. 20 N., R. 19 E., in a railroad cut south of the Oklahoma Ordnance Guard office the Hale is represented by a conglomeratic sandstone that locally cuts through the Fayetteville to form a channel deposit. About 200 yards due west of this exposure in another railroad cut the Hale is absent and the Atoka rests on the black shales of the Fayetteville.

Stratigraphic relations. The Hale is underlain unconformably by the Fayetteville and is unconformably overlain by the Atoka.

Paleontology. The limestone and sandstone of the Hale are fossiliferous with *Pleurodictyum sugenese*, and *Dictyoclostus morrowensis* common. (See Table X).

Age and correlation. The Hale is lower Morrowan in age and is correlated with part of the Upper Pottsville of eastern North America, the Union Valley and Cromwell of Central Oklahoma, and the Primrose of the Ardmore Basin.[47]

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[47] G. G. Huffman, Oral Communication, 1950.

TABLE X

FAUNULES FROM THE HALE IN THE LOCUST GROVE AREA

	Localities			
	1	2	3	4
Pleurodictyum eugeneae (White)	.	X	.	.
Zaphrentis gibsoni (White)	.	.	.	X
Ethelocrinus oklahomensis Moore and Plummer	.	X	.	.
Pentremites sp.	.	X	.	.
Polypora magna Mather	.	X	.	.
Stenopora tuberculata Prout	.	X	.	.
Composita deflecta Mather	.	X	.	.
Composita ovata Mather	.	X	.	X
Composita ozarkana Mather	.	X	.	.
Composita wasatchensis White	.	X	.	.
Dictyoclostus morrowensis (Mather)	X	.	X	.
Dictyoclostus welleri (Mather)	.	X	.	.
Spirifer rockymontanus Mather	X	X		X
Aviculopecten hertzeri Meek	X	.		.

1. North end of gully on the west side of the large hill in the center of sec. 21, T. 20 N., R. 19 E.
2. One half mile east of the southwest corner of sec. 31, T. 20 N., R. 19 E. in bar-ditch on the north side of road.
3. Top of hill in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ of sec. 34, T. 20 N., R. 19 E.
4. On the south line of sec. 31, T. 20 N., R. 20 E. on the west side of the hill.

Atoka Formation

History of nomenclature. The Atoka formation was named by Taff and Adams[48] from the town of Atoka, Oklahoma, where it is well developed.

Distribution. The resistant sandstones of the Atoka formation cap the hills in the south central portion of the Locust Grove area. West of the Grand River, they support the gently sloping prairie lands of the Prairie Plains Homocline.

Character and thickness. The Atoka is characteristically a medium-grained, white to reddish brown sandstone. Thin beds of black shale are present in northern exposures. A complete section is not present; exposed thicknesses range from 0 to 50 feet.

Stratigraphic relations. Atoka seas advanced across a land surface which had been exposed to erosion long enough to completely remove the Bloyd formation and to cut locally through the Hale into the Fayetteville shale. This relationship is demonstrated in the NW¼ NW¼ sec. 4, T. 20 N., R. 19 E., in a railroad cut where the Atoka sandstones rest on the Fayetteville black shale. The upper limits of the Atoka are unknown in the Locust Grove area although northward in Craig and Ottawa Counties, the Warner or Little Cabin sandstone of McAlester age rests on the Fayetteville.

Paleontology. No fossils were collected from the Atoka. The fucoidal marking, *Taonurus*, is common on weathered surfaces.

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[48] J. A. Taff and G. I. Adams, U. S. Geol. Survey, 21st. Ann. Rept., Pt. 2, 1900, p. 273.

Age and correlation. The Atoka formation is assigned to the Atokan series of Middle Pennsylvanian age.

Quaternary System

Pleistocene and Recent Deposits

Three distinct terrace and alluvium levels are present. The lower, composed of fine sands and silts, is readily identified by its association with the Grand River and its tributaries. An intermediate terrace level composed of gravels, sand, and silt is 20 feet above the river alluvium of Grand River while a high level terrace deposit of rounded and worn chert gravels occurs 75 feet above the river alluvium. Bone fragments associated with the high level terrace gravels to the north of this area have been assigned to the Pleistocene epoch.

CHAPTER V

STRUCTURE

Regional Setting

The Locust Grove Area is located on the western side of the Ozark uplift where the strata dip gently in a westerly direction. The regional dip is interrupted locally by minor anticlines, synclines, domes and faults.

The area includes the extreme eastern portion of the Prairie Plains Homocline and the Springfield Structural Plain.

Local Folding and Faulting

The most prominent feature is the Locust Grove fault which trends north-south, forming a prominent faultline scarp in the Keokuk chert east of the town of Locust Grove. To the south in sec. 34, T. 20 N., R. 20 E., and just west of this scarp, the "Moorefield" is dipping 12 degrees to the southwest, indicating drag on the downthrown side of a normal fault. No other field evidence was found to support this fault, but due to loose residual chert and similarity of Keokuk lithology making it difficult to determine horizons within the chert, it is quite possible that other fault evidence is concealed. Aerial photographs show a distinct line of vegetation change where a heavily wooded area on the east terminates abruptly at the scarp, leaving the area to the west relatively free of trees. Snider[49] states that at the south end of the fault, which is not in the Locust Grove area, the displacement approximates 200 feet.

Extending northeast-southwest in secs. 31 and 32, T. 20 N., R. 19 E., is a small normal fault with a displacement of approximately 50 feet with the downthrown side on the northwest. In sec. 32, T. 20 N., R. 19 E., where Chouteau Creek makes a 90 degree turn to the southeast, the Fayetteville is faulted against the Atoka. Southwestward along this fault, Hale sandstone and limestone is adjacent to the Atoka with increased dips indicating proximity to faulting.

In sec. 4, T. 20 N., R. 19 E., is a series of small normal faults trending northwest and southeast. These may represent the southern extension of the Seneca fault. Structural interpretation is made difficult by the nature of exposures and the absence of beds due to regional unconformity. The upper Fayetteville has been eroded away locally before Morrowan deposition and the Hale formation is represented by discontinuous lenses of coarse-grained, calcareous, cross-bedded sandstone.

Several local domes, anticlines, and synclines are present in the Locust Grove Area. These are discussed in order of magnitude.

In secs. 17, 18, 19, and 20, T. 20 N., R. 19 E., a dome of considerable areal extent exposes the "Grand River" formation in the center. The dips to the north, south and west are gentle and never

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[49] L. C. Snider, *op. cit.*, 1915, p. 57.

more than 5 degrees, and to the east there is no measureable dip, indicating the dome is raised only high enough to compensate for the regional dip to the west.

In sec. 32, T. 20 N., R. 19 E., Chouteau Creek flows along the crest of an anticline that plunges north 60 degrees west. The northeast flank and southeast end are concealed beneath a cover of alluvium and terrace deposits. No indication of this structure was found in the beds across the river to the southeast, thereby limiting the fold to secs. 31 and 32. Gas seeps are present along the crest and a well drilled on this structure is flowing large quantities of sulphur water.

On the west side of sec. 1, T. 20 N., R. 19 E., in a creek bed are exposed a series of small anticlines and synclines, with the cores of the anticlines exposing the Keokuk chert. The structures are obscured from view on either side of the creek by terrace deposits. Extending southward, as a possible extension of the above structures, is a large Keokuk chert knob protruding as a high area with Meramec and Chester beds overlapping and dipping away from it on the west. Here the course of the Grand River is sharply deflected southward from an otherwise westward course.

In sec. 6, T. 20 N., R. 20 E., a cross section of a Keokuk knob, with younger units dipping from it, is seen along a bluff on the Grand River. Below and to the west of Lindsey-Mayes Bridge is a Keokuk knob with younger units dipping sharply to the east.

Throughout the area are slight variations in dips, indicating a multitude of small structures.

Snider[50] considered the faulting and folding in the area to be of late Pennsylvanian age.

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[50] *Ibid*., p. 53.

CHAPTER VI

GEOLOGICAL HISTORY

The geologic history of the Locust Grove Area shall be carried from Osagean time forward, since the oldest rock exposed in the area is Reeds Spring in age.

The geologic history is related to the movements of the Ozark Dome.[51] The sediments, which were deposited in fluctuating seas caused by the oscillation of the dome, were derived from the Ozark land mass during times of emergence or partial emergence.

After a short withdrawal at the end of Chattanooga time, the seas again advanced over the area in Fern Glen time depositing the St. Joe formation, which is present both north and south of the Locust Grove Area. The Reeds Spring was subsequently deposited with local withdrawal at the end of Reeds Spring time as evidenced by absence of typical Burlington equivalents. The area was again inundated and the limestones of the Keokuk were deposited. Again a withdrawal of seas produced a hiatus representing late Osagean time. A sharp faunal change[52] at this point indicates sufficient withdrawal to allow the disappearance

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[51] H. A. Ireland, op. cit., p. 28.

[52] G. G. Huffman, Oral Communication, Summer 1950.

of much of the Keokuk type fauna. The Keokuk had assumed its cherty character before the deposition of the "Moorefield" and younger beds, because chert pebble zones believed derived by weathering of the Keokuk chert are found in beds of younger age in close proximity to the chert hills. In the "Hindsville" limestone a chertified fossil, Spirifer floydensis of Keokuk age was found.

The character of the sediments in late Osagean time indicates quiescent seas and absence of nearby land masses.

The "Moorefield" seas encroached upon an irregular topography which did not become completely inundated until "Grand River" or possibly Fayetteville time as shown by the overlapping relationship of these units onto the chert beds.

Ireland[53] states that during Mayes and Fayetteville time detritals were introduced into the area indicating oscillation of the Ozark land mass as a prelude to the major uplift at the end of Mississippian time.

The unconformity between the Fayetteville and the overlying Hale indicates another period of long emergence with the Upper Chesterian Pitkin and lower Pennsylvanian Springeran equivalents absent.

After Morrowan deposition, the seas again withdrew to bring about erosion of the Bloyd before the encroachment of the Atoka seas. Post-Atokan deformation followed by long erosion produced the features present today.

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[53] H. A. Ireland, op. cit., p. 28.

CHAPTER VII

ECONOMIC GEOLOGY

Economically the geology of the Locust Grove area is poor; however, the gravel deposits furnish excellent road building material for the local roads. Abundant limestone for crushing purposes is available.

Petroleum possibilities have been considered in the area primarily because of the many sulphur gas seeps near the mouth of Chouteau Creek where it bisects the anticline in sec. 32, T. 20 N., R. 19 E. An exploratory oil well drilled in the SW SE NE of sec. 32, T. 20 N., R. 19 E. was abandoned and is now flowing sulphur water and gas. Some of the farm homes have natural gas from what were originally intended to be water wells. This gas is not prolific enough to be of commercial value.

There are a number of places where the Keokuk has weathered to tripoli, but these also are not extensive enough to warrant exploitation.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

All formations in the Locust Grove Area are sedimentary in origin, ranging from middle Mississippian, Osagean series, to lower Pennsylvanian in age. Quarternary terrace gravels and alluvium are present along a wide band following the Grand River.

The Reeds Spring and Keokuk members of the "Boone" comprise the Osagean series, and occur in the eastern one-half of the area. Known unconformities exist at the bottom and top of the Keokuk. The overlying formations, "Moorefield," "Hindsville," and "Batesville" of Meramecian age are essentially conformable and can be mapped over most of the area. The "Grand River" limestone unconformably overlies the "Batesville" and grades upward into the Fayetteville limestone and shale. Fayetteville, the youngest Mississippian formation in the area, is classed as Chesterian.

The Hale sandstone and limestone of lower Pennsylvanian, Morrowan age is bound below and above by unconformities. The overlying Atoka sandstone extends into the area from the west.

The major structural feature is the north-south trending Locust Grove fault in the western portion of the area. A low dome in the Oklahoma Ordnance Area, and a west plunging anticline along Chouteau

Creek are structural features of note. Throughout the area smaller structures interrupt the regional dip.

The principal economic product of the area is gravel. Petroleum possibilities are discouraged by a dry hole drilled in the southern portion. The mineral resources are considered of little commercial value.

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