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GEOLOGY OF THE STRANG AREA, MAYES COUNTY, OKLAHOMA

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The manuscript was read and criticized by Professor Carl A. Moore, Professor A. J. Williams, and Mr. R. H. Dott, Director of the Oklahoma Geological Survey.

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GEOLOGY OF THE STRANG AREA, MAYES COUNTY, OKLAHOMA

CHAPTER I

INTRODUCTION

Location

The Strang area is located in the northeastern portion of Mayes County, Oklahoma (see shaded area in Figure 1). It includes the eastern half of T. 22 N., R. 19 E.; all of T. 22 N., R. 20 E.; and the west one-half of T. 22 N., R. 21 E. It lies about 43 miles northeast of Tulsa and about 42 miles north of Muskogee. Pryor, the county seat of Mayes County, is two and one-half miles southwest of the southwest corner. The area, which is rectangular in shape, is six miles in width in a north-south direction, 12 miles in length in an east-west direction, and encompasses a total of 72 square miles. The town of Adair lies three-quarters of a mile to the north of the northwest corner whereas Spavinaw is located three-quarters of a mile to the east of the eastern boundary which crosses the Spavinaw Creek bridge on Highway No. 20.

Purpose of Present Investigation

The primary purpose of the investigation was the detailed mapping of all lithic units in the area. Fossil collections were made from various formations to assist in stratigraphic correlations. Structural

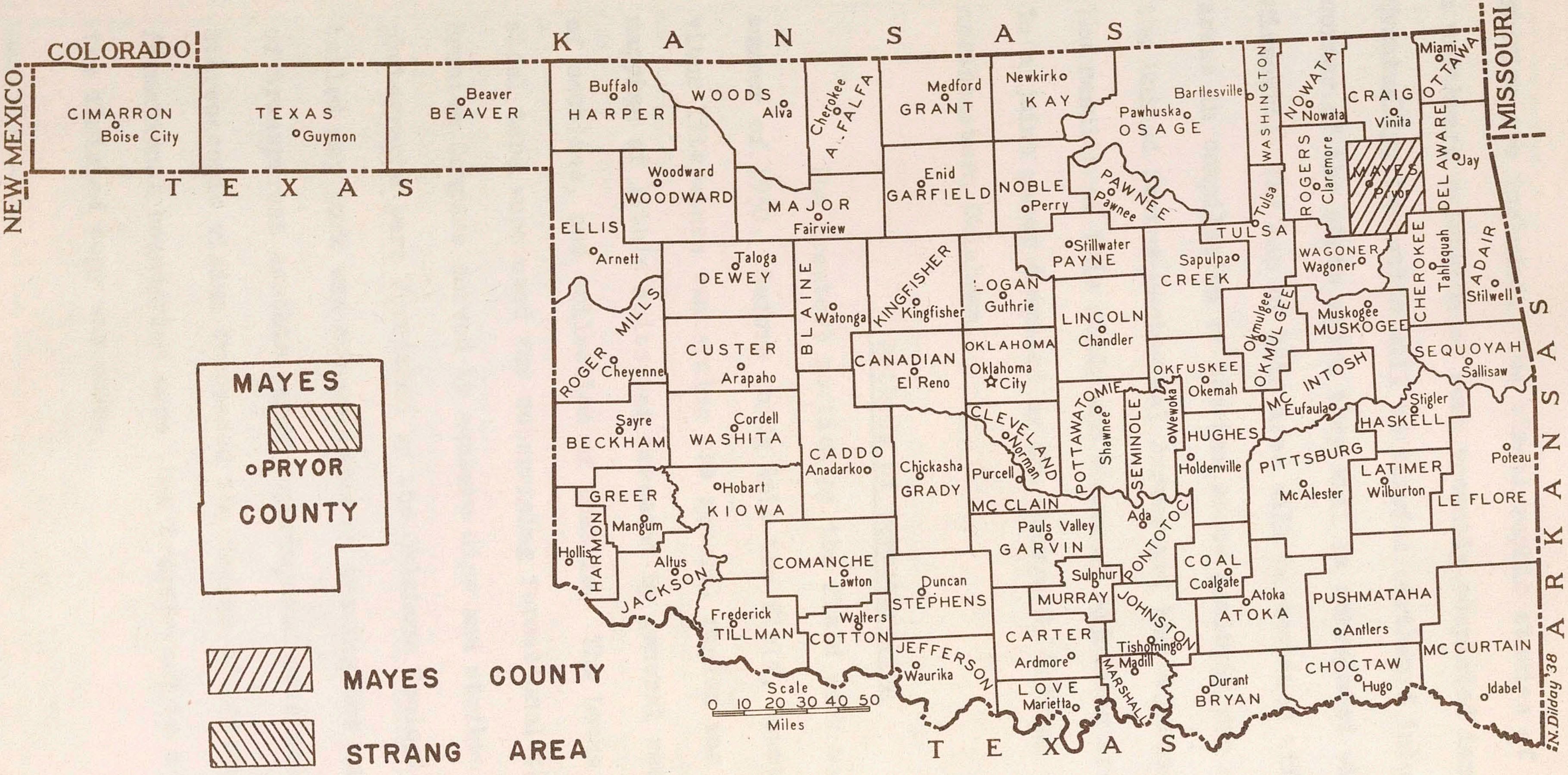

FIGURE I. INDEX MAP SHOWING LOCATION OF STRANG AREA studies are included. The stratigraphic studies of this area represent a northward extension of work recently completed immediately to the south. Eventually, the units will be carried northward into the northeastern corner of the state where they will be correlated with the formations of Missouri. The map of this area will be combined with maps of adjacent areas in compilation of the new state geologic map now being prepared by the United States Geological Survey and the Oklahoma Geological Survey. The results of this study and those of adjoining areas will be incorporated in a joint paper compiled by Dr. George G. Huffman on the geology of northeastern Oklahoma.

Methods of Investigation

The greatest portion of the field work was completed during the summer of 1950. Before going into the field, however, some of the previous literature concerning the general region was reviewed. Detailed mapping of lithic units was preceded by general reconnaissance, measuring of sections, and collection of fossils. The Locke Hand Level and a steel tape were used for determining formational thicknesses and the Brunton Compass served to measure dips and strikes of the beds. Aerial photographs were furnished by the Oklahoma Geological Survey. The detailed map work was accomplished by tracing the unit contacts on a sheet of transparent acetate paper superimposed over the aerial photograph. Stereoscopic vision increased the degree of accuracy of this method. The formational boundaries were then transferred to a base map from which the finished copy was made.

History of Previous Investigations

The first work in this area was probably done in connection with topographic studies. C. H. Fitch[1] and his party surveyed the Pryor Quadrangle in 1896 and completed a polyconic projection of the topography in 1901.

N. F. Drake[2], in 1898, was one of the first to attempt a discussion on the stratigraphy and structure of this region. He endeavored to draw a crude map showing the contact between the Pennsylvanian and Mississippian systems and pointed out the existence of dolomites, fossiliferous cherts, and granite in the vicinity of Spavinaw.

Taff's[3] early work to the south had some bearing on the geology of this area. He mapped the geology of the Tahlequah and Muskogee Quadrangles which was published in 1905 and 1906, and divided the Mississippian into two units, the Boone and Fayetteville. The Morrow was described as a separate Pennsylvanian unit. Siebenthal[4] referred to this geology in many instances in his report on the mineral resources of northeastern Oklahoma, which was published in 1908. Beside the dolomites at Spavinaw he recognized the Chattanooga shale and stated that the Sylamore sandstone member at the base of the Chattanooga does not appear in this area. His

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[1] C. H. Fitch, U. S. Geol. Survey, Topographic Sheet, Pryor Quadrangle, 1901.

[2] N. F. Drake, "A Geological Reconnaissance of the Coal Fields of the Indian Territory," Proc. Am. Phil. Soc., Vol. 36, 1897, p. 377.

[3] J. A. Taff, U. S. Geol. Survey Atlas, Tahlequah Folio (No. 122), 1905; Muscogee Folio (No. 132), 1906.

[4] C. E. Siebenthal, "Mineral Resources of Northeastern Oklahoma," U. S. Geol. Survey Bull. 340, 1908, pp. 187-190.

recognition of the Boone and Fayetteville corresponded to the conclusions reached by Taff.

L. C. Snider[5] (1912) published a report pertaining to the lead and zinc fields in northeastern Oklahoma. In his stratigraphy he considered the Ordovician dolomite equivalent to the Burgen sandstone, but Siebenthal's earlier conclusions as to stratigraphy and structure in 1908 were generally accepted. Snider,[6] in 1915, published a fairly complete report on the geology of northeastern Oklahoma with the paleontology of the Chester Group as part II in the same bulletin. In part I he proposed the name Mayes formation for all rocks between the Fayetteville black shale and the Boone formation.[7]

In 1915, K. F. Mather[8] published a detailed study of the fauna of Morrow Group of northwest Arkansas and northeast Oklahoma. Stratigraphic relations of the fauna of the Morrow Group were discussed. This book proved valuable in identifying Hale sandstone and limestone fossils collected in the Seneca graben of this report.

The subsurface stratigraphy of the northern midcontinent oil

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[5]L. C. Snider, "Preliminary Report on the Lead and Zinc of Oklahoma," Okla. Geol. Survey, Bull. 9, 1912, pp. 34-41.

[6]L. C. Snider, "Geology of a Portion of Northeastern Oklahoma," Okla. Geol. Survey, Bull. 24, 1915.

[7]L. C. Snider, ibid., pp. 27-35.

[8]K. F. Mather, "The Fauna of the Morrow Group of Arkansas and Oklahoma," Dennison Univ. Sci. Lab. Bull., Vol. 18, 1915-1916.

fields was published by Aurin, Clark, and Trager in 1921.[9] Pre-Pennsylvanian subsurface units were correlated with outcropping beds in northeastern Oklahoma. They correlated the Arbuckle limestone with the siliceous limestone (Cotter dolomite) at Spavinaw, the Chattanooga with the Woodford, and the Boone with the Mississippi lime. They were uncertain concerning the exact relation between the Mayes and the upper part of the Mississippi lime.

Charles N. Gould[10] published the "Index to the Stratigraphy of Oklahoma" in 1925. Charles E. Decker compiled the characteristic fossil lists. This was the first complete summation of formations with respect to their ages and correlations to be assembled up to this time. The Ozark Mountain section and the Carboniferous of northern Oklahoma[11] were dealt with in a separate portion of the book.

An article by G. S. Buchanan[12] (1927) discussed the distribution and correlation of the Mississippian of Oklahoma. Tentative sea expanses were shown and correlations were made between the formations of the Arbuckle Mountains and northeastern Oklahoma.

In an article on the oil and gas possibilities in Mayes,

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[9]F. L. Aurin, G. C. Clark, and E. A. Trager, "Notes on the Subsurface Pre-Pennsylvanian Stratigraphy of the Northern Mid-Continent Oil Fields," Amer. Assoc. Petrol. Geol. Bull., Vol. V, No. 2, 1921, pp. 117-154.

[10]Chas. N. Gould, "Index to the Stratigraphy of Oklahoma," Okla. Geol. Survey, Bull. 35, 1925.

[11]Chas. N. Gould, ibid., pp. 54-86.

[12]G. S. Buchanan, "The Distribution and Correlation of the Mississippian of Oklahoma," Amer. Assoc. Petrol. Geol. Bull., Vol. 12, Pt. 2, pp. 1307-1320.

Delaware, and Ottawa counties, Ireland[13] (1930) gave a good description of the formations from the pre-Cambrian granite through the Cherokee shale and pointed out the relatively negative prospects for oil and gas in these counties.

In the same bulletin Cram[14] wrote a similar article on the oil and gas possibilities in Cherokee and Adair counties which lie to the south and east of Mayes County.

In 1930, a report was published on the geology of the Paleozoic area of Arkansas by Carey Croneis.[15] This proved valuable in identifying some fossils inasmuch as many of the formations or their equivalents discussed in this bulletin extend into the Strang area.

Laudon,[16] in 1939, wrote a paper on the stratigraphy of the Osage subseries of northeastern Oklahoma. He described many Boone sections extending from Wyandotte southward to near Marble City, and called attention to the massive, crinoidal bioherm reefs in many localities within the St. Joe. He also offered evidence of an unconformity between the Reeds Spring and "Keokuk".

In 1941, R. A. Brant,[17] in an unpublished master's thesis,

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[13]H. A. Ireland, "Geology of Mayes, Ottawa, and Delaware Counties," Okla. Geol. Survey, Bull. 40 NN, 1930.

[14]Ira H. Cram, "Geology of Cherokee and Adair Counties," Okla. Geol. Survey, Bull. 40QQ, 1930.

[15]Carey Croneis, "Geology of the Arkansas Paleozoic Area," Ark. Geol. Survey, Bull. 3, 1930.

[16]L. R. Laudon, "Stratigraphy of the Osage Subseries of Northeastern Oklahoma," Amer. Assoc. Petrol. Geol. Bull., Vol. 23, No. 3, 1939, pp. 325-335.

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

subdivided the Mayes of Snider into four units of formational rank which he assigned to the Meramecian series. Some of the questionable conclusions reached in this thesis stimulated further detailed work on the problem of the Mayes.

Mackenzie Gordon, Jr.[18] published a paper on the Moorefield formation and Ruddell shale of the Batesville District of Arkansas in 1944. He restricted the term Moorefield to the lower limestones (Spring Creek member of older reports) and introduced Ruddell for the upper shale previously included in the Moorefield. Many of the fossils found in this area correspond to those included in his faunal listings.

The Morrow series of northeastern Oklahoma was described by Carl A. Moore[19] in 1947. His report contains a Greenbriar section located within the Seneca fault zone of this report where he measured a two-foot section of Hale limestone, thus establishing its presence as far north as the Greenbriar school house.

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[18]Mackenzie Gordon, Jr. "Moorefield Formation and Ruddell Shale, Batesville District, Arkansas," Amer. Assoc. Petrol. Geol. Bull., Vol. 28, No. 11, 1944, pp. 1626-1634.

[19]Carl A. Moore, "The Morrow Series of Northeastern Oklahoma," Okla. Geol. Survey, Bull. 66, 1947.

CHAPTER II

GEOGRAPHY

Climate

The climate of this region is typified by intermediate continental[20] or the warm subtype with mean temperatures of the coldest month below 32 degrees and from six to nine months above 50 degrees. The length of the growing season is 140 to 220 days. The rainfall is between twenty and forty inches a year with a summer maximum. The summer rains generally come in the form of thunderstorms of short duration, but the winter rains are generally slow and extend through long periods during which the atmosphere is very moist. Blizzards are very infrequent, and as a rule, temperatures during extremely cold periods do not remain below zero for more than 24 hours. Temperatures of 100 degrees are common, but they last only a few days each season. The windiest period of the year is during late March and early April with the wind movement at a minimum during August. The wind velocity is variable, increasing toward the warmest part of the day and falling at night. "Hot winds" usually occur during a prolonged heated period and cause great injury to growing crops, but they are irregular and uncommon. April 6 and October

[20] Thomas A. Blair, Climatology, (New York: Prentice-Hall Inc., 1942), pp. 132, 219-226.

22 are the average dates between the last and first killing frosts.[21]

Principal Cities and Towns

Strang, with a population of 283 inhabitants,[22] is the only town within the 72 square mile rectangle. It is situated in the north central part of the area, one and one-half miles east of Grand River. Nearby farmers use its few stores primarily as a community center. The railroad enables the shipment of agricultural products. Spavinaw, lying just outside the eastern boundary, is a resort town and is the site of Spavinaw Lake which furnishes the Tulsa water supply. According to the 1940 census, the population of Spavinaw was 255; 1950 figures are unreleased at this time. Pryor, two and one-half miles to the southwest of the area, increased its population from 2,504 in 1940 to 4,441 in 1950. On the whole, Mayes County shows a decrease from 21,668 to 19,486 over this same period. The decrease in population seems to have taken place in the smaller towns of the county as denoted by vacant houses and stores and in the rural areas where many tenant farmers were unable to survive on smaller tracts of land.

Roads and Railroads

The Kansas, Oklahoma, and Gulf Railroad traverses the region in a north-south direction just to the east of Grand River following the

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[21] M. H. Layton and O. H. Brensing, Soil Survey of Mayes County, Oklahoma, (Washington, D. C.: Bureau of Chemistry and Soils, March, 1937), 3-4.

[22] Security Abstract Company, Pryor, Oklahoma, Official U. S. Bureau of Census Figures, 1940; Mayes County and Pryor, Oklahoma, 1950.

river terraces mainly. It connects Strang with large markets to the north and shipping centers along the Gulf to the south making long hauls for agricultural products unnecessary. One-eighth of a mile to the west of the northwest corner of the area runs the Missouri, Kansas and Texas Railroad. It affords Pryor and many other smaller towns in the county the same market outlets as Strang. Highway number 69 parallels this railroad leading to Miami, Oklahoma, and Kansas City to the north, and Dallas to the south. State Highway 20 winds through the southeastern part of the area connecting Pryor to Spavinaw and offers a good bypass route to other major highways in the northeastern part of the state. Other than these two highways there are no other paved roads within or near the area. To the west of Grand River beyond the "Boone Hills," most sections are bordered by good gravelled roads under county maintenance. In many localities near Grand River, terrace gravel deposits are plentiful. Such deposits render good surfacing materials within easy reach of all section roads. To the east of Grand River, bedrock and terrace gravels form a natural base for the roadways. Some of these roads do not parallel section lines, however, but follow the valleys or divides, whichever affords the cheapest means of construction.

Principal Industries

Agriculture in this county has been built largely around some type of livestock raising. In the extreme western part of the area, in regions underlain by the Fayetteville formation or Atoka and younger units, ranching is the chief industry. Between here and the "Boone hills" to the east of Grand River, fertile flat lands make agricultural crops such as corn and cereal grains important.

In the hilly regions in the eastern part of the area there are a few orchards in which apples, small patches of blackberries, strawberries, and melons are raised.

Nearly every farmer cultivates his own garden, has poultry and eggs, and raises his own cattle and hogs.

Spavinaw Creek and Grand River offer ideal cabin sites for Tulsans and the people of nearby cities. Spavinaw and Grand Lakes spur recreational activities, making camping, fishing, and boating important in the warmer months of the year.

CHAPTER III

PHYSIOGRAPHY

Physiographically, the area can be divided into two provinces: the Ozark Region, comprising the hills to the east of Grand River; and the Prairie Plains province, making up the homoclinal slopes west of the river.

Relief and Elevations

Except for the middle one-third of the area to the west of Grand River, the surface of the region gradually increases in elevation from west to east in the direction of the Ozark Uplift. The increase becomes more abrupt at the foot of the "Boone hills" in the vicinity of Grand River. C. H. Fitch[23] and his surveying party show a minimum elevation of 500 to 600 feet along the Grand River in the south-central part of the area. This is about 50 feet lower than the beds of creeks in the southwest corner of the area. The maximum elevation of 950 to 1000 feet is recorded in the southeast corner. The eastern one-third stands from 200 to 400 feet higher than the area to the west. Many steep valleys give the Boone surface a well-dissected appearance exposing underlying formations and affording great relief in many instances. The western sector is reasonably level with many east-facing escarpments,

[23] C. H. Fitch, op. cit., 1901.

especially along Grand River and two or three miles to the west. A few knobs, buttes, and mesas interrupt the regularity of the terrain in other cases. Erosion progressing down the dip slope decreases the elevation to the west in the west one-third of the area.

Topography and Drainage

The hills east of the Grand River appear to have undergone rejuvenation as indicated by the steep valleys and high, relatively flat divides. The V-shaped valleys contain intermittent streams with very high gradients except in one or two cases. Spavinaw Creek has developed a flood plain of variable width, measuring from a few hundred yards to over one mile. This is bordered by steep cliffs which exceed 200 feet in height in places. Cliffs of this nature were developed on the outside of meanders as a result of stream undercutting. (See Plate I, Figure 2.) A similar situation prevailed along Grand River which enabled the stream to broaden its flood plain. Three separate alluvial and two distinct gravel terraces prove former positions of the river. In the western part of the area gently westward dipping cuestas break the monotony of the flat topography. Some topographic highs were left as a result of resistant beds acting as cap rocks. Other elevated localities act as structural and depositional highs developed by Boone knobs. One unique high was left as a result of a collapse-structure.

Eventually the waters from all of the streams in the area enter Grand River. East of the river most of the intermittent streams drain almost at right angles into Spavinaw Creek. This creek in turn flows to the west-southwest into Grand River. The run-off in the western one-fourth of the area is toward the west and southwest into Pryor Creek while the south-central sector is drained to the southeast by Wolf Creek and its tributaries. The north-central part of the area is drained by several creeks which flow directly into Grand River. During the wet seasons the water in most of the intermittent streams east of the river is clear and almost completely lacking in sediment. Those west of the river are usually muddy for they drain dark and sticky farmlands and areas covered by eolian deposits.

Vegetation

The vegetation in the eastern "Boone hills" consists mainly of a dense growth of blackjack, red and post oaks with intermingling thorny vines and bushes. Many of the bush patches contain edible berries. Grasses are sparse except in elevated portions covered by high terrace gravels. Here sparse shrub trees and grasses made cultivation possible, and most of these areas have been converted into apple orchards, hay, or grass meadows. Hickory, locust, pine, haw, shittimwood, persimmon, and Osage-orange trees form a minor part of the vegetation. The chief grasses consist of broomsedge, wild oatgrass, and needlegrasses. Thin layers of leafmold cover other localities within this hilly sector, especially in canyons. The Prairie Plains region in the western part of the area has a native vegetation consisting almost entirely of tall grasses intermixed with wild legumes, such as prairie clover and wild alfalfa. Some poverty grass and weeds have grown in overgrazed areas. On some of the Atoka capped mesas and Boone knobs, shrubs and vines of sumac, dogwood, wild grape, woodbine and butternut can be found. Marsh grasses predominate in the alluvial lands while pecan, elm, ash, pin oak, and many other types of minor trees may be found in the lowlands next to the river and creeks.

Nature of Rock Exposures

Excellent bedrock exposures may be found in many localities but continuous rock sections are essentially absent. Measured sections had to be taken piecemeal throughout the area. Canyons and bluffs along Spavinaw Creek offer complete measurable sections of the Chattanooga, St. Joe, and Reeds Spring. The true thickness of the "Keokuk" could not be ascertained at any exposure in the area because of erosion on its upper surface. About 300 yards up Spavinaw Creek from the eastern boundary of the area, four linear, northeast trending exposures of Spavinaw granite may be seen. Overlying Cotter, Chattanooga, St. Joe, Reeds Spring and a partial section of "Keokuk" are exposed in the first ravine inside the area on the southwest side of Spavinaw Creek. West of Grand River, post-"Keokuk" units are described in many localities. The "Moorefield," "Hindsville," and "Batesville" are typically developed along the creek on the west side of section 10, T. 22 N., R. 20 E. Partial or complete sections were obtained at several other locations, mainly along the west side of the Grand River in the north central part of the area. A complete Hale sandstone and limestone section and a partial Fayetteville black shale section were measured on the south side of the north Seneca fault in a roadcut three-quarters of a mile to the west-southwest of the Greenbriar school house. A section of "Grand River" was measured just west of this Seneca fault zone in the north roadcut extending from the bridge westward to the top of the hill. Fayetteville shale exposures were good except at the base of the formation where alluvial material covers the lower few feet. Inasmuch as most of the Atoka and younger Pennsylvanian units lie outside of the area, no detailed study of these beds was undertaken.

CHAPTER IV

STRATIGRAPHY

General Statement

The formations exposed at the surface in the Strang area range in age from Ordovician to Middle Pennsylvanian. Locally these are overlain by terrace gravels, alluvium, and eolian deposits of Pleistocene and Recent age.

The Pennsylvanian beds crop out in the western part of the area and in the Seneca Fault zone. Pennsylvanian strata include the Hale formation of Morrowan age and undifferentiated Pennsylvanian units of Atoka and younger.

Beds of Mississippian age are widely distributed throughout the area. Kinderhookian, Osagean, Meramecian, and Chesterian series are represented.

Pre-Boone units are exposed only in the deeper canyons near the eastern boundary. The Chattanooga black shale is believed to include Upper Devonian correlatives in lower portions. The Ordovician is represented by a single formation, the Cotter dolomite, classed as Beekmantown or Canadian.

A generalized columnar section of rocks as exposed in the Strang area is shown in Figure 2.

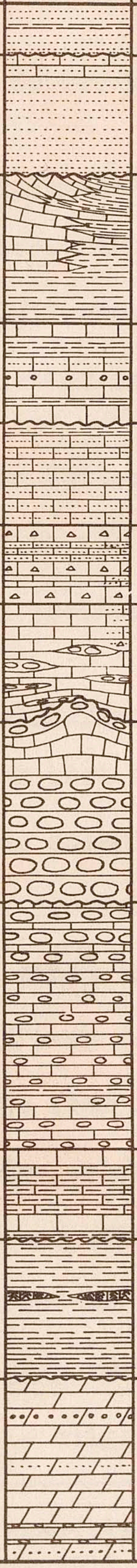
SYSTEM	SERIES	GROUP AND FORMATION	ROCK	THICKNESS	REMARKS
PENNSYLVANIAN	DES MOINESIAN	UNDIFFERENTIATED ATOKA AND CHEROKEE		?	RED TO BROWN FINE- TO COARSE-GRAINED SANDSTONE. SOME BLACK SHALE.
	MORROWAN	HALE		0' - 39'	MASSIVE, SANDY, COARSELY CRYSTALLINE LIMESTONE AND BRIGHT RED PITTED AND FLUTED SANDSTONE.
MISSISSIPPIAN	CHESTERIAN	FAYETTEVILLE		16' - 44'	SUBLITHOGRAPHIC TO COARSELY CRYSTALLINE LIMESTONE AND BROWNISH-GREEN TO YELLOWISH-GREEN SHALE WITH DICTYOCLOSTUS INFLATUS. SOME BLACK FISSILE SHALE.
		MAYES: "GRAND RIVER"		0' - 14'	GRAY, COARSELY CRYSTALLINE TO DENSE AND SANDY LIMESTONE WITH DIAPHRAGMUS ELEGANS, SPIRIFER LEIDYI, AND AGASSIZOCRINUS CONICUS.
	MERAMECIAN	MAYES: "BATESVILLE"		0' - 14'	BLUE-GRAY, CALCAREOUS SILTSTONE; SANDY LIMESTONE; AND MINOR AMOUNTS OF YELLOW SHALE.
		MAYES: "HINDSVILLE"		0' - 9'	GRAY, COARSELY CRYSTALLINE LIMESTONE WITH ANGULAR FRAGMENTS OF CHERT; LOCALLY CROSS-BEDDED; CAMAROTOECHIA PURDUEI, SYRINGOTHYRIS TEXTUS, AND SPIRIFER ARKANSANUS.
		MAYES: "MOOREFIELD"		0' - 36'	GRAY, MASSIVE, DENSE TO MEDIUM CRYSTALLINE LIMESTONE; LOCALLY CHERTY WITH DICTYOCLOSTUS CRAWFORDVILLENSIS, LEIORHYNCHUS CARBONIFERUM, AND GRIFFITHIDES PUSTULOSUS.
	OSAGEAN	BOONE: "KEOKUK"		64' - 250'	MASSIVE WHITE FOSSILIFEROUS CHERT; BLUISH-GRAY CRINOIDAL LIMESTONE; ORTHOTETES KEOKUK, PSEUDOSYRINX KEOKUK, AND SPIRIFER KEOKUK.
		BOONE: REEDS SPRING		132' - 156'	INTERBEDDED GRAY TO WHITE LIMESTONE AND CHERT.
		BOONE: ST. JOE		18' - 25'	GRAY, MASSIVE, CRINOIDAL AND THIN-BEDDED SHALY LIMESTONE.
MISSISSIPPIAN ? DEVONIAN	KINDERHOOKIAN	CHATTANOOGA		65'	BLACK PLATY SHALE WITH BLACK CONE-IN-CONE LIMESTONE NEAR CENTER.
ORDOVICIAN	CANADIAN	COTTER		85'	HARD, MASSIVE, WHITE TO GRAY DOLOMITE WITH SOME SANDY DOLOMITE AND OOLITIC CONGLOMERATE. UNEXPOSED BELOW WATER LEVEL.

FIGURE 2. GENERALIZED COLUMNAR SECTION FOR THE STRANG AREA

Ordovician System

Cotter Dolomite

History of Nomenclature.--E. O. Ulrich[24] named the Cotter dolomite from exposures at Cotter, Baxter County, Arkansas in 1912. He first called this formation the Jefferson City but subsequent study at the type localities determined the latter formation to be older than the Cotter.

Distribution.--The Cotter dolomite is exposed only on the southwest bank of Spavinaw Creek at the eastern boundary of the area for a distance of about 200 yards in section 16, T. 22 N., R. 21 E.

Character and Thickness.--The Cotter consists largely of white to gray dolomite. The lower part of the formation contains massive layers of white, slightly sandy dolomite, separated by thin layers of gray dolomite and laminations of irregular, yellow chert. A nodular weathering, light gray zone of massive sandy dolomite immediately overlies. Massive to occasionally thin-bedded gray dolomite forms the middle part of the formation. This zone varies from finely crystalline to dense in texture. Whitish to light gray massive intraformational conglomerate overlies the central zone. The pebbles and cobbles are disc-shaped and flattened parallel to the bedding surfaces. They are composed mainly of dolomite but some consist of light gray chert. Characteristically, the well-cemented dolomitic matrix is slightly sandy and very oolitic. Massive

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[24]E. O. Ulrich, "Revision of the Paleozoic Systems," Geol. Soc. Amer. Bull., Vol. 22, No. 3, 1911, pp. 281-680.

gray to white beds of finely crystalline dolomite mark the top of the formation. Its total exposed thickness measures slightly over 85 feet with the basal portion concealed.

Stratigraphic Relations.--The Cotter formation overlies the pre-Cambrian Spavinaw granite unconformably just outside the eastern boundary of the area. The dolomite is overlain unconformably by the Chattanooga shale. The Burgen and Sylamore sandstones are absent in this area, presumably by erosion before the deposition of the Chattanooga.

Paleontology.--Although some fossils have been reported from the Cotter in this area, none were obtained during the course of this investigation.

Age and Correlation.--The Cotter formation is classed as lower Ordovician[25] in age and has been correlated with the upper part of the Arbuckle limestone. Ireland[26] considered the unnamed dolomites of this area as equivalent to the Cotter dolomite of the Canadian Series correlated in part with the Beekmantown of eastern North America.

Mississippian System

Chattanooga Shale

History of Nomenclature.--C. W. Hayes[27] described the

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[25] C. N. Gould, op. cit., p. 54.

[26] H. A. Ireland, op. cit., p. 16.

[27] C. W. Hayes, "Geology of the Chattanooga Quadrangle," U. S. Geol. Survey, Atlas, Chattanooga Folio, (No. 6), 1894.

Chattanooga shale in 1891. It was named from the type locality at Chattanooga, Tennessee. The term was introduced in Oklahoma by Taff.[28]

Distribution.--The Chattanooga is exposed at six different localities along Spavinaw Creek. Three of these, previously mapped in earlier reports, are located at or near the eastern boundary of the area. The first one crops out in the ravine to the south of the Spavinaw bridge; the second appears in a road cut on Highway 20 a few hundred yards to the southwest of the Spavinaw bridge; and the third is revealed below a bluff of St. Joe limestone on the north bank of Spavinaw Creek in the southeast corner of section 9, T. 22 N., R. 21 E. Three additional outcrops were located and mapped during this investigation. One lies in and along the north bank of Spavinaw Creek at the section line of sections 8 and 9, T. 22 N., R. 21 E., and another is located in the southwest quarter of section 8, T. 22 N., R. 21 E. The most westerly one parallels the southeast side of the road at the base of the bluff in the southern part of section 18 and continues across the northwestern corner of section 23, T. 22 N., R. 21 E. The outcrop extends to within one-half mile of the east bank of Grand River.

Character and Thickness.--The Chattanooga formation is a black, carbonaceous, thin-bedded, platy shale characterized by prominent vertical jointing. Its weathered surface is usually iron stained, and occasional bits of pyrite are found within a freshly broken piece. Sporadic lenticular masses of black, coarsely crystalline, cone-in-cone limestone

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[28] J. A. Taff, op. cit., 1905, p. 3.

are common near the center of the formation. A measured section in the ravine to the south of the Spavinaw bridge indicates a thickness of 65 feet.

Stratigraphic Relations.--The Chattanooga rests unconformably on the Cotter dolomite. Intervening units of Burgen sandstone, Tyner shale, Fite limestone, Fernvale limestone, Sylvan shale, St. Clair limestone, Sallisaw sandstone and chert, and Sylamore sandstone present in areas to the south, are missing in this area. The Chattanooga is separated from the overlying St. Joe by unconformity as indicated by the variable thickness of green shale at their contact. (See Plate I, Figure 1.)

Paleontology.--The fauna of the formation includes some linguloid brachiopods, many conodonts, and an occasional pelecypod.[29] Remains of the fish, Dinicthys,[30] and a plant spore, Sporangites huronensis, are characteristic of the Chattanooga. No fossils were collected from the formation in this area.

Age and Correlation.--The Chattanooga has been variously correlated. Ireland[31] considered it as Kinderhookian or basal Mississippian in age. R. C. Moore[32] classified the Chattanooga and the basal Sylamore

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[29] H. A. Ireland, op. cit., pp. 19-20.

[30] J. A. Taff, op. cit., 1905, p. 3.

[31] H. A. Ireland, op. cit., p. 8.

[32] R. C. Moore, "Early Mississippian Formations of the Ozark Region," Mo. Bur. of Geol. and Mines, Vol. XXI, 2nd Series, 1928, p. 108.

PLATE I

Figure 1. St. Joe massive limestone and green shale (at contact) unconformably overlying Chattanooga black shale. Road fork, NW corner of section 19, T. 22 N., R. 21 E.

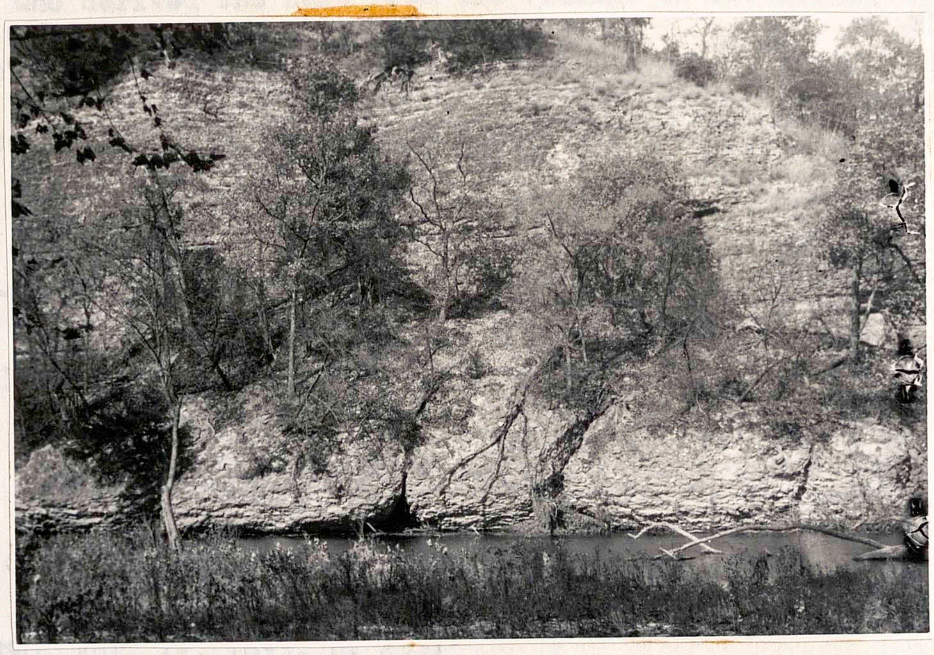

Figure 2. Slumping Reeds Spring beds accomplished by stream undercutting on outside of meanders, north side of Spavinaw Creek, west side of section 18, T. 22 N., R. 21 E.

sandstone member as lower Kinderhookian. Recent studies of the black shale problem by Campbell[33] indicate that the New Albany shale of Indiana and its equivalent, the Chattanooga of Tennessee, contain conodonts of both lower Mississippian and upper Devonian age. The Chattanooga of the Strang Area may be partially or wholly equivalent to the type Chattanooga of Tennessee. It is correlated with the Woodford chert[34] in the Arbuckle Mountains and the Grassy Creek shale of northeastern Missouri.

Boone Formation

History of Nomenclature.--The Boone formation was named by J. C. Branner of the Arkansas Geological Survey and described by Simonds in a report on the geology of Washington County, Arkansas.[35] The basal member of the Boone was named the St. Joe marble in 1893 by T. C. Hopkins[36] who derived the name from the village of St. Joe in Searcy County, Arkansas. The overlying Reeds Spring member was named by Moore in 1928 from exposures in Stone County in southwest Missouri.[37] The uppermost unit has been called the "Keokuk," an extension of the

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[33] G. Campbell, "New Albany Shale," Geol. Soc. Amer. Bull., Vol. 57, 1946, pp. 829-908.

[34] C. N. Gould, op. cit., p. 58.

[35] J. C. Branner and F. W. Simonds, "The Geology of Washington County," Ark. Geol. Survey, Ann. Report 1888, Vol. IV, 1891, pp. 27-37.

[36] T. C. Hopkins, "The St. Joe Marble," Ark. Geol. Survey, Ann. Report 1890, Vol. IV, 1893, p. 253.

[37] R. C. Moore," Early Mississippian Formation of the Ozark Region," Mo. Bur. Geol. & Mines, Vol. 21, 2nd Series, 1928, pp. 143-145, 161-163.

terminology applied by Owen (1852) for exposures at Keokuk, Iowa.[38] In 1934, L. M. Cline[39] suggested that the term "Boone" be suppressed as a synonym of the term "Osage" and that the St. Joe, Reeds Spring, and "Keokuk" divisions of the Boone be elevated to formational rank. The United States Geological Survey continues to assign formational rank to the Boone and considers the subdivisions of member standing.

Distribution.--The Boone formation covers most of the eastern and southeastern portions of T. 22 N., R. 20 E., and the western one-half of T. 22 N., R. 21 E. A large area of Boone lies to the northwest side of the Seneca graben in the southeast corner of T. 22 N., R. 20 E. Other scattered localities are exposed as knobs or in creek cuts in all but the northwestern and extreme western parts of the area.

The basal member of the Boone, the St. Joe, is exposed at nine different localities along Spavinaw Creek. The three easternmost exposures have been mapped previously. The remaining six appear as linear outcrops on each side of the creek with the most westerly one extending to within one-half mile of Grand River.

The middle member, the Reeds Spring, is characteristically exposed in bluffs and escarpments along the east side of Grand River and on both sides of Spavinaw Creek (see Plate I, Figure 2). Tributaries

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

[39] L. M. Cline, "Osage Formations of Southern Ozark Region, Missouri, Arkansas, and Oklahoma," Amer. Assoc. Petrol. Geol. Bull., Vol. 18, No. 9, 1934, pp. 1132-1159.

entering these larger streams have cut through the overlying "Keokuk" in nearly all cases exposing the Reeds Spring in the creek bottoms and occasionally, where not covered by talus and debris, along the creek embankments. Detailed work on the west side of Grand River did not reveal a single exposure of Reeds Spring.

The "Keokuk" is the most widely distributed member of the Boone formation. East of Grand River it caps the high plateaus except in the north central sector where it is exposed as knobs and in the deeper creek cuts where it forms a hard surface over which the streams flow.

Character and Thickness.--The Boone formation has a total thickness of over 250 feet. Irregularity of the erosional surface at the top of the "Keokuk" east of Grand River and concealment of the Reeds Spring-"Keokuk" contact on the west side of the river makes accurate measurement impossible. The "Keokuk" increases in thickness on the west side of the river by the induction of crinoidal bioherm reefs.

The St. Joe varies from 18 to 25 feet in thickness along Spavinaw Creek, thinning toward the river. It is mainly a massive to thin, irregularly bedded buff limestone containing abundant small crinoidal stems except at the base where a variable green shale marks the contact. Above the basal shale and at the upper contact are two heavy beds of dense to finely crystalline limestone. These are separated by the softer central portion composed of shaly limestone (see Tables I and II).

The Reeds Spring comprises the thickest complete unit in the area, approximating 156 feet. From top to bottom it is characterized by an alternating sequence of interbedded limestone and chert. Near the

TABLE I

SECTION IN RAVINE TO SOUTH OF SPAVINAW CREEK BRIDGE

East side, section 16, T. 22 N., R. 21 E.

Formational Description	Thickness in Feet Of Unit	Thickness in Feet To Base of Formation
Boone formation:		
"Keokuk" member:		
Chert, white, yellowish to reddish-brown tripolitic at top, massive, jointed and fractured, fossils common as molds and casts......	64.0	64.0
Reeds Spring member:		
Limestone and chert, gray, blue to buff (darker near base), interbedded, medium, hard, limestone softer..................................	132.0	132.0
St. Joe member:		
Limestone, bluish-gray, dense to finely crystalline, massive, hard, crinoid stems small and abundant..	6.0	25.3
Limestone, light gray, dense, cherty and shaly, nodular and laminated on weathered surface....	4.0	19.3
Limestone, bluish to buff yellow, dense to finely crystalline, massive to thin bedded, shaly and soft, upper massive limestone parted by soft shaly limestone, crinoid stems...........	11.0	15.3
Limestone, gray, dense to finely crystalline, massive, hard, crinoid stems...................	3.0	4.3
Shale, green, laminated, calcareous, mainly covered...	1.3	1.3
Chattanooga formation:		
Shale, black, slightly iron stained, platy and fissile, pyritic, cone-in-cone black limestone near center, jointed and fractured......	65.3	65.3
Cotter formation:		
Dolomite, white to buff, finely crystalline, hard, massive, some beds appear cherty........	25.4	85.1
Dolomitic conglomerate; pebbles and cobbles, gray, dense to semi-crystalline, hard, cherty, and dolomitic, elongated parallel to bedding; matrix, white to light gray, slightly sandy, very oolitic, well-cemented, hard, massive....	3.4	59.7

Dolomite, white to light gray, lithographic to crystalline, limy, hard, massive, medium to thin bedded, nodular weathering surface.......	30.2	56.3
Dolomite, white to buff, finely crystalline, sandy, hard, massive........................	12.8	26.1
Dolomite, white, buff to vitreous gray, finely crystalline, sandy with some laminations of yellow chert near base, hard, massive to laminated, basal beds unexposed..................	13.3	13.3

TABLE II

SECTION ON BLUFF SOUTHEAST OF ROAD FORK

Northwest corner section 23, T. 22 N., R. 21 E.

Formational Description	Thickness in Feet: Of Unit	Thickness in Feet: To Base of Formation
Boone Formation:		
St. Joe member:		
Limestone, gray, dense to finely crystalline, hard, massive, crinoidal..........................	2.8	18.8
Limestone (mainly covered with slump), gray to bluish gray, dense, soft, irregular bedded and nodular appearing, shaly limestone, slightly cherty near top, crinoidal...........	11.2	16.0
Limestone, gray, dense to finely crystalline, hard, massive, crinoidal.....................	4.2	4.9
Shale, green to yellow, soft, platy, calcareous.	0.7	0.7

base the limestone is dense bluish-gray and dolomitic while the chert is dark gray, rather flinty, to opalescent. The layering occurs every 4 to 6 inches. Approximately 17 feet above the base, a 2- to 4-inch zone of gray, splintery, shaly limestone affords the only break in the formation. Above this, the alternating sequence becomes lighter in color. The chert content increases toward the top of the formations as the percentage of limestone decreases. The limestone changes upward to light gray and the chert eventually becomes white. Two measured sections are listed in Tables I and III.

The base of the first massive, white chert layer at the top of the escarpment along Spavinaw Creek marks the contact of the Reeds Spring with the "Keokuk" (Plate II, Figure 1). East of Grand River, the "Keokuk" is composed of approximately 70 feet of massive to thick bedded, white tripolitic, mottled chert. Some layers are as much as 4 feet in thickness. The weathered surface of the formation varies from yellow, red, to dark brown due to iron staining. From 60 to 80 feet of "Keokuk" is exposed on the west side of the river. Here reefs of crinoidal limestone are abundant in regions of maximum thickness. Laudon[40] reported similar deposits are in the St. Joe and noted that the "Keokuk" is also crinoidal. Within this area the crinoidal bioherms appear to be limited to the "Keokuk" west of Grand River. In the "Boone hills" area of this report no reefs are evident in the St. Joe although all exposures exhibit the crinoidal limestone phase.

The St. Joe and Reeds Spring contact was easy to map because

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[40] L. R. Laudon, op. cit., pp. 325-338.

PLATE II

Figure 1. "Keokuk" massive chert (K) and Reeds Spring (RS) contact at top of cliff, west side of section 18, T. 22 N., R. 21 E.

TABLE III

SECTION AT LARGE BLUFF ON NW SIDE SPAVINAW CREEK

West side section 18, T. 22 N., R. 21 E.

Formational Description	Thickness in Feet Of Unit	Thickness in Feet To Base of Formation
Boone formation:		
"Keokuk" member:		
Chert, white, sometimes mottled, iron stained, to reddish-brown on weathered surface, massive, fractured and jointed, upper contact unexposed by erosion, fossiliferous...........	69.0	69.0
Reeds Spring member:		
Interbedded limestone and chert; chert, white to light gray, layers over 1 foot thick at top to 6 inches at bottom, hard, weathers buff to yellow; limestone, light gray, dense, hard, medium to thin bedded at top, weathers dirty..	34.7	155.7
Interbedded limestone and chert; chert, light gray to gray, medium bedded, beds heavier near top, hard; limestone, bluish-gray, dense, medium bedded, beds thinner near top, hard; zone bluff forming......................	103.5	121.0
Shale, dark gray, calcareous, splintery, soft, weathers one to four feet back in bluff.......	0.2 to 0.4	17.5
Interbedded limestone and chert, chert, dark gray to opalescent, very fine grain, flinty, hard; limestone, dark bluish-gray, fine grain and dense, dolomitic, hard; alternate beds of apparent equal thickness, 4 to 6 inches......................................	17.2	17.2

of lithologic differences between the two members as shown by Cline[41] and Laudon[42]. The Reeds Spring and "Keokuk" contact is mapped for the first time in this region. In the Spavinaw Creek area the interbedded limestone and chert of the Reeds Spring grade into massive chert layers of "Keokuk" at the top of all bluffs (Plate II, Figure 1). The Reeds Spring forms the more precipitious lower portions of the escarpments while the "Keokuk" occupies the lesser slopes above which pass at the top into a plateau-like divide. In many of the smaller valleys the contact is not too definite, being covered by talus and debris. Where concealed or indefinite, the contact is shown by dashed line.

Stratigraphic Relations.--The St. Joe formation rests unconformably on the Chattanooga shale as illustrated by the variable thicknesses of the green shale at the base of the St. Joe (see Plate I, Figure 1).

A questionable disconformity exists between the St. Joe and Reeds Spring. Laudon[43] states that it is his personal belief one exists but that he cannot prove it. A picture of this contact along a bluff on the west side of Spavinaw Creek shows several feet of Reeds Spring converging against the upper massive bed of the St. Joe (Plate III, Figures 1 and 2). While this is not indicative of a regional unconformity, it could possibly represent a local stratigraphic break.

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[41] L. M. Cline, op. cit., pp. 1141, 1154.

[42] L. R. Laudon, op. cit., p. 325.

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

PLATE III

Figure 1. Reeds Spring (RS) limestone and chert beds converging against the upper bed of St. Joe (SJ) massive limestone; N. side of Spavinaw Creek, center of section 18, T. 22 N., R. 21 E.

Figure 2. Highly weathered contact between Reeds Spring (RS) and St. Joe (SJ) limestone, N. side of Spavinaw Creek, center of section 18, T. 22 N., R. 21 E.

The "Keokuk" lies unconformably on the Reeds Spring with the hiatus representing Burlington time.[44] Laudon[45] states that the unconformity is greater in Missouri and decreases in magnitude on the southwest flank of the Ozark Uplift. The break is also substantiated by a distinct faunal change in other regions, but in this area it is not too apparent, the contact appearing almost gradational.

The "Mayes group" rests unconformably on the "Keokuk". Authorities agree that the unconformity is due to irregular deposition of Mayes units on the uneven erosional surface of the Boone chert. Many of the "Keokuk" knobs within the area of this report are typically dome-like structures with a core of crinoidal reef limestone. The general alignment of these from northeast to southwest parallel to the Seneca fault zone suggests a genetic relationship between the regional structure and silicification of the upper "Keokuk" beds which pass above the reef-like knobs. Differential compaction of younger "Keokuk" beds over these crinoidal reefs followed by extensive silicification formed resistant knobs which now appear as inliers projecting through younger Mississippian units.

Paleontology.--No fossils other than crinoid stems were recovered from the St. Joe. The Reeds Spring is non-fossiliferous in this region. The "Keokuk" yielded an assemblage of fossils characteristic of late Osagean beds. (See Table IV.)

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[44] L. R. Laudon, *op. cit.*, p. 329.

[45] L. R. Laudon, *ibid.*

TABLE IV

FAUNULES FROM THE "KEOKUK" MEMBER OF THE BOONE FORMATION

	1	2	3	4	5
Neozaphrentis sp.	-	-	-	-	-
Fenestralia sancta ludovici Prout	x	-	-	-	-
Fenestrella serratula	x	-	-	-	-
Polypora varsoviensis	x	x	-	-	-
Crinoid stems	-	-	x	-	-
Acambona prima (White)	x	-	-	-	-
Avonia concentrica (Hall)	x	-	-	-	-
Chonetes multicosta Winchell	x	-	-	-	-
Cravaena globosa Weller	x	-	-	-	-
Cyrtina sp. cf. C. neogenes Hall and Clarke	x	-	-	-	-
Dictyoclostus crawfordvillensis (Weller)	x	-	-	-	-
Dielasma sp.	x	-	-	-	-
Echinoconchus altenatus (Norwood and Pratten)	x	-	-	-	-
Linoproductus altonensis (Norwood and Pratten)	x	-	-	-	-
Linoproductus ovatus (Hall)	x	-	-	-	-
Linoproductus sp.	x	-	-	-	-
Marginicinctus wortheni (Hall)	x	-	-	x	-
Orthotetes keokuk Hall	x	x	-	-	-
Orthotetes sp.	x	-	-	-	-
Productus sp. cf. P. scitulus Meek and Worthen	x	-	-	-	-
Pseudosyrinx keokuk Weller	x	-	-	x	-
Rhynchopora sp.	-	-	-	-	x
Schellwienella inaequalis (Hall)	x	-	-	-	-
Schizophoria sp.	-	-	-	x	-
Spirifer floydensis Weller	-	x	-	-	-
Spirifer keokuk Hall	x	-	-	-	-
Spirifer mortonanus Miller	-	x	-	-	-
Spiriferina solidirostris White	x	-	-	-	-
Spiriferina sp. cf. S. subtexta White	x	-	-	-	-
Myalina keokuk Worthen	x	-	-	-	-
Phillipsia sp.	x	-	-	-	-

1. Along aqueduct, SW Corner Sec. 33, T. 22 N., R. 20 E.
2. Wolf Creek, East line of Sec. 25, T. 22 N., R. 19 E.
3. Left fork of Creek, center, Sec. 23, T. 22 N., R. 20 E.
4. Up creek 350 yards from south line, Sec. 2, T. 22 N., R. 20 E.
5. North boundary, west side of Grand River, NE corner of Sec. 4, T. 22 N., R. 20 E.

Age and Correlation.--The Boone formation represents the Osagean series of the Mississippian system. The St. Joe can be correlated with the Fern Glen of Missouri. Branson[46] says, "there is no doubt that the two formations are in part contemporaneous." The Reeds Spring is considered equivalent to the upper Chouteau in Missouri by Branson[47] but has been correlated with the Fern Glen and possibly the lower Burlington by others. According to Laudon[48], it has no correlatives outside the type area in southwestern Missouri, northwestern Arkansas, and northeastern Oklahoma. The "Keokuk" correlates with the Montrose cherts of the type section at Keokuk, Iowa.

"Mayes Group"

The term Mayes was proposed by L. C. Snider[49] in 1915 for rocks between the Boone chert and the Fayetteville formation in northeastern Oklahoma. The type locality is in southern Mayes County. In an unpublished master's thesis in 1941, R. A. Brant subdivided the Mayes into four lithic units of formational rank which he termed the "Moorefield," "Hindsville," "Batesville," and "Grand River." The validity of his correlations with the Arkansas section has not been established. Usage of Brant's terminology is therefore qualified in this report by insertion in quotation marks.

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[46] E. B. Branson, op. cit., p. 208.

[47] E. B. Branson, ibid., p. 179.

[48] L. R. Laudon, op. cit., p. 328.

[49] L. C. Snider, op. cit., p. 27.

"Moorefield" Formation

History of Nomenclature.--The Moorefield was named by Adams and Ulrich[50] in 1904. It included the shaly beds lying between the Boone limestone and Batesville sandstone at Moorefield, Arkansas. In 1941, Brant applied the term "Moorefield" to the beds immediately overlying the Boone in Mayes County, Oklahoma. In 1944, Gordon[51] divided the formation of the Batesville district into two parts. He restricted the term Moorefield to the lower limestone sequence and applied the name Ruddell formation to the upper shale beds.

Distribution.--The "Moorefield" is very limited in extent and is exposed mainly along the west side of Grand River in sections 3, 4, 10, and 11; T. 22 N., R. 20 E. At Beng Creek in section 10, it is exposed westward for three-quarters of a mile from the river. Two other minor exposures occur in the creek cut in the northeast corner of section 16, T. 22 N., R. 20 E. and in the road culvert in the central part of section 33 of the same township.

Character and Thickness.--The formation is very inconsistant where exposed, varying from 0 to 36 feet in thickness. For the most part it is divisible into a lower cherty limestone phase and an upper series of massive to thinly-laminated limestone beds. The lower part is mainly

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[50] G. I. Adams, A. H. Purdue, and E. O. Ulrich, "Zinc and Lead Deposits of Northern Arkansas," U. S. Geol. Survey, Prof. Paper 24, 1905, p. 26.

[51] Mackenzie Gordon, Jr. "Moorefield Formation and Ruddell Shale, Batesville District, Arkansas," Amer. Assoc. Petrol. Geol. Bull., Vol. 28, No. 11, 1944, p. 1631.

a dense gray to lithographic limestone, sometimes lenticular in nature, with alternating irregular layers of light gray chert. Cherty nodules similar to baseballs are infrequent within the limestone. The upper zone tends to be massive if unweathered, but on a weathered surface it alters to platy, laminated layers. Often it appears medium bedded along Grand River. The zone is mainly a dense to finely crystalline limestone of bluish-gray color. Table VI shows the most complete measured section in the area.

Stratigraphic Relations.--The "Moorefield" lies unconformably on the "Keokuk" (Plate IV, Figure 1). Its irregular distribution through this area may be attributed to the shallow seas which failed to deposit the formation over part of the irregular Keokuk surface. The "Moorefield" is overlain conformably by the "Hindsville". Small stringers of "Hindsville" limestone extend downward into the dense beds of the "Moorefield."

Paleontology.--The "Moorefield" contains few fossils within this area. *Griffithides pustulosus* is sporadically abundant near the base of the cherty-limestone phase. Just above the "Keokuk" contact in the northeast corner of section 4, T. 22 N., R. 20 E., a zone of *Dictyoclostus crawfordvillensis* yielded the greatest amount of fossils. *Leiorhynchus carboniferum* occurs sparingly.

Age and Correlation.--Brant[52] correlated the "Moorefield" of

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[52] R. A. Brant, "Mississippian Rocks of Eastern Oklahoma," Tulsa Geol. Soc. Field Trip, May 11, 1946, p. 14.

PLATE IV

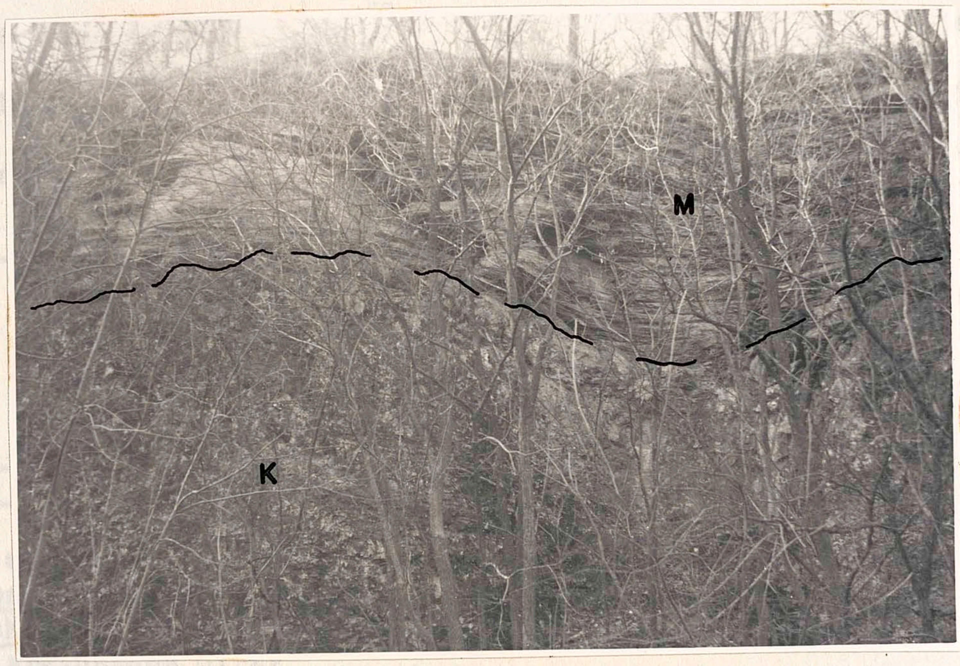

Figure 1. "Keokuk" (K) and "Moorefield" (M) unconformity, bluff on west side of Grand River, west side of section 11, T. 22 N., R. 20 E.

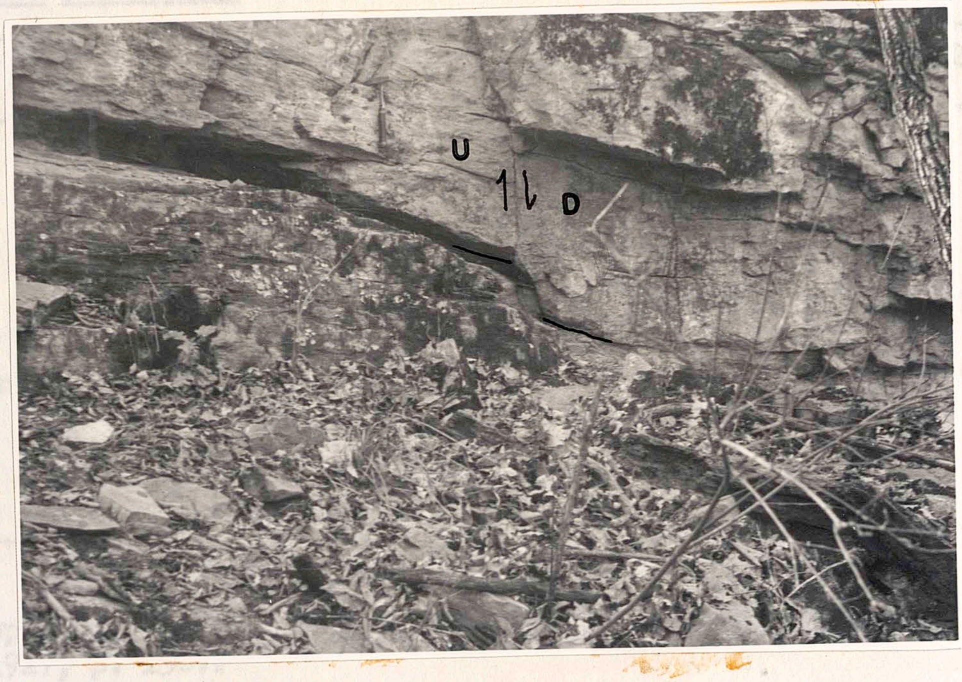

Figure 2. Small fault on SE limb of Seneca fault zone in "Keokuk" limestone, SE quarter of section 11, T. 22 N., R. 20 E.

this area with the Moorefield of Arkansas and the Warsaw of Lower Meramecian age. In 1927, Buchanan[53] classified the Moorefield as the equivalent of the St. Louis formation of Middle Meramecian age, and this has been the accepted correlation by many geologists.

TABLE V

FAUNULES OF THE "MOOREFIELD"

	1
Buxtonia sp.	x
Dictyoclostus crawfordvillensis (Weller)	x
Leiorhynchus carboniferum Girty	x
Spirifer arkansanus Girty	x
Spirifer sp. cf. s. bifurcatus Hall	x
Syringothyris textus (Hall)	x
Aviculopecten sp. cf. A. batesvillensis (Girty)	x
Griffithides pustulosus Snider	x

1. NE corner Sec. 4, West side of Grand River, T. 22 N., R. 20 E.

"Hindsville Formation"

History of Nomenclature.--Brant[54] applied the term "Hindsville" to beds in this area which he considered equivalent to the Hindsville limestone of Arkansas. The latter was named and assigned to the base of

[53] G. S. Buchanan, "The Distribution and Correlation of the Mississippian of Oklahoma," Amer. Assoc. Petrol. Geol. Bull., Vol. 11, No. 12, 1927, p. 1307.

[54] R. A. Brant, op. cit., 1941, pp. 1, 23-25.

TABLE VI

SECTION ON SOUTH EMBANKMENT, BENG CREEK

West side section 10, T. 22 N., R. 20 E.

Formational Description	Thickness in Feet: Of Unit	Thickness in Feet: To Base of Formation
"Batesville":		
Shale, buff yellow, thin bedded, soft, mainly covered..	1.2	12.5
Limestone, gray to yellowish-brown where weathered, finely crystalline, silty, platy where weathered, otherwise slabby to massive, medium hard, mainly covered by debris................	11.3	11.3
"Hindsville":		
Limestone, covered..............................	5.5	9.0
Limestone, mainly covered, gray, coarsely to finely crystalline, angular varicolored chert fragments at base, massive to platy, hard to medium hard......................................	3.5	3.5
"Moorefield":		
Limestone, light bluish gray, dense to finely crystalline, massive, slabby to platy on weathered surface, medium hard, strong petroliferous odor, few fossils......................	16.1	36.0
Limestone, bluish-gray, dense to semi-crystalline, irregular bedded with slightly discolored lenticles of chert, contains knobs of chert similar to baseballs, hard, zone of *Griffithides pustulosa* and *Leiorhynchus carboniferum* near base..........................	19.9	19.9
Boone formation:		
"Keokuk":		
Chert, white to reddish-brown at contact, massive, hard, fractured and jointed, unexposed below creek bottom............................	8.5	8.5

PLATE V

Figure 1. Arched up "Keokuk" (K) weathered chert overlain unconformably by "Moorefield" (M) limestone. Dr. H. D. Miser removing fossils from Dictyoclostus crawfordvillensis zone. West side of Grand River, NE corner of section 4, T. 22 N., R. 20 E.

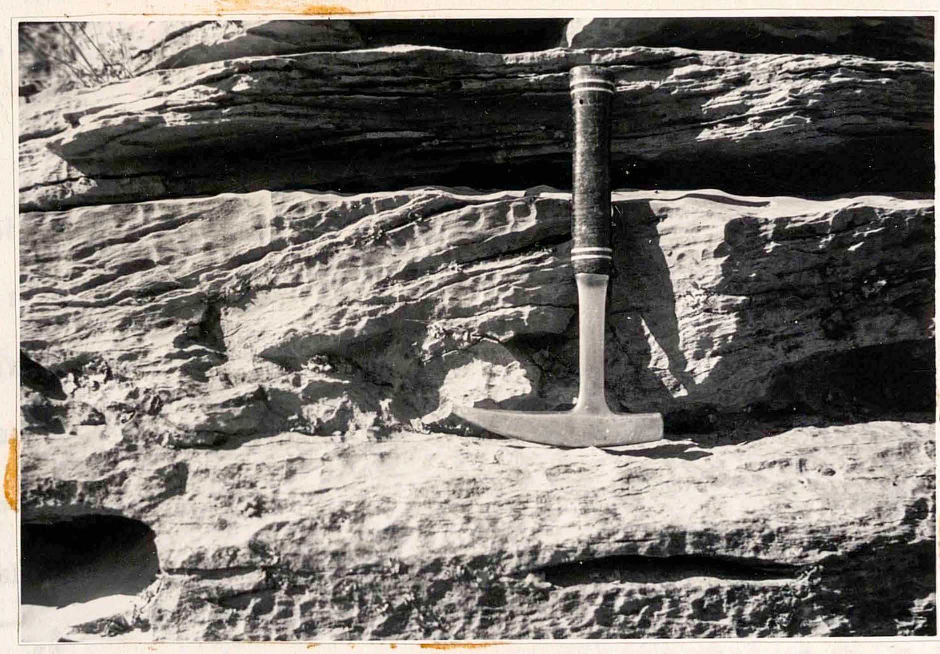

Figure 2. Cross-bedded "Moorefield" limestone, West side of Grand River, NE corner of section 4, T. 22 N., R. 20 E.

the Batesville sandstone of Arkansas by Purdue and Miser[55] in 1916.

Distribution.--Being stratigraphically above the "Moorefield" the "Hindsville" achieved wider distribution in the area. It floors the low fertile portions of section 33, T. 22 N., R. 20 E.; overlaps the "Moorefield" in the center of the section; and comes to rest against "Keokuk" chert by lapping onto the chert knobs. In the north-central part of the area the "Hindsville" is widely exposed along the west side of the Grand River escarpment and locally in creek cuts. In section 9, T. 22 N., R. 20 E., and at the eastern boundary of section 13, T. 22 N., R. 20 E., units of "Hindsville" lithology lap onto small "Keokuk" knobs. In the north-central part of section 11, T. 22 N., R. 20 E., a topographic high contains a complete section of "Hindsville" which lies between partial sections of the "Batesville," and "Moorefield." A small exposure which resembles the "Hindsville" crosses the northern boundary in the northwest corner of section 5, T. 22 N., R. 22 E.

Character and Thickness.--The "Hindsville" varies from 0 to 9 feet in thickness due to the irregular nature of the Boone surface. A complete section shows three gray, coarsely crystalline beds containing angular fragments of varicolored chert. One chert fragment-bearing bed is located at the base, another one two feet above the base, and the third is located at the top of the section. The lower two beds are separated by whitish-gray, finely to very finely crystalline limestone layers. The

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[55] A. H. Purdue and H. D. Miser, "Description of the Eureka Springs and Harrison Quadrangles," U. S. Geol. Survey Atlas, 1916, Eureka Springs and Harrison Folio, No. 202, p. 12.

middle and the upper cherty beds are separated by several feet of gray silty limestone which resembles "Batesville" lithology. The upper conglomeratic bed is distinguished by its oolitic, highly fossiliferous, and slightly yellow-stained nature. Tables VII and VIII include a detailed description of the "Hindsville" formation.

Stratigraphic Relations.--The "Hindsville" overlies the "Moorefield" conformably and is in turn overlain conformably by the "Batesville" formation. Where the "Hindsville" onlaps "Keokuk" knobs it has an unconformable relationship with the underlying chert. The "Hindsville" seas did not completely cover the higher knobs resulting in local absence through non-deposition.

Paleontology.--The "Hindsville" is fossiliferous only in the three coarsely crystalline beds containing the angular chert fragments. The best preserved fossils are found in the top conglomeratic layer. Most of the recovered specimens are internal molds and casts of fragmentary nature. Similarity of fossil forms suggest close relationship with the underlying "Moorefield." The fauna collected and identified from the "Hindsville" is listed in Table IX.

Age and Correlation.--Brant[56] correlated the "Hindsville" of Mayes County with the Hindsville of Arkansas which he considered Meramecian in age. The "Hindsville" is lithologically and faunally related to the "Moorefield" and probably represents an upper crystalline facies of the Moorefield of Arkansas, classed as upper Meramecian, St. Louis in age. The true Hindsville of Arkansas carries a lower Chester fauna.

[56] R. A. Brant, op. cit., 1941, p. 25.

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[56] R. A. Brant, op. cit., 1941, p. 25.

TABLE VII

SECTION ON WEST SIDE STRANG RIVER BRIDGE
North side section 10, T. 22 N., R. 20 E.

Formational Description	Thickness in Feet Of Unit	Thickness in Feet To Base of Formation
"Grand River":		
Limestone (only basal bed exposed), gray, coarsely crystalline, massive, hard, very fossiliferous, strong petroliferous odor, zone of Diaphragmus elegans..........................	1.2	1.2
"Batesville":		
Siltstone, brown, very fine grain, massive, soft due to leaching, light weight "Cotton rock"...	0.5	9.2
Limestone, gray to yellowish brown where weathered, fine to medium crystalline, silty, highly cross-bedded in places................	8.7	8.7
"Hindsville":		
Limestone, gray, corasely crystalline, angular varicolored chert fragments, oolitic and fossiliferous, massive, hard....................	0.7	7.9
Limestone, light gray, semi-crystalline, silty, platy, medium hard............................	4.5	7.2
Limestone, gray, coarsely crystalline, contains a few angular fragments of dark chert, massive, hard..................................	0.6	2.7
Limestone, gray, fine to medium crystalline, massive to thin irregular beds, medium hard......	1.5	2.1
Limestone, gray, coarsely crystalline, few angular chert fragments, massive, hard...........	0.5	0.5
"Moorefield":		
Limestone, bluish-gray, dense to finely crystalline, irregular beds of whitish-discolored chert, massive, hard.........................	14.0	14.0
Boone formation:		
"Keokuk":		
Limestone, gray, coarsely crystalline; crinoidal, medium irregular bedded......................	1.0	7.0
Chert, white (if unweathered), massive, hard, fractured and jointed, yellowish, reddish to brownish on weathered surface, base unexposed at water level..............................	6.0	6.0

TABLE VIII

SECTION AT NORTHEAST SIDE OF BENG CREEK BRIDGE

West side section 10, T. 22 N., R. 20 E.

Formational Description	Thickness in Feet: Of Unit	Thickness in Feet: To Base of Formation
"Hindsville":		
Limestone, gray, corasely crystalline, contains angular fragments of varicolored chert, massive, hard, slightly yellow stained, oolitic, highly fossiliferous	0.7	8.9
Limestone, light gray, semi-crystalline, massive (platy where weathered), silty, medium hard, specks of iron staining where slightly weathered	4.8	8.2
Limestone, gray, coarsely crystalline, contains angular fragments of chert, massive, hard, specks of iron staining	0.6	3.6
Limestone, gray, finely crystalline, massive to thin irregular bedded, slightly iron-stained	1.3	3.0
Limestone, whitish-gray, very finely crystalline to dense, irregular bedded, soft, contains light whitish-yellow iron stains near weathered surface	1.2	1.7
Limestone, gray, coarsely crystalline, contains angular fragments of varicolored chert, massive, hard, fossiliferous and crinoidal	0.5	0.5

Base of exposure at water level

TABLE IX

FAUNULES OF THE "HINDSVILLE"

	1	2	3	4
Fenestella serratula	x	-	-	-
Buxtonia multiliratus (Girty)	-	x	-	-
Camarotoechia purduei var. inflata Girty	x	-	-	-
Dictyoclostus crawfordvillensis (Weller)	-	-	x	-
Dielasma arkansanum Weller	x	-	-	-
Echinoconchus sp.	-	x	-	-
Eumetria verneuiliana (Hall)	x	x	-	-
Orthotetes kaskaskiensis McChesney	-	x	-	-
Orthotetes sp.	x	-	-	-
Orthotetes sp. cf. subglobosus Girty	x	-	-	-
Rhynchopora sp.	x	-	-	-
Spirifer arkansanus Girty	-	-	x	-
Spirifer bifurcatus Hall	x	x	-	-
Syringothyris textus (Hall)	x	-	-	-
Tetracamera sp. cf. T. cuneata (Hall)	-	-	-	x
Aviculopecten sp. cf. A. batesvillensis (Girty)	x	-	-	-
Caneyella sp.	-	x	-	-
Griffithides sp. cf. G. pustulosus Snider	x	-	x	-

1. South creek bank, west side sec. 10, T. 22 N., R. 20 E.
2. North road, sec. 5, T. 22 N., R. 21 E.
3. At culvert, SW corner sec. 33, T. 22 N., R. 20 E.
4. West side of Strang river bridge, NW corner sec. 10, T. 22 N., R. 20 E.

TABLE X

SECTION AT NORTH BOUNDARY, WEST SIDE GRAND RIVER

Northeast corner of section 4, T. 22 N., R. 20 E.

Formational Description	Thickness in Feet Of Unit	Thickness in Feet To Base of Formation
"Batesville":		
Siltstone, brownish-yellow, very fine grain, silt and iron oxide, massive, soft, light weight "cotton rock" or punkstone.............	0.9	6.7
Limestone, gray, dense to medium crystalline, silty, platy; slabby to massive, cross-bedded.	5.8	5.8
"Hindsville":		
Limestone, gray, coarsely crystalline, contains brown angular chert fragments, sandy, massive, hard, cross-bedded, some fossils..............	1.1	11.8
Limestone, light gray, fine grain, silty, thinly plated to massive, cross-bedded...............	7.1	10.7
Limestone, gray, coarse grain, contains brown angular chert fragments, massive, hard, fossiliferous..................................	0.9	3.6
Limestone, gray, dense to finely crystalline, coarsely crystalline 6 inches from top with tiny brown chert fragments, massive, hard.....	1.8	2.7
Limestone, gray, coarsely crystalline, slightly iron stained, massive, hard, fossiliferous....	0.9	0.9
"Moorefield":		
Limestone, gray, medium crystalline, slightly silty, massive, hard, cross-bedded............	2.5	11.0
Limestone, gray, dense to medium crystalline, silty, massive, hard, characterized by dark streaks, few crinoid stems, scattered dark fragments, and cross-bedded in places.........	2.4	8.5
Limestone, light gray, fine, medium to coarsely crystalline, abundant reddish-brown angular chert fragments, massive, hard, slightly crinoidal and fossiliferous..................	0.9	6.1
Limestone, light bluish-gray, dense to finely crystalline, massive, hard, scattered reddish-brown angular chert fragments and Dictyoclostus crawfordvillensis......................	1.2	5.2

Limestone, light gray, dense, medium, lenticular bedded, pinches out on knob zone of <u>Dictyoclostus crawfordvillensis</u> at base on flank of arch..	.0 to 4.0	4.0
Boone formation:		
"Keokuk" member:		
Chert, white, massive, highly fractured and jointed, dark brown on weathered surface......	3.0	7.0
Interbedded chert and limestone; chert, white massive, irregular bedded; limestone, bluish-gray, dense, irregular bedded, unexposed below water......................................	4.0	4.0

"Batesville" Formation

History of Nomenclature.--Brant[57] correlated the sequence of silty limestones of Mayes County, which he termed the "Batesville" formation, with the Batesville sandstone of Arkansas. The term Batesville was first applied by Branner and Simonds[58] for exposures in Washington County, Arkansas. These beds are now known to be the Wedington sandstone member of the Fayetteville formation. Penrose[59] applied the term Batesville to sandstones between the Moorefield and Fayetteville formations near Batesville, Arkansas. The latter usage is currently accepted.

Distribution.--The "Batesville" formation is more extensive than the "Hindsville" chiefly because it is higher in the section and has a greater areal expanse between the Boone knobs. In the north-central part of the area good exposures are found in the ravines and near the top of the escarpment on the west side of Grand River. A hill capped with "Batesville" in section 11, T. 22 N., R. 20 E. and a creek cut in section 3 of the same township form the only exposures east of the river. Southeast of the Seneca fault zone several square miles of the formation occupy the flat lands between the Boone knobs. Most of the creeks to the north of the fault near the river are floored with "Batesville". Two domal

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[57] R. A. Brant, op. cit., 1941, pp. 1, 26-30.

[58] F. W. Simonds, op. cit., p. 13.

[59] R. A. F. Penrose, Jr., op. cit., p. 113.

structures in section 10, T. 22 N., R. 20 E. show siltstone arching up through "Grand River" limestone. In most cases the "Batesville" is absent over the knobs due to non-deposition.

Character and Thickness.--The maximum thickness of the "Batesville" is about 14 feet. It thins to zero around the edges of the Boone chert knobs. Characteristically, it is a gray silty limestone that weathers brown to form a light-weight "punkstone" which makes it easily recognizable in the field. The depth of weathering varies from a few inches to over a foot and is more intense in creek bottoms or wherever exposed to solution activity. The formation exhibits a peculiar type of parallel jointing over flatly exposed surfaces. Near the base it breaks into slabby layers which renders it good as a building or siding stone for houses. Cross-bedding occurs almost throughout the formation. Toward the top it becomes shaly before grading into a buff-yellow shale immediately below the "Grand River" contact.

Stratigraphic Relations.--The "Batesville" silty beds overlie the "Hindsville" formation conformably. An unconformable relationship exists at the base only when the siltstones lap onto Boone knobs. In a few cases the "Batesville" seas deposited the formation over the smaller chert domes. An unconformity separates the "Batesville" from the overlying "Grand River" limestone.

Paleontology.--The "Batesville" contains few fossils in this area. Buxtonia multiliratus proves the most abundant form and is preserved largely as internal molds and casts.

TABLE XI

FAUNULES OF THE "BATESVILLE" FORMATION

	1	2
Buxtonia multiliratus (Girty)	x	-
Camarotoechia purduei var. agrestis Girty	-	x
Sphenotus sp. cf. S. vulgaris Girty	-	x

1. In Wolf Creek, north central part, sec. 31, T. 22 N., R. 20 E.
2. NE corner sec. 4, west side Grand River, T. 22 N., R. 20 E.

Age and Correlation.--Brant[60] correlated the "Batesville" formation with the Batesville of Arkansas and the St. Louis limestone of middle Meramecian age. Recent work in these areas to the south tends to place the "Batesville" as the equivalent of the Ruddell of Arkansas which Gordon[61] has tentatively classed as St. Genevieve in age.

"Grand River" Formation

History of Nomenclature.--The term was applied by Brant in 1941[62] for the limestone beds lying below the Fayetteville formation and above the "Batesville" calcareous siltstone in Mayes County. Inasmuch as the term Grand River is also applied to beds of Pennsylvanian age in Michigan it is herein placed in quotation marks.

[60] R. A. Brant, op. cit., 1946, p. 12.

[61] M. Gordon, Jr., op. cit., p. 1626.

[62] R. A. Brant, op. cit., 1941, pp. 1, 31-36.

Distribution.--The "Grand River" formation crops out in a southwest-northeast direction extending across the area from the southwest corner to the west side of Grand River in the north-central part of the area. The belt varies in width from one-half to over two miles. The formation is present in the Seneca graben southwest of the river but is covered by the mantle rock near the southern boundary. Two small areas extend southeast of the fault. One outcrop is a little over a quarter of a mile south of Greenbriar school and the other at the southern boundary just below the fault. In several localities the formation may be seen dipping away from Keokuk knobs.

Character and Thickness.--The "Grand River" is a gray, coarsely crystalline limestone which grades upward into yellow weathering calcareous shale. The top of the formation is marked by a massive bed of gray, sublithographic limestone which resembles limestones in the Fayetteville, but it differs inasmuch as tiny crystals of calcite are disseminated through it to give a birds-eye appearance. The basal part of the formation is crinoidal and fossiliferous and is characterized by an *Agassizocrinus* zone which serves as a useful field marker. The formation contains scattered oolitic beds, a conglomeratic layer near the center, and is cross-bedded in sandy portions. The units are typically thick-bedded but may be platy on weathered surface. On fresh break the limestone has a highly petroliferous odor like that in the Moorefield. The total thickness in this area at the only locality where a complete section could be measured is 13.7 feet. A detailed section is included in Table XII.

TABLE XII

SECTION IN NORTH ROAD CUT ON SLOPE EXTENDING EAST TO WEST

Southwest corner section 16, T. 22 N., R. 20 E.

Formational Description	Thickness in Feet: Of Unit	Thickness in Feet: To Base of Formation
"Grand River":		
Limestone, gray, sub-lithographic with tiny calcite crystals, massive, hard, weathers whitish-yellow, highly variable in thickness throughout area..................................	0.5	13.7
Shale, buff yellow, calcareous, soft, thin-bedded (mainly covered by wash in road cut)...	4.0	13.2
Limestone, gray, dense coarsely to finely crystalline, massive, hard, fossiliferous.........	1.2	9.0
Limestone, gray, finely to semicrystalline, massive, well-cemented conglomerate with dense gray pebbles..................................	1.5	7.8
Limestone, dense, finely to coarsely crystalline in center, sandy, massive, hard, highly cross-bedded, contains streaks of asphalt...........	2.6	6.3
Limestone, gray, coarsely crystalline, massive, hard, zone of <u>Agassizocrinus</u> <u>conicus</u>, small brachiopods and crinoid stems abundant........	1.9	3.7
Shale, buff yellow, thin bedded, calcareous, soft..................................	1.3	1.8
Limestone, gray, coarsely crystalline, massive, hard, fossiliferous, crinoid stems............	0.5	0.5

Stratigraphic Relations.--The "Grand River" overlies the "Batesville" with apparent unconformity. This is also true of the formation as it onlaps the Keokuk knobs. It underlies the Fayetteville formation conformably.

Paleontology.--The basal beds in the "Grand River" are the most fossiliferous, but few collecting localities are available in the area. The most common forms are Diaphragmus elegans and Agassizocrinus conicus, both located near the base of the formation. These fossils offered particularly good markers for field mapping. The faunules as collected from the "Grand River" are listed in Table XIII.

TABLE XIII

FAUNULES OF THE "GRAND RIVER"

	1	2
Triplophyllum spinulosum (Edwards and Haime)	-	x
Composita subquadrate (Hall)	x	-
Diaphragmus elegans (Norwood and Pratten)	x	x
Dictyoclostus inflatus McChesney	x	-
Dielasma arkansanum Weller	x	x
Eumetria verneuiliana (Hall)	x	-
Linoproductus ovatus (Hall)	x	-
Spirifer increbescens Hall	-	x
Spirifer leidyi Norwood and Pratten	-	x
Agassizocrinus conicus Owen and Shumard	x	x

1. At hill on west side Strang River bridge, NW corner of sec. 10, T. 22 N., R. 20 E.
2. South creek bank, west side sec. 10, T. 22 N., R. 20 E.

Age and Correlation.--Brant[63] classified the "Grand River" as

[63] R. A. Brant, op. cit., 1946, p. 14.

St. Louis and St. Genevieve in age on the basis of micro-fauna. However, such genera as Agassizocrinus and Diaphragmus indicate that it is of Chester age and a correlative of the Hindsville of Arkansas.

Fayetteville Formation

History of Nomenclature.--Simonds[64] named the Fayetteville shale in 1891 for exposures in Fayetteville Valley, Arkansas.

Distribution.--The Fayetteville formation occupies a prominent belt across the northwest part of the area. The outcrop has a maximum width of approximately three miles just below the north boundary. The belt of outcrop narrows toward the southwest to approximately three-fourths of a mile. An anticline brings blocky limestone to the surface at the north boundary, section 2, T. 22 N., R. 19 E. Good exposures of the Fayetteville were mapped on each end of the broadened part of the Seneca graben and black shale is exposed on the northwest side of the northernmost fault. A few pieces of the typical Fayetteville limestone were found in the fault zone, immediately north of the southern boundary line below the Hale formation.

Character and Thickness.--The Fayetteville formation varies from about 16 to 44 feet in thickness, attaining its maximum near the north boundary and its minimum near the southwest corner. The basal few feet near the south boundary contain a greenish-brown shale. Massive, white limestone beds separated by a dark, greenish-brown shaly parting

[64] F. W. Simonds, op. cit., pp. 42-48.

constitute the upper and major portion of the section. The limestone weathers into sub-cuboidal blocks, and on a fresh break the color changes inward from light grayish-green to a dull black. These limestones are typically sublithographic in texture to the south, and thin and disappear to the north. Near the northern boundary fissile grayish-green shale and beds of dark gray, finely crystalline fossiliferous limestone are present within the formation. The upper dull black, fissile shale has been removed by pre-Hale erosion except in two localities. On the west side in the Seneca graben 18 feet of black shale is exposed. A measured section is included in Table XIV. Evidence of black shale is seen in the pond excavation near the north line of section 1, T. 22 N., R. 19 E., just below the upper contact.

Stratigraphic Relations.--The Fayetteville overlies the "Grand River" conformably, apparently grading into it without too much change in lithology. It is overlain unconformably by the Hale sandstone in the Seneca Fault region and by the younger Pennsylvanian beds in the western part of the area. At a collapse-structure in section 8, T. 22 N., R. 20 E., Hale limestone rests on Fayetteville.

Paleontology.--The upper shaly portion of the Fayetteville yielded no fossils. To the south the limestone beds and shale partings were highly fossiliferous while to the north the only fossils were collected from the limestones. Dictyoclostus inflatus proved most abundant. Table XVI lists the faunules collected in this area.

Age and Correlation.--The Fayetteville is Mississippian,

TABLE XIV

SECTION EXTENDING UP NORTH ROAD CUT TO TOP OF BUTTE

SW corner section 5 and SE corner section 6, T. 22 N., R. 20 E.

Formational Description	Thickness in Feet Of Unit	Thickness in Feet To Base of Formation
Atoka:		
Siltstone, gray, very fine grain, siliceous cherty, massive, hard, spicular, weathers red and blocky	0.4	0.4
Fayetteville:		
Limestone, dark gray, dense to finely crystalline, very hard, layer acts as cap rock in places, many Archimedes sp. and very fossiliferous......	0.5	44.0
Shale, light greenish-gray, calcareous, fissile, soft, some stringers of finely crystalline gray limestone......................................	5.3	43.5
Limestone, dark gray, mainly fine but also dense to coarsely crystalline, medium bedded, hard, very fossiliferous, weathers yellowish..........	0.4	38.2
Shale, light greenish-gray, calcareous, fissile, soft, thin limestone layer at top...............	2.2	37.8
Limestone, dark gray, sublithographic to finely crystalline, thin bed, hard, weathers light yellowish-green..................................	0.1	35.6
Shale, light greenish-gray, calcareous, fissile, soft, weathers light gray......................	2.1	35.5
Limestone, dark gray, dense to coarsely crystalline, massive, hard, very fossiliferous, weathers buff-yellow, zone of Dictyoclostus inflatus...	0.7	33.4
Shale, light greenish gray, calcareous, fissile, soft..	3.0	32.7
Limestone, dark gray, dense, medium bed, hard, weathers buff yellow, very fossiliferous; zone of Dictyoclostus inflatus.................	0.4	29.7
Shale, light greenish-gray, calcareous, fissile, soft..	6.0	29.3
Limestone, dark gray, sublithographic, medium bedded, hard, weathers yellowish................	0.3	23.3
Shale, light greenish-gray, calcareous, fissile, soft, weathers yellowish.......................	12.0	23.0
Limestone, dark gray, dense to finely crystalline, medium bed, hard, fossils mainly small..........	0.4	11.0
Shale, greenish-gray, calcareous, fissile, soft, basal three quarters of zone covered but believed to be same as shown 1 mile to north......	10.6	10.6

TABLE XV

SECTION EXTENDING UP SLOPE IN NORTH ROAD CUT

South side section 27, T. 22 N., R. 19 E.

Formational Description	Thickness in Feet: Of Unit	Thickness in Feet: To Base of Formation
Fayetteville:		
Limestone, dark gray, sublithographic, massive, hard, weathers into subcuboidal blocks and white on surface, on fresh break fractures almost conchoidal, layers separated by 2 or 3 inch dark yellowish-gray shale parting containing abundant Dictyoclostus inflatus.........	12.4	15.9
Shale, dark yellowish-gray, thin bedded, calcareous, contains a few stringers of sublithographic limestone near top, shale covered at base......................................	3.5	3.5

TABLE XVI

FAUNULES OF THE FAYETTEVILLE

	1	2	3	4
Pleurodictyum sp.	-	x	-	-
Triplophyllum spinulosum (Edwards and Haime)	x	-	-	-
Crinoid calyxes	-	x	-	-
Prentremites sp.	-	-	-	x
Archimedes compactus Ulrich	-	x	-	-
Archimedes sp.	-	x	-	x
Archimedes swallovanus Hall	-	x	-	-
Batostomella sp.	x	-	x	-
Fenestrellina sp.	x	x	-	-
Athyris cestriensis Snider	-	-	x	-
Brachythyris ozarkensis Snider	-	x	-	-
Camarotoechia purduei Girty	-	-	x	-
Camarotoechia purduei var. agrestis Girty	x	-	-	-
Camarotoechia purduei var. laxa Girty	x	-	-	-
Chonetes chesterensis Weller	-	x	-	-
Cliothyridina sublamellosa (Hall)	-	x	-	-
Composita subquadrata (Hall)	x	x	x	-
Dictyoclostus inflatus McChesney	x	x	x	x
Hustedia multicostata Girty	-	x	-	-
Leiorhynchus carboniferum Girty	-	x	-	-
Linoproductus ovatus (Hall)	-	x	-	-
Punctospirifer transversa	x	-	x	-
Reticulariina spinosa (Norwood and Pratten)	x	x	x	-
Spirifer increbescens Hall	-	x	-	-
Spirifer leidyi Hall	-	x	-	-
Paladin mucronatus Girty	-	x	-	-

1. North side of ditch, SE corner sec. 33, T. 22 N., R. 19 E.
2. At mesa at bend in road, south line sec. 6, T. 22 N., R. 20 E.
3. In ditch, SE corner sec. 13, T. 22 N., R. 20 E.
4. Seneca fault, SW corner sec. 20, T. 22 N., R. 20 E.

middle Chester in age and may be correlated with the upper Caney[65] shale of the Arbuckle section.

Pennsylvanian System

Hale Formation

History of Nomenclature.--The Morrow series was described in 1891 by F. W. Simonds[66] and named in 1904 by G. I. Adams and E. O. Ulrich[67] from exposures near Morrow, Washington County, Arkansas. The sequence of rocks was subdivided in 1907 by Purdue who named the lower sandstone the Hale and the upper thin limestone the Bloyd.[68] In the Tahlequah area of eastern Oklahoma Taff,[69] in 1905, considered the Morrow as a single formation divided into 3 lithic units. Carl A. Moore[70] (1947) subdivided the Morrow of Oklahoma into the Hale and Bloyd formations corresponding to the units of the Arkansas section.

Distribution.--The Hale formation is limited in distribution. Exposures surrounding the broad expanse in the Seneca Fault zone in the

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[65] C. N. Gould, op. cit., p. 60.

[66] F. W. Simonds, op. cit., pp. 1-154.

[67] G. I. Adams, A. H. Purdue, and E. O. Ulrich, op. cit., 1904, pp. 28, 109-113.

[68] A. H. Purdue, "Description of the Winslow Quadrangle," U. S. Geol. Surv., Winslow Folio, No. 154, 1907, p. 3.

[69] J. A. Taff, op. cit., 1905, p. 5.

[70] Carl A. Moore, op. cit., pp. 24, 38.

central part of the area form practically all of its outcrop. Three rubble mounds in the southwest quarter of section 36, T. 22 N., R. 19 E. are believed to be capped by Hale sandstone. The faunules collected from the collapse (Plate VII, Figure 1) structure indicate a small ring of Hale limestone at the south line of section 8, T. 22 N., R. 20 E.

Character and Thickness.--The Hale formation is composed of lower bright red sandstone and upper gray limestones. The sandstone contains abundant fossils of marine origin which are left as internal molds and casts where percolating solutions have dissolved them leaving pitted and fluted appearance throughout the unit. It is typically limonitic and iron-stained and varies in texture from fine to coarse grain. At the Fayetteville contact the beds are massive and concretionary. Overlying sandstone units are irregular and show cross-lamination. The upper limestones consist of two massive beds of almost equal thickness. They are coarsely crystalline and in places quite sandy. Fossils are plentiful within these two layers but are hard to extract because of their friable nature. The limestones grade laterally into coarse, massive sandstone within the space of a few yards.

The maximum thickness measured is 39 feet. Its thickness elsewhere with reference to the minimum and maximum is indeterminable for lack of good exposures. However, it can be said with fair certainty that the thickness is quite variable with 39 feet representing a near maximum.

Subdivisions.--The Hale formation within the Seneca fault zone is distinctly divisible into a lower sandstone unit and an upper limestone. The sandstone constitutes the greatest portion of the formation with a thickness of 31 feet. The two limestone layers measure a little over 8 feet.

Stratigraphic Relations.--The Hale formation rests unconformably on the Fayetteville limestone and shale. This relationship is illustrated by the absence of the uppermost Fayetteville black shale in many places and by complete absence of the Pitkin limestone which disappears northward along the southern Mayes County line. In the western part of the area the Atoka (?) sandstone rests directly on the Fayetteville limestone. Elsewhere the Hale is overlain unconformably by Atoka and younger Pennsylvanian. The upper Morrow, Bloyd formation is not present in this area.

Paleontology.--Both units of the Hale formation are very fossiliferous. The multiple coral, *Pleurodictyum exilimura*, is common within the limestone. Poorly preserved *Spirifer* sp. occur in abundance within the sandstone as internal and external molds and casts. Table XVIII lists the Hale faunules as collected in this area.

Age and Correlation.--The Hale formation marks the base of the Morrow series and Pennsylvanian beds of northeastern Oklahoma. It correlates with the Hale of Arkansas, the Union Valley[71] of the Ada area, the Cromwell of the subsurface, and the Primrose[72] of the Ardmore Basin.

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[71]Robert Roth, "A Comparative Faunal Chart of the Mississippian Fauna of the Pennsylvanian Union Valley Formations of Oklahoma and Arkansas," Okla. Geol. Surv., Circular 18, February, 1929, p. 13.

[72]C. W. Tomlinson, "Regional Stratigraphy of Mid-Continent," Amer. Assoc. Petrol. Geol. Bull., Vol. 25, January, 1941, p. 1629.

TABLE XVII

SECTION IN SOUTH ROAD CUT, WEST FLANK SENECA FAULT ZONE

Northwest corner of section 21, T. 22 N., R. 20 E.

Formational Description	Thickness in Feet: Of Unit	Thickness in Feet: To Base of Formation
Atoka and younger Pennsylvanian:		
Sandstone, red to reddish brown, medium to coarse grain, iron-stained, medium to massive, irregular bedded, hard to friable	unmeasured	unmeasured
Siltstone, gray, fine grain, medium bedded, very hard, red and iron-stained on weathered surface, contains some light gray chert	0.4 to 0.5	0.4 to 0.5
Hale:		
Limestone, gray, coarse grain, very massive, hard, sandy, cross-bedded, has peculiar feature of changing laterally to sandstone in just a few yards, very fossiliferous, zone of Delocrinus and Pleurodictyum	8.2	39.2
Sandstone, red, medium to coarse grain, pity and fluted, loosely cemented, sub-angular, friable, fossils common as molds and casts, many brachs and Spirifers	29.0	31.0
Sandstone, red, medium grain, friable, loosely cemented, non-fossiliferous	1.1	2.0
Sandstone, yellowish-red, fine grain, limonitic, pity and fluted, highly weathered, fossils common as molds and casts	0.9	0.9
Fayetteville:		
Shale, black, platy, greenish at contact, base unexposed	18.0	18.0

TABLE XVIII

FAUNULES OF THE HALE FORMATION

	1	2	3	4
Amplexus corrugatus Mather	–	–	–	x
Pleurodictyum exilimura (Mather)	–	x	–	–
Crinoid stems	x	x	x	x
Delocrinus sp. *cf. D. pentanodus* Mather	–	–	x	–
Eupachycrinus sp. *cf. E. magister* Miller and Gurley	–	–	–	x
Fenestella morrowensis Mather	–	–	x	–
Polypora sp.	x	–	–	–
Polypora triseriata Mather	–	–	x	–
Chonetes choteauensis (Mather)	–	–	x	–
Chonetes laevis Keyes	–	–	x	–
Composita ovata Mather	x	–	–	–
Composita ozarkana Mather	–	x	–	–
Composita wasatchensis White	–	x	–	–
Dictyoclostus fayettevillensis Mather	x	–	x	–
Dictyoclostus morrowensis Mather	x	–	x	–
Dictyoclostus sp.	x	–	–	–
Dielasma arkansanum Weller	–	x	–	–
Hustedia miseri Mather	–	x	x	–
Linoproductus sp.	x	–	x	–
Orthotetes robusta (Hall)	–	–	x	–
Spirifer rockymontanum Marcou	x	x	x	–
Spirifer sp.	x	–	–	–
Myalina sp.	x	–	–	–
Paladin morrowensis (Mather)	x	–	–	–

1. Seneca Fault, center sec. 20, T. 22 N., R. 20 E.
2. On west flank of Seneca Fault, NW corner sec. 21 and south side sec. 16, T. 22 N., R. 20 E.
3. Collapsed structure, south line, sec. 8, T. 22 N., R. 20 E.
4. Seneca Fault, SW corner sec. 20, T. 22 N., R. 20 E.

Undifferentiated Atoka and Younger

South of the Arkansas River in the Muskogee-Porum District and on the Ozark uplift, the Morrow is overlain unconformably by great thicknesses of Atoka formation which comprises several important sandstone and shale members.[73] The Atoka is succeeded by the Hartshorne-McAlester sequence. These units converge northward and the McAlester overlaps various units of the Atoka formation.

North of the Arkansas River corresponding units have been included in the Cherokee shale. The Little Cabin, mapped by Renfro[74], across the western part of the Strang area is believed to correspond to the Warner sandstone in areas to the south. Lithologically, some of these beds in the Strang area resemble the sandstones in the Atoka.

Subdivision and correlation of the Pennsylvanian units above the Hale in this area is beyond the scope of this report, and hence, the units are mapped as Atoka and younger.

Atoka and younger units occupy practically the entire northwestern corner of the area. A strip of the units over one-half mile wide and over two miles long lies in the basal portion of the Seneca fault zone. The tongue-like projection in section 7, T. 22 N., R. 20 E. is capped by a hard layer of post-Morrow rock. Other patches of the units cap mesas and buttes. Several feet of sandstone rest at a comparatively

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[73] C. W. Wilson and N. D. Newell, "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma," Okla. Geol. Surv. Bull. 57, 1937.

[74] H. B. Renfro, "Geologic Map of the Vinita-Wagoner District, Northeast Oklahoma," Unpublished Doctor's Thesis, Wisconsin University, 1947.

high angle in the center of a collapse-structure in section 8, T. 22 N., R. 20 E.

The four to six-inch cap-rock bed in section 7, T. 22 N., R. 20 E. is a gray siliceous siltstone, almost quartzitic in places, and immediately overlies the upper Archimedes zone of the Fayetteville. Typically, it weathers red and blocky and along a fresh break when moistened reveals tiny spicules under the hand lens. Light gray chert spots are common. In cap rock areas it supports a growth of ragweed. In the south road cut in the Seneca fault zone (northwest corner of section 21, T. 22 N., R. 20 E.) this bed overlies the Hale limestone. For the most part the rest of the Atoka and younger units of this area consist of massive to medium irregularly bedded sandstones varying from coarse to medium grain in texture and from red, reddish-brown, to buff in color. A blackish, iron-stained shale is found in one locality at the northwest corner of section 27, T. 22 N., R. 19 E.

Quaternary System

Pleistocene Terrace Gravels

Terrace gravels composed of rounded and subrounded pieces of chert are widespread in the north-central part of the area. Several square miles of this sector lying just above the river alluvium may be designated as "low terrace gravels." In the north part of section 3, T. 22 N., R. 20 E., a water well was drilled to a depth of 23 feet[75] and

[75]Frank Ross, Personal Communication, Strang, Oklahoma, July, 1950.

PLATE VI

Figure 1. Low terrace gravel deposits on east side of Grand River along north boundary, NW quarter of section 3, T. 22 N., R. 20 E.

terminated in gravels. Probably such deposits are thicker near the river and thin to the east toward the Boone hills.

Terrace gravels achieve spotty distribution at higher levels. Those occupying the highest divides in the Boone hills to the east of Grand River rest directly on Keokuk and are from 100 to 300 feet higher than the "low terrace gravels." These may be designated as "high terrace gravels" and are found as far removed as four miles to the east of the river. Similar deposits blanket the highest places immediately adjacent to or near the west side of the river. Some of these reach a thickness of from 10 to 12 feet and are mainly intermediate in elevation with respect to the high and low terrace gravels within this area.

J. W. Stovall and W. N. McAnulty[76] assign most of the high-level gravel deposits in Oklahoma to the Pleistocene.

Recent Alluvium Deposits

Alluvial material is located principally along the river flood plain, Spavinaw Creek and some of its larger tributaries, and the lower part of Wolf Creek. Three former alluvial levels are exposed on the inside of the large river meander in the central part of the area. Most of the alluvium consists of a dark gray to blackish residual soil. Deposits along Spavinaw Creek are mainly of mixed gravel and dark soil although gravel predominates near or in the creek bottom. The tributary deposits to the east of the river contain alluvial flats of dark soil mixed with angular talus material.

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[76] J. W. Stovall and W. N. McAnulty, "The Vertebrate Fauna and Geologic Age of the Trinity River Terraces in Henderson County, Texas," _Amer. Mid. Nat._, Vol. 44 (1), 1950, pp. 211-250.

Recent Eolian Deposits

Wind blown material covers a major portion of the western one-third of the area. The thickness is quite variable; the writer believes the average is from 3 to 4 feet with the maximum exceeding 10 feet in places. The deposits are unsorted and without signs of layering. Typically, the material is buffish-gray to gray in color and contains a thick covering of grass, especially over the Atoka formation.

CHAPTER V

STRUCTURE

General Regional Picture

Northeastern Oklahoma lies on the southwest flank of the Ozark uplift. The formations strike in an arcuate pattern and dip away from the central region around the dome. The northerly location of the Strang area relative to the southwest extension of the uplift causes the formations to dip in a west-northwestly direction across the area at an estimated rate of 20 to 50 feet per mile. Knobs of Boone chert and the Seneca fault zone trending in a northeast-southwest direction in the central part of the area locally effect the dip of the strata. Local folding is responsible for many irregularities along the formational contacts.

Local Folding and Faulting

The graben-like Seneca fault zone in the central township and in section 36, T. 22 N., R. 19 E. constitutes the only visible surface faulting in the area. Although Ireland[76] considers the fault continuous from near Spurgen, Missouri to south of Pryor, Oklahoma, it is quite discontinuous in this sector. No traces of the fault are found to the

[76]H. A. Ireland, op. cit., pp. 30-31.

northeast of Grand River extending to the north township line in the area. The Seneca graben passes northeastward into a broad syncline whose flanks are visible along the bluff immediately southwest of the river in the southwest corner of section 11, T. 22 N., R. 20 E. Here the southeast limb is cut by a small normal fault with a ten-inch displacement (Plate 4 Figure 2). The Seneca fault zone broadens to nearly a mile in width in the center of T. 22 N., R. 20 E. forming a faulted synclinal structure. At the southwest corner of section 22, T. 22 N., R. 20 E., the southeast limb has a dip of about 25 degrees. The northwest limb at the northwest corner of section 21, T. 22 N., R. 20 E. has a dip of 10 to 15 degrees. In Wolf Creek in the northwest part of section 31, T. 22 N., R. 20 E. beds within the Seneca graben form a syncline with each limb dipping inward from 6 to 10 degrees. In section 36, T. 22 N., R. 19 E., the fault position is covered by mantle rock, but rubble of Hale and Fayetteville in the southwest quarter of the section is indicative of further synclinal development.

A fault offsetting Atoka units in the southwest corner of section 27, T. 22 N., R. 19 E. as mapped by Renfro[77] is not verified by present field evidence.

Along Spavinaw Creek at the eastern boundary, Cotter beds dip to the west away from the Spavinaw granite at the rate of 5 to 10 degrees. For more than four miles to the west of the eastern boundary, minor folding along the creek exposes Chattanooga and St. Joe units. Reeds Spring and St. Joe strata dip slightly inward adjacent to the north and south sides

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[77]H. B. Renfro, _op. cit._

of the creek, but the overall picture is generally anticlinal for the Spavinaw area with the axis of the gentle uplift extending along the creek in an east-west direction. Along the south line of section 10, T. 22 N., R. 20 E. monoclinal folding occurs in Reeds Spring and "Keokuk" beds. Westerly dips from 8 to 12 degrees are recorded in the north road cut before the strata passes under the low terrace gravels.

Throughout a larger portion of the central part of the area and adjacent to the Seneca faults, several Boone domes align themselves in a northeast-southwest direction. Most of the Mayes units thin as they onlap the domes with unconformable relationship. In many cases differential compaction over the irregularities of the "Keokuk" surface effects the Mayes units giving them a crinkled or jumbled appearance. Conditions of this nature prevail on the flanks of the knobs in section 9, T. 22 N., R. 20 E. and at the south line in section 13, T. 22 N., R. 20 E.

A collapse-structure (Plate VII, Figures 1 and 2) caused by the dissolution of underlying limestones is located at the south line of section 8, T. 22 N., R. 20 E. On the south side of the structure Atoka sandstone dips northward at a 20-degree angle and on the east side units of the formation are arched around the side of a dolomitic plug.

Local flattening of the dip in the northwestern part of the area where the thin, siliceous Atoka (?) caps the Fayetteville mesa indicates gentle anticlinal folding. A three-degree reversal of dip is recorded on the east flank of the structure. Minor folding in the form of undulations occur in many places. Small synclines are noted by surface mapping in sections 9, 10, and 16 of T. 22 N., R. 20 E.

PLATE VII

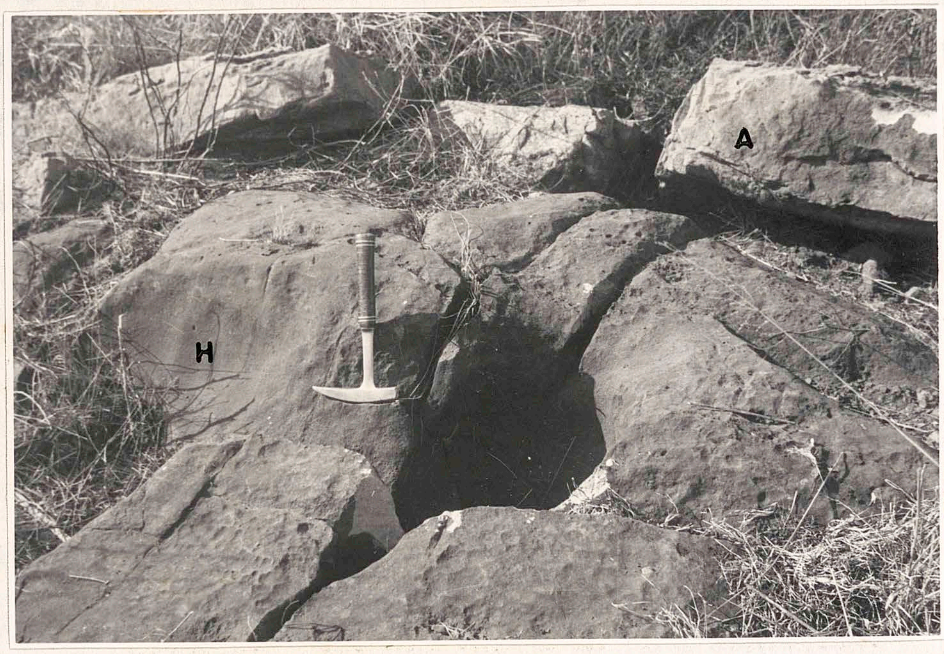

Figure 1. Solution cavity in Hale limestone. Overlain by slumped Atoka sandstone, collapse-structure, south side of section 8, T. 22 N., R. 20 E.

Figure 2. Atoka sandstone slumped into collapse-structure. South side of section 8, T. 22 N., R. 20 E.

Probable Age of Structures

The Seneca faults and minor folding within the area probably formed in post-Atoka times. In the eastern sector rejuvenation of the Ozark uplift is indicated by successive stages in terrace gravel deposition during the Pleistocene.

CHAPTER VI

GEOLOGIC HISTORY

Marine sedimentation began with the invasion of early Ordovician seas which deposited the Cotter dolomite over the Spavinaw granite contemporaneously with the upper Arbuckle limestone of central Oklahoma. No doubt the sandy phases within the Cotter indicate the land mass, Ozarkia, was high to the northeast. Further uplift continued in the Spavinaw area at the close of early Ordovician times and erosion progressed throughout the remainder of the period. Near shore conditions persisted to the south during middle and late Ordovician as the Burgen, Tyner, Fite, Fernvale, and Sylvan formations were deposited. In northeastern Oklahoma the period closed with a general withdrawal of the seas.

In the Spavinaw area the long period of erosion existed until the deposition of the Chattanooga black shale in late Devonian time. Partial inundation of the land to the south occurred during the Niagaran, Ulsterian, and Bradfordian epochs, but each is separated by periods of erosion caused by repeated Ozarkian uplifts. Widespread deposition of the black shale continued in the area and in most of Oklahoma and throughout much of the eastern interior of the continent until the close of the Kinderhookian epoch in early Mississippian time. Following the deposition of the Chattanooga the seas withdrew giving rise to erosion.

Osagean seas advanced over the area, depositing the St. Joe crinoidal limestone. Whether the seas retreated following the deposition of the formation is questionable. Possible local emergence occurred before the Reeds Spring was laid down. After the deposition of the Reeds Spring limestone a withdrawal of the sea and erosion followed, the hiatus being greater to the south and in the Missouri areas. Following the period of erosion, the seas covered vast areas depositing the "Keokuk" limestone. Although the vast quantities of chert in the Reeds Spring and Keokuk create an unsolved problem, they are considered to be of secondary origin within the area and are believed to have been induced by ground waters following the deposition of the limestones. Numerous crinoidal bioherms within the "Keokuk" in the area gave rise to highly arched domes which stood as "islands" throughout the rest of the Mississippian. A retreat of the seas and subsequent erosion closed the Osagean epoch.

Meramecian seas advanced filling in low spaces between the Boone knobs with "Moorefield" limestone. Changing sea level and lowering of wave base occurred during the deposition of the "Hindsville" chert conglomerates. The seas lapped higher onto the knobs and in some cases completely across them by "Batesville" time before they withdrew at the close of the Meramecian epoch. An ensuing submergence deposited the "Grand River" limestone and Fayetteville limestones and shales, seemingly without withdrawal of the seas until the close of the Mississippian period. In many instances the "Grand River" seas did not cover the larger Boone knobs. The Pitkin limestone was laid down to the south but the formation thins and disappears before reaching this area. Renewed uplift of Ozarkia and a long period of erosion brought the Mississippian period to a close.

Morrow seas advanced from the south and southwest but failed to onlap much of the area in the direction of the Ozark uplift. The Bloyd is restricted to areas to the south whereas the underlying Hale sandstone and limestone were deposited as far north as the Strang area. The close of Morrowan times saw a retreat of the seas from the general area to the southwest, and it is difficult to ascertain the extent of the post-Hale erosion which was no doubt intense. Middle Pennsylvanian Atoka and Cherokee seas advanced across the area lapping onto the Ozark dome. Marine and shallow water or swampy conditions existed during much of this deposition.

Northeastern Oklahoma underwent diastrophic movement in post-Atoka and pre-Savanna time as the seas possibly withdrew for the last time in this area. Renewed uplift in the Pleistocene is marked by successive stages of terrace gravel deposition.

CHAPTER VII

ECONOMIC GEOLOGY

Economic resources of the Strang area are limited to local usage. The chief products found in commercial quantities are building stone and gravel. Asphalt, lead and zinc ores, oil and gas and tripoli are present in such small quantities they are impractical to mine or produce.

Asphalt

Some prospecting for natural asphalt has been done in rocks of Mayes age. In the southwestern quarter of section 29, T. 22 N., R. 20 E. several shallow test wells were drilled but with poor results. Asphalt in this area seems to be limited to very thin, black residual veins within the "Moorefield" and "Grand River" formations.

Building Stone

The peculiar property of the "Batesville" formation to break into thin slabby layers provides excellent siding material for houses. Many residences in the area are constructed with this type of limestone. Quarries yielding the material are located in the southwest corner of section 3 and the west side of section 10, T. 22 N., R. 20 E. The upper zone of the "Moorefield" has been quarried for the same purpose in the southwest corner of section 11 of the same township.

Gravel

Gravel is used locally for road maintenance. Excellent pits are located in the southeast corner of section 4, the central part of section 10, and on the west side of section 12, T. 22 N., R. 20 E. The higher terrace gravels tend to be better for commercial usage in that they contain far less river alluvium.

Lead and Zinc Ores

Sphalerite and galena ores of the Boone chert as typically developed in the Tri-State region do not appear in this vicinity.

Limestone

In adjacent areas the "Grand River" limestone has proved useful as a crushed stone. However, the thin development and onlapping nature of the formation relative to Boone highs in the area gives preference to more complete sections located elsewhere.

Oil and Gas Possibilities

The prospects for oil and gas are slight. The formations crop out across the area permitting the upturned edges to be exposed at the surface. Any oil and gas within them would be allowed to escape unless confined to local structural pockets. Also, extensive ground water action has acted as a flushing agent.

The Sylamore sandstone below the Chattanooga shale, if present in subsurface in the area, occupies an ideal position for a reservoir rock. However, the sandstones of Ordovician age to the east of Grand River in Mayes, Delaware, and Ottawa counties contain water and any oil present has been flushed out.[78] Structure and ideal conditions prevail in many places but water is always found in place of oil.

In the south part of section 10, T. 22 N., R. 20 E., a gas seep occurs within the Boone chert. It was piped to a farmhouse and served for cooking purposes for many years. No gas well has been found within the area containing sufficient quantities for commercial production.

Tripoli

Tripoli is a light weight porous rock originating from weathered chert and is usually confined to the upper surface of the "Keokuk" formation. The material is used as a filtering agent, but when ground into a fine powder the tiny granules act as a metal polish or abrasive. Small amounts of the material have spotty distribution in the central part of the area. Better deposits in other regions supersede the extraction of tripoli from this area.

Water Resources

The eastern part of the area is endowed with an unlimited supply of clear spring water draining from the "Boone hills." The high rate of rainfall and retarded run-off due to thick vegetation are attributes to continuous supply. The fractured nature of the Keokuk chert offers ideal conditions for the downward movement of ground water. For the most part the springs seep from between the interbedded limestone and chert beds of the Reeds Spring formation.

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[78] H. A. Ireland, op. cit., p. 32.

East of the eastern boundary, Spavinaw Creek has been dammed to furnish a water supply for the City of Tulsa. Water from the Grand River is utilized by Pryor, Oklahoma and supplied the Choteau Ordinance Works during World War II. Hydro-electric power is furnished by the Grand River dam near Pensacola, Oklahoma. Upon completion of the Markam-Ferry Dam to the south, much of the low floodplain adjacent to the river and Spavinaw Creek will be flooded permanently.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The formations within this area are all sedimentary, ranging from Ordovician to Pennsylvanian in age. Pre-Cambrian granite crops out in Spavinaw Creek immediately east of the eastern boundary.

The Cotter dolomite of Ordovician age is exposed only along the eastern boundary on the southwest side of Spavinaw Creek. Silurian units are absent. The Chattanooga black shale unconformably overlies the Cotter and is assigned to the upper Devonian and principally the Kinderhookian series of the lower Mississippian. The St. Joe, Reeds Spring, and Keokuk members of the "Boone" comprise the Osagean series. These have been mapped separately. Known unconformities exist at the bottom and top of each member except the questionable one at the St. Joe-Reeds Spring contact. The Meramecian is represented by essentially conformable rock units of the "Moorefield," "Hindsville," and "Batesville" formations. The "Grand River" limestone overlies the "Batesville" and Keokuk knobs unconformably and grades upward into the Fayetteville formation. The "Grand River" and Fayetteville are classed as Chester in age and form the youngest Mississippian rocks in this area.

The Hale sandstone and limestone of lower Pennsylvanian age lie unconformably on the Fayetteville. The formation constitutes the basal portion of the Morrow group and is practically restricted in areal distribution to the confines of the Seneca fault zone.

The major structural feature of this area is the Seneca graben which trends in a northeast-southwest direction. Keokuk knobs noticeably aligned themselves with the fault's trace. The dome-like structures are attributed mainly to crinoidal bioherms within the Keokuk. Minor folding causes some surface irregularities.

The principal economic resources of this area are gravel, building stone, and water. The future possibilities for oil and gas production in commercial quantities are negligible.

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