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A STUDY OF THE SHORT CREEK OOLITE, OTTAWA COUNTY, OKLAHOMA

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A STUDY OF THE SHORT CREEK OOLITE, OTTAWA COUNTY, OKLAHOMA

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APPROVED FOR THE SCHOOL OF GEOLOGY

BY

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CHAPTER I

INTRODUCTION

Location of Area

Ottawa County, located in the northeastern part of the state of Oklahoma, is bounded on the north by Cherokee County, Kansas; on the east by Newton and McDonald Counties, Missouri; on the south by Delaware County, Oklahoma; and on the west by Craig County, Oklahoma. It includes approximately 500 square miles in T. 25 N. to T. 29 N. and R. 21 E. to R. 25 E., measuring twenty-one and one-half miles from east to west and twenty-three miles in a north-south direction.

Purpose of Investigation

In the mapping of Ottawa County by Siebenthal[1] and later by Weidman[2], the Boone formation, ranging in thickness from 315 to 400 feet, was not sub-divided. At the time of the earlier mapping, units of the Boone which are now recognized were not completely worked out in many

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[1]C. E. Siebenthal, Unpublished manuscript, U. S. Geological Survey.

[2]Samuel Weidman, "Miami-Picher Zinc-Lead District," Okla. Geol. Survey Bull. 56, 1932.

areas, and in several cases confusion as to the boundaries of the units existed. Considerable work has been done on the stratigraphy of the Boone since that time, and a more detailed mapping, though difficult is possible.

As a starting point for a map showing the sub-divisions of the Boone, the Short Creek oolite was chosen as the most widespread and persistent member which could be easily identified in Ottawa County. The outcrops, which are limited to the eastern and southern parts of the county, were mapped, and the subsurface extent was determined from well logs of prospect holes in the mining district and from deep wells penetrating the Boone to reach the Roubidoux Sandstone (Ordovician), a prominent artesian water horizon. A structure map, using the Short Creek as the datum horizon, was prepared as an aid to further mapping by enabling the approximate position of beds within the Boone to be determined.

Methods of Investigation

Field mapping of the Short Creek was done at intervals during the summers of 1947, 1948, and 1949. Owing to the nature of the outcrops, which are usually in timber-covered areas or partially covered by chert detritus, mapping was done entirely in the field. Aerial photographs were used for the purpose of location. Elevations on the top of the Short Creek Oolite were taken at many points using an aircraft altimeter which had an accuracy within five feet, and a surveying barometer with an accuracy within two feet. Readings were always referred back to a bench mark within thirty minutes of the time of observation. In most cases the level of Grand Lake was used as a datum inasmuch as it was easily accessible from most outcrops. Elevations of road intersections taken from the USGS topographic map of the Wyandotte quadrangle were also used, and in several cases elevations of bench marks such as bridge abutments or culvert headwalls were obtained from the county surveyor's office. It is realized that considerable opportunity for error in elevation exists, but key elevations were rechecked several times during the period of the field work and were found to be within or very near the limits of error of the instruments.

Subsurface information was obtained from well logs furnished by several mining companies, published information by several authors, and from well logs of deep water wells drilled by the City of Miami, the samples from which were examined and identified by the Missouri Geological Survey.

History of Previous Investigations

The Short Creek Oolite was named and studied by Smith and Siebenthal[3] in their description of the Joplin mining district. In this report mention was made of the occurrence of the Short Creek in the Wyandotte region of Indian Territory. Further reference was made by Siebenthal[4] and Snider[5]. Weidman[6], in his work on the Miami-Picher

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[3] W. S. T. Smith and C. E. Siebenthal, U. S. Geol. Survey Geol. Atlas, Joplin District Folio, No. 148, 1907, p. 5.

[4] C. E. Siebenthal, "Mineral Resources of Northeastern Oklahoma," (U. S. Geol. Survey Bull. 340, 1907), pp. 187-228.

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

[6] Samuel Weidman, ibid.

district, described the Short Creek in the mining area and made limited mention of it elsewhere in the county. Fowler and Lyden[7] also described the oolite in the mining district but made little note of its occurrence at other localities within the county. Laudon[8] briefly mentioned the Short Creek in Ottawa County. Outside Ottawa County the Short Creek has been identified throughout much of southwestern Missouri, and an oolite bed at about the same horizon in the Boone as the Short Creek at the type locality was noted by Purdue and Miser[9] in their report on the Eureka Springs-Harrison, Arkansas, area and correlated by them with the Short Creek. This area is some one hundred miles to the east of Ottawa County. Giles[10] also mentioned the occurrence of an oolite horizon which he called the Short Creek in several localities in northwestern Arkansas. Presence of the Short Creek has not been definitely established in Oklahoma south of Ottawa County where it is absent either through non-depositions or post-Boone, pre-Mayes erosion. Isolated patches of white oolite in the upper Boone in Cherokee and Adair Counties may prove to be a southern extension of the Short Creek horizon[11].

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[7]G. M. Fowler and J. P. Lyden, "The Ore Deposits of the Tri-State District," (Am. Inst. Min. Metall. Eng. Transactions, Vol. 102, 1932), pp. 206-251.

[8]L. R. Laudon, "Stratigraphy of Osage Subseries of Northeastern Oklahoma," (Am. Assn. Pet. Geol. Bull., Vol. 23, No. 3, March 1939), pp. 325-338.

[9]A. H. Purdue and H. D. Miser, U. S. Geol. Survey Atlas, Eureka Springs-Harrison Folio, No. 202, 1916, p. 11.

[10]A. W. Giles, "Boone Chert," (Geol. Soc. Am. Bull. Vol. 46, 1935), pp. 1815-1878.

[11]G. G. Huffman, Personal Communication, June 1951.

CHAPTER II

GEOGRAPHY

Topography and Drainage

The western edge of the Ozark plateau is well defined by the courses of Grand River and Spring River so that Ottawa County lies in two physiographic provinces, the Prairie Plains Homocline to the west and the Springfield Structural Plain to the east.

The topography of the western part of Ottawa County is characterized by a rolling surface with both mature and old age streams draining the area. It is underlain by Pennsylvanian shales and sandstones and is in general an area of low relief. A few low hills supported by layers of more resistant sandstones rise above the flat grassy lowlands to a height of fifty feet or more.

The eastern part of the county is a maturely dissected plateau with many youthful streams and valleys. There the topography is shaped by resistant cherts and limestones of the Mississippian system and a much more rugged terrain results. The rolling slopes of the northeast part give way in the central and southeastern parts to an area of mature dissection with a relief of two to three hundred feet within a half mile. The maximum topographic relief of the county is attained within a distance of five miles in the extreme southern part. There the normal level of the water in the Grand Lake standing 745 feet above sea level marks the lowest elevation in the county, whereas five miles to the east an elevation of 1,130 feet above sea level is reached.

The drainage of the county is in general from north to south, converging toward the south central part. The major streams are the Neosho River, which enters the county in the northwest corner and flows generally southeasterly to a point one mile west of Wyandotte, and Spring River, which enters the county in the northeastern part and joins the Neosho near Wyandotte. The resulting stream, known as the Grand River, flows to the south and southwest to join the Arkansas River near Muskogee, Oklahoma.

In 1941 a dam for the purposes of flood control and generation of hydro-electric power was completed across Grand River approximately twenty miles south of Ottawa County. The resulting lake has its head waters reaching to a point five or six miles north of Miami on the Neosho River and eight miles north of Wyandotte on Spring River. The lake, named "Lake O' The Cherokees", but popularly known as Grand Lake, at its normal stage of 745 feet above sea level, floods some 10,000 to 12,000 acres in Ottawa County.

Major tributary streams which flow into Spring River or Grand Lake from the east are Five Mile Creek, Warrens Branch, Lost Creek, Sycamore Creek, and Cowskin (Elk) River, which is entirely in Delaware County except for the last few hundred yards where it enters Ottawa County. On the west some of the principal small streams are Elm Creek, Tar Creek, Coal Creek, and Hudson Creek, all of which join the Neosho

River, and Horse Creek which flows from the southwest part of the county into Delaware County where it empties into Grand Lake.

The average gradient of the major streams before flooding by the Grand Lake was between one and two feet per mile. The smaller streams in the western half of the county have gradients ranging from five to ten feet per mile while the smaller streams in the eastern half have much higher gradients, ranging from ten feet to as much as seventy-five feet per mile.

Roads and Railroads

The county is served by several major highways and three railroads. The federal highways which traverse the county are U.S. 60, 66, and 69. State highways are numbers 10, and 25. In addition to these all weather roads, a system of county maintained gravel and dirt roads furnish access to nearly all parts of the area. The southeastern part of the county is sparsely populated and has fewer roads. Throughout the rest of the county roads are present on nearly all section lines. The railroads which serve the county are the St. Louis and San Francisco Railroad; the Kansas, Oklahoma, and Gulf Railroad; and the Northeast Oklahoma Railroad.

Principal Cities and Towns

Miami, located in the west central part, is the county seat and principal city of the county with an estimated population in 1950 of 12,000 people. Other towns, in decreasing order of size, are Picher in the north, Afton and Fairland, in the south, Quapaw in the north, and

Wyandotte in the southeast. In addition to these towns several smaller communities are found in the northern part of the county representing the remnants of once larger mining camps which flourished during the boom days of the first World War and for a decade thereafter.

CHAPTER III

STRATIGRAPHY

Introduction

The stratigraphic units exposed at the surface in Ottawa County include the Boone, Mayes, and Fayetteville formations of Mississippian age and the Cherokee of Pennsylvanian age. Locally these are overlain by the flood plain deposits of the Neosho and Spring Rivers. Subsurface strata include in descending order, the Chattanooga shale of late Devonian and early Mississippian age; a sequence of Cambro-Ordovician dolomites and limestones; and the pre-Cambrian granite. The Chattanooga shale and underlying Cotter dolomite, previously exposed in Sec. 32, T. 26 N., R. 24 E., are now concealed beneath the waters of Grand Lake. The generalized stratigraphic sequence is summarized in Table I.

The Boone formation, whose outcrop covers over one-half of Ottawa County, was named by J. C. Branner and described by Simonds for exposures in Boone County, Arkansas.[12] Where fully represented it includes five fossiliferous marine units; in ascending order these are the St. Joe, Reeds Spring, Burlington, Keokuk, and Warsaw. In Ottawa County the Boone varies in thickness from 315 to 400 feet.

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[12] J. C. Branner and F. W. Simonds, Ark. Geol. Survey Annual Report, 1888, Vol. 4, pp. xiii, 27-37.

TABLE I

GENERAL GEOLOGIC SECTION OF OTTAWA COUNTY

SYSTEM	FORMATION	THICKNESS AND DESCRIPTION
Quaternary	Alluvium	Found along flood plain of Neosho and Spring rivers.
Pennsylvanian	Cherokee	0' to 300'. Black shale, thin sandstones, thin coal beds.
Mississippian	Fayetteville	0' to 40'. Grey shale with thin sandstone and limestones.
	Mayes	0' to 60'. Variable in thickness and character. Generally thin bedded limestones at base with shales and sandstonesnear top. Chert conglomerate sometimes present at base.
	Boone	315' to 400'. Interbedded cherts and limestones of variable thickness and character. See detailed description.
Devonian	Chattanooga	0' to 30'. Black, thin bedded shale. Absent in northern part of county.
Ordovician	Cotter	120' to 160'. Dolomite and chert. Few thin sandstones.
	Swan Creek	15' to 30'. Sandstone. An artesian water horizon.
	Jefferson City	290' to 310'. Dolomite and chert.
	Roubidoux	150' to 180'. Dolomite and sandstone. Some chert. Well-known

TABLE I (Continued)

SYSTEM	FORMATION	THICKNESS AND DESCRIPTION
Ordovician	Roubidoux (Continued)	artesian water horizon.
	Gasconade	320' to 360'. Dolomite and chert with some sandstone.
	Gunter	40' to 50'. Dolomite and chert.
Cambrian	Eminence	80' to 90'. Dolomite, some chert.
	Bonne Terre	200' to 250'. Dolomite at top becoming sandstone at base.
Pre-Cambrian		Granite. Pink to red in color.

Compiled from Weidman's report (O.G.S. Bull. 56, Miami-Picher Zinc-Lead District, 1932) and from well log data furnished by the City of Miami and described by the Missouri Geological Survey.

The Short Creek oolite horizon, which lies in the upper one-third of the Boone, was named by Smith and Siebenthal[13] from the type locality on Short Creek near Galena, Kansas.

The outcrop at the type locality is exposed along a bluff on the north side of Short Creek, a westward flowing stream on the north edge of Galena, Kansas. The bed outcrops about forty to fifty feet above the level of the stream and about one hundred yards northwest of the crossing of the Missouri, Kansas, and Texas Railroad, and the little used branch of the St. Louis and San Francisco Railroad. The site may be reached easily by driving north on the main street of Galena across Short Creek, turning west about one-quarter mile, and then walking down the track of the Frisco branch to its crossing with the north side of the stream.

The Short Creek Oolite is found in many places in the Joplin District and is known in many other localities in southwestern Missouri. In Oklahoma it is found outcropping in the southeastern part of the Wyandotte quadrangle, which includes all of Ottawa County. The Short Creek is believed to outcrop in northwestern Delaware County and may be represented in Cherokee and Adair Counties where isolated exposures of white oolite have been found in the upper part of the Boone.

Nature and Distribution of Outcrops

In Ottawa County outcrops of the Short Creek are limited principally to the eastern and southern portions. (See Figure 1 - in folder)

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[13]Smith and Siebenthal, op. cit., p. 5, 1907.

The most northerly exposure is found at Dripping Springs on Spring River, some six or seven miles east of Miami where erosion along the axis of a small anticline has exposed the bed for a short distance on the west side of the river. Excellent exposures are found at the Twin Bridges locality (Figure 2) west of Wyandotte at the junction of Neosho and Spring Rivers, along road cuts on the highway leading east from Wyandotte, in road cuts on the highway leading south from Wyandotte, along the bluffs on the north side of Sycamore Creek south of Wyandotte, along the bluffs on the north side of Lost Creek near Seneca, Missouri, in the Bee Creek locality east and south of Bee Creek.

In most places the outcrop of the Short Creek is partially covered by chert detritus from the Boone, and careful search of the hill-side is necessary to find traces of the bed. Frequently small pieces of float are the only indication of its presence but in nearly all cases where float is found the bed can be uncovered by digging beneath the several inches to several feet of loose mantle rock. In all such cases the float may be considered to be within a few feet of the true position of the bed, as the soft oolite is very easily weathered to disintegration and could have moved but a short distance from the bedrock position. This of course is not true of the silicified pieces of float which are occasionally found. On fresh exposures, such as road cuts and stream channels, good sections of the oolite are exposed. In several places where the unit is completely exposed, such as at the Bee Creek area and along the banks of the river at Twin Bridges, the uppermost portion tends to form a very slight reentrant in the cliff face whereas the

Figure 2. Short Creek Oolite exposed at Twin Bridges on Neosho River, Sec. 19, T. 27 N., R. 24 E.

middle and lower portions form a more resistant ledge. The middle part shows a tendency to weather off in shell-like layers an inch or so in thickness to form a slightly rounded surface. The lower part merges with the thick bedded limestones below, which form a ledge extending outward from the base of the oolite. This lower boundary is not very well marked, as the change from oolite to moderate or finely crystalline limestone is gradual.

The color of the bed on fresh surfaces is grey, but upon slight exposure to weathering it becomes a light grey to white in color. This is particularly noticeable on outcrops in road cuts where fresh cuts show the grey color but older cuts made some twenty to thirty years before have a lighter color. In some places the outside of the bed is stained red by iron oxides from the clays above, but the red color is never found within the bed. The small pieces of float found are nearly always white in color and stand out from the darker chert and limestone fragments which litter the hillsides.

<u>Character and Thickness</u>

Smith and Siebenthal[14] in their work in the Joplin district described the Short Creek as follows:

> The Short Creek member is a thin but very persistent bed of oolitic limestone. Generally it forms a single, massive, homogeneous bed which in the Joplin area ranges from 18 inches to 8 feet in thickness. Exceptionally it divides into two beds which may have slightly different characteristics. The spherules are round, never flattened, though some are concave where they touch, as if pressed into one another or as if they had interfered with one another in the process of concentric

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[14]Smith and Siebenthal, op. cit., p. 5, 1907.

growth. One of the most constant characteristics of the Short Creek oolite is the regularity in size of the spherules in a hand specimen, though they vary somewhat in size from place to place. They are uniformly smaller than those of the Carterville formation, averaging perhaps one-fiftieth of an inch in diameter, while the Carterville spherules are about one-twenty-fifth of an inch. The individual spherules in the Short Creek are solid and though apparently formed by concentric growth, rarely show the center darker than the shell, as is common in those of the Carterville. The Short Creek spherules are embedded in a calcareous matrix which in places is coarsely crystalline. On a freshly broken surface the matrix gives a patchy reflection from cleavage surfaces one-fourth to one-half inch across, in which the embedded spherules appear as dark spots, a variety of poikilitic structure. In most cases the rock has a slightly splintery fracture, and this character is more pronounced the more complete the cementation. The Short Creek has two characteristic methods of weathering. In one it scales off in flakes parallel to the surface, and, being softer than the crystalline limestones above and below it in the bluff, it generally forms a slightly retreating gallery. A somewhat harder variety is found locally on sloping hillsides, where it usually breaks into rhomboid blocks which weather away along the cracks, leaving the blocks firmly fastened together and standing out somewhat in the fashion of irregular paving blocks; or the loose blocks may be strewn over the surface. In a few instances about Lowell and on Killibrew Branch the oolite is silicified into chert, but this was not noticed elsewhere. In the eastern part of the area the limestones above and below are in places altered to dolomite, but the oolite was nowhere observed to be so altered.

In Ottawa County the Short Creek shows practically the same characteristics as described by Smith and Siebenthal from the Joplin district. The bed ranges in thickness on the outcrop from 12 to 14 inches at its thinnest to as much as 8 to 10 feet in the Wyandotte area. As much as 20 feet has been reported encountered in prospect drill holes in the mining district; however, this figure may be the result of caving and contamination of the samples, as no such thickness has been reported from any known outcrop. Typical thicknesses as encountered in this study are listed in Table II. This table is of course not a complete listing of all measured sections, but merely a sampling to show representative thicknesses from north to south in the county.

Detailed Descriptions of Selected Localities

SW SE Sec. 22 T. 27 N., R. 24 E. - This outcrop is located about one and a half miles east of Wyandotte on the former route of U. S. Highway 60, now a county road. The road parallels the Frisco railroad, and the outcrop is best exposed in a cut on the south side of the highway. This cut was made over twenty-five years ago and the Short Creek shows the effects of this relatively short period of weathering to a considerable degree.

The basal contact is gradational upward from a moderately crystalline, grey limestone into the calcareous oolite with no appreciable change in color. In the lower 8 inches, calcite cleavage faces show on broken surfaces with the size of the faces from three to five mm. across. The oolite spherules are from .02 inches to .03 inches in diameter and uniform in size and color. Above this 8 inch layer the oolite becomes a greyish white color and is weathered so that the oolite spherules become loosened from their matrix and can be picked up in the hand like loose shot. This characteristic of the weathered middle portion is noted at many other outcrops. The thickness of the weathered portion at this outcrop is 4 feet 6 inches. This bed is uniform both in size of spherules and in color. Above are 24 inches of grey hard oolitic limestone with the size of the spherules slightly larger than those of the lower parts. This increase in size is not noticeable except on close examination. Again the bed is quite uniform in size of oolites and color. The upper 4 inches of the oolite consists of chert and silicified

TABLE II

THICKNESS MEASUREMENTS OF THE SHORT CREEK OOLITE

LOCATION	THICKNESS IN FEET	REMARKS
NE NW 17, 29 N., 24 E.	5	Prospect hole
NW 36, 29 N., 23 E.	9	" "
SW 17, 29 N., 23 E.	5	" "
NW NW 19, 29 N., 23 E.	25	" "
NE NW 19, 29 N., 23 E.	5	" "
NW SE 17, 29 N., 23 E.	10	" "
SW NE 33, 29 N., 23 E.	7	" "
SE SW 18, 28 N., 23 E.	10	Miami Water Well
NW 31, 28 N., 24 E.	6	Outcrop
SE 19, 27 N., 24 E.	10	"
SE 22, 27 N., 24 E.	8	"
SW 24, 27 N., 24 E.	4	"
NW 9, 27 N., 25 E.	6	"
NW 35, 27 N., 24 E.	5	"
NE 13, 26 N., 23 E.	6	"
SW SW 20, 26 N., 24 E.	5	"

oolite. This bed is distinct from the oolitic limestone below; however, the silicified oolites are found only in the lower two inches of the bed with a gradual gradation upward into white chert. Above this bed is a thin layer of reddish clay succeeded by thick beds of chert from 12 inches to 24 inches in thickness. No oolites are found above the lower two inches of the lowermost chert bed mentioned above.

Indistinct cross-bedding can be seen on part of the weathered surface at this outcrop; however, no trace of it can be found on fresher surfaces. The uniform size of the oolite spherules no doubt masks the effects of current bedding. Stylolites are found in the upper part of the bed but they are not a prominent feature of the exposure. This is true of most of the other outcrops examined.

Silicification of the upper part is irregular and not always along the same zone. In some places as much as 18 inches of the upper part are silicified but these are limited in lateral extent. It is thought that most of the silicification is secondary, especially in the thicker portions, but the upper contact may represent precipitation of silica on the newly formed oolite and replacement of the calcareous oolite by silica almost immediately after deposition.

<u>NW, Sec. 35, T. 27 N., R. 24 E.</u> - This exposure is located on State Highway 10 approximately two miles south of the junction of this highway with U. S. 60, east of Wyandotte. The outcrop is seen in a large cut on the east side of the road (See figures 3 and 4). Again the basal contact is gradational upward from a grey limestone to a white oolitic limestone. The size of the oolites does not differ from that

Figure 3. Short Creek Oolite and overlying shale, east side Highway 10, Sec. 35, T. 27 N., R. 24 E.

Figure 4. Upper contact of Short Creek Oolite and overlying beds, east side Highway 10, Sec. 35, T. 27 N., R. 24 E.

of the above described location. This cut was made only a few years ago and the oolite bed does not show effects of weathering as markedly as older exposures. However, where the oolite bed is near the former surface and especially where moist, the middle portion of the bed again shows the loose oolites (Figure 5) which can be picked up. The color of the bed is grey to greyish white. Calcite cleavage faces are shown in the lower few inches and the upper part shows a sharp separation from chert beds which lie directly on the calcareous oolite with no oolite spherules in the chert (Figures 6 and 7). A nodular band of dark silicified oolite (Figure 8) one to two inches in thickness and several feet in length was found in the middle bed. The oolites showed no differences in size or arrangement within the silicified portion from the calcareous part outside (Figures 9, 10, and 11). The total thickness of the Short Creek at this outcrop is about five feet.

NW Sec. 31, T. 28 N., R. 24 E. - This outcrop is found on the west side of Spring River about one half mile below the bridge on State Highway 10 at Dripping Springs. A small anticlinal axis trending northwest-southeast crosses the river here and the Short Creek is lifted high enough to be exposed in the bluff and along the deep ravine which enters the river at this point. Good exposures are found in the ravine just east of the former Boy Scout camp, now a private residence, at a distance of about one hundred yards. The bed can be traced continuously on both sides of the ravine back to the bluffs along the river where the dip away from the axis of the anticline carries it below water level within a distance of a few hundred yards to the north and three-quarters of a mile

Figure 5. Weathered and detached spherules, Short Creek Oolite, Sec. 35, T. 27 N., R. 24 E.

Figure 6. Details of contact of Short Creek Oolite and overlying chert, Sec. 35, T. 27 N., R. 24 E.

Figure 7. Oolite-chert contact, Sec. 35, T. 27 N., R. 24 E.

Figure 8. Dark band of silicified oolite within the upper Short Creek, Sec. 35, T. 27 N., R. 24 E.

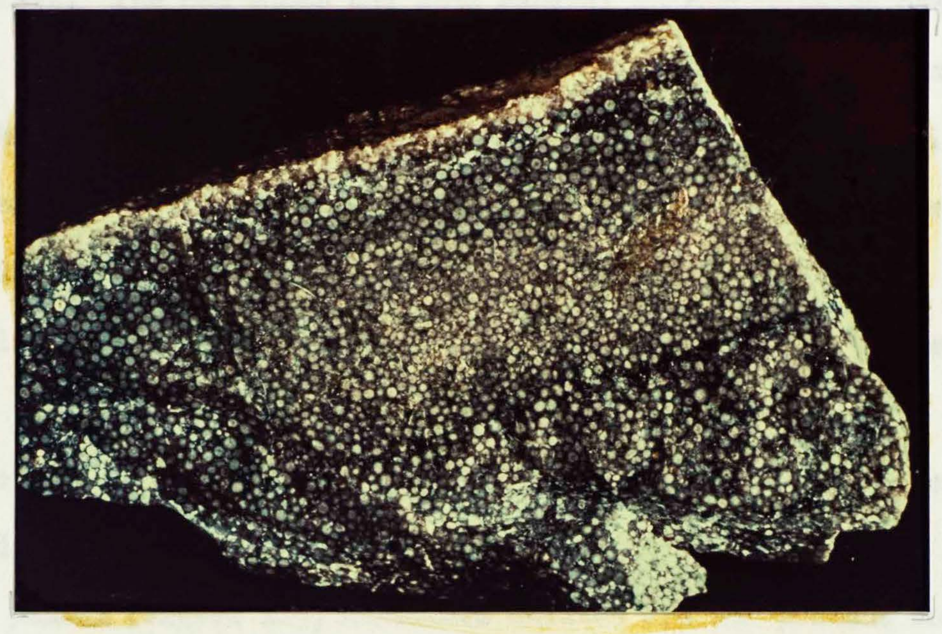

Figure 9. Detail of dark, silicified oolite band in upper Short Creek, Sec. 35, T. 27 N., R. 24 E.

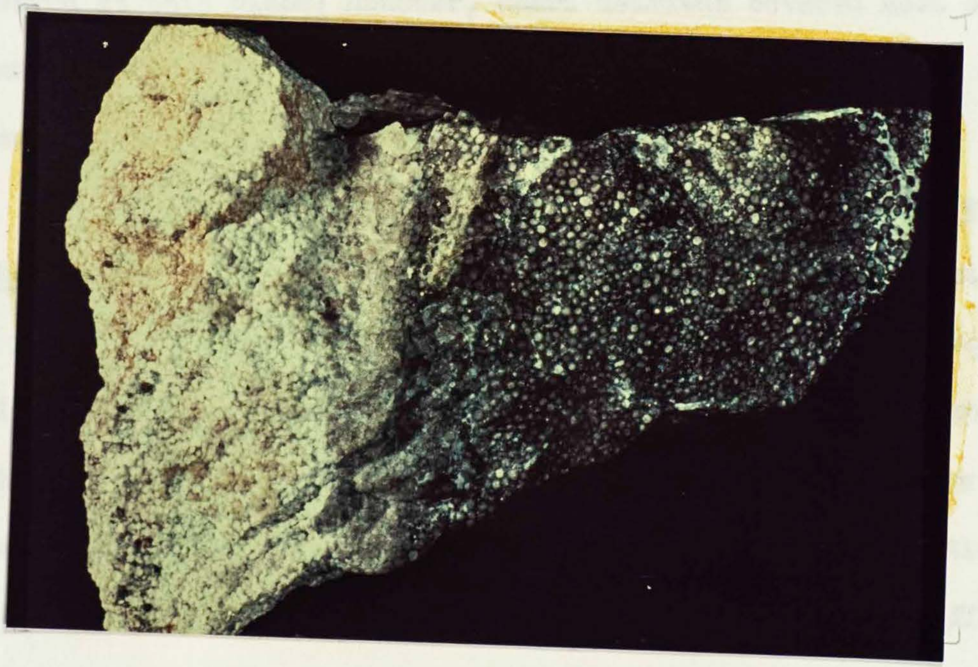

Figure 10. Silicified oolite, Sec. 35, T. 27 N., R. 24 E.

to the south. The average thickness of the Short Creek at this point is about 6 feet. The bed shows the same general characteristics described at other localities. The cleavage faces of calcite seem to be somewhat larger than usual but still less than one-quarter inch in general. The lower contact shows the usual gradation from limestone of a moderately crystalline character into oolitic limestone, and again the size of the oolites is the same as at other places. At one place in this location distinct cross-bedding was found on a weathered surface but when freshly broken no trace is apparent. The upper contact is sharply defined by chert beds. Oolite spherules are present in the lower half inch of the chert in places (Figure 12), elsewhere oolites are not present and dense chert is directly in contact with the oolitic limestone below. The weathering of the central portion of the oolite to loose particles was not observed at this place; however, chert detritus covered most of the slopes and obscured the outcrop in many places. This is the most northerly exposure in Ottawa County.

SE Sec. 19, T. 27 N., R. 24 E. (Twin Bridges, one mile west of Wyandotte on U. S. Highway 60). - This exposure is one of the best developed in Ottawa County. The Short Creek is found slightly above the normal level of Grand Lake on both the Neosho and Spring Rivers where they join to form Grand River. It extends up the Neosho River for about one mile before dipping under the water and probably extends upstream on Spring River for a half mile. (See Figure 2). However, the bluff on the Spring River side decreases very rapidly and the outcrop is lost in the flood plain deposits. The oolite here has a thickness of from 8 to ten

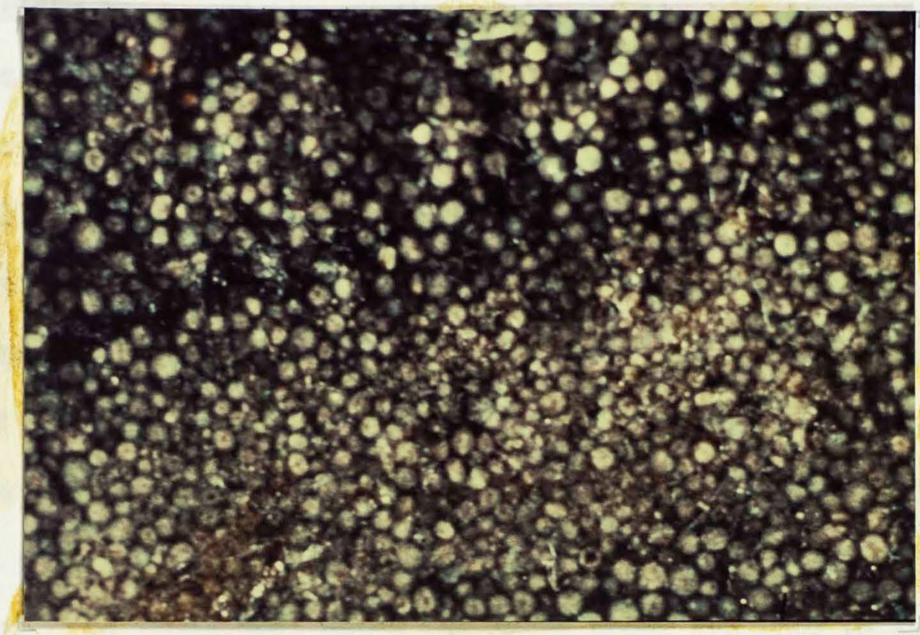

Figure 11. Enlargement of silicified oolite of Figure 10 (x5).

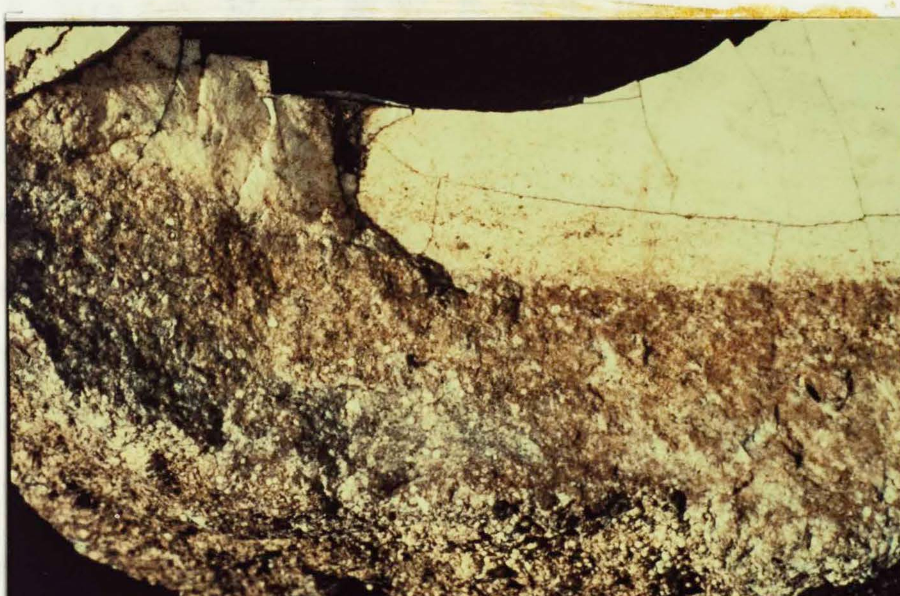

Figure 12. Contact of Short Creek and overlying chert showing oolite spherules in basal portion of chert. NW $\frac{1}{4}$ Sec. 31, T. 28 N., R. 24 E.

feet. The usual gradational contact from crystalline limestone to oolite occurs at the base, and the middle portion of the bed shows the shell-like weathering giving a somewhat rounded surface on the outcrop. The oolite is more firmly consolidated here, but the absence of the separated oolite grains is explained by the fact that the river floods the area several times each year thus removing the weathered material. The upper contact is sharply defined by a thin shale layer immediately above the oolite. This is succeeded by a chert layer about two inches in thickness followed by thin shale and thicker cherts above. Neither the shale in contact with the oolite nor the cherts above show any oolitic character. The limestones below the Short Creek are grey in color while the oolite bed is white and is easily seen along the bluff on the Neosho side upstream for some distance.

S. line Sec. 12, T. 26 N., R. 23 E. (One mile south and three miles east of Fairland). - Here the Short Creek is exposed in the bed of a small stream which crosses the east-west road leading toward Grand Lake. The oolite bed at this point is similar to the outcrop at Twin Bridges both in thickness and in character. Because of the more dissected terrain the outcrop is covered in many places with detritus but can be followed with some difficulty to the south and west until it disappears below the water of the lake. Again the gradational contact at the base and the rather sharp contact at the top of the oolite are characteristic. The thickness of the bed at this locality is from 6 to 8 feet. A quarry, now covered by water, located about three-quarters of a mile to the southwest used the Short Creek and other limestones in the Boone for agricultural lime.

Figure 13. Partially silicified oolite. Sec. 27, T. 27 N., R. 24 E.

Figure 14. Enlarged part of Figure 13. (x5)

SW SW, Sec. 20, T. 26 N., R. 24 E. - This outcrop is the most southerly examined in Ottawa County. The bed is found in a deep ravine leading up from Grand Lake and may be traced both north and south to the bluffs on the west side of Grand Lake where it becomes inaccessible for examination. The bed is rising to the south as it approaches the axis of the Horse Creek anticline and within a distance of one mile is lost in the flat land in the area away from the lake. This is within two miles of the south line of the county. It seems very likely that the bed can be found in Delaware County, as the thickness at the above outcrop is between 4 and 5 feet and the horizon is well below the top of the Boone so that the possibility of removal by pre-Mayes erosion is unlikely at this point. The bed exhibits the characteristics found at nearly all other outcrops with the possibility that the oolite spherules may be slightly larger but still less than .05 inches in diameter. Thus the remarkable uniformity of size of the oolites is exhibited from north to south in the county over a distance of 12 to 13 miles, and the same character of size is found at the type locality some 25 to 30 miles away. Cuttings from wells 8 to 10 miles west of the outcrop also show the same gradation of size, thus the maximum variation in size is less than .02 inches to .03 inches from the smallest to the largest.

Stratigraphic Relations

The upper contact of the Short Creek is apparently conformable everywhere in the Joplin-Miami area. The widespread occurrence of the oolite throughout the district, present in all exposures where its horizon is at the surface and not covered by soil or mantle rock and in hundreds of drill holes, indicates that any post-Short Creek erosion must have occurred after deposition of many feet of sediments over the oolite and therefore at a much later time. Moore, Fowler, and Lyden[15] have placed an unconformity at the base of their "J" bed which lies some 35 to 40 feet above the Short Creek oolite. The bed consists of a greenish-grey limestone, very glauconitic in many places, and contains an oolite member locally. This bed is now generally considered to be the base of the Warsaw. In places the pre-Warsaw erosion has removed intervening beds so that the "J" bed rests on the "M" bed with the "K" and "L" beds missing. In a quarry east of Fairland a glauconitic oolite bed (Figure 15) lying some 30 to 40 feet above the Short Creek (Figure 16) is tentatively correlated by the writer with the "J" bed of Fowler and Lyden.

The lower contact of the Short Creek is gradational from the non-oolitic limestone below at all places examined. No evidence of an unconformity could be found in the field. Examination of a limited number of well logs shows an interesting relationship of the thickness of the Boone above the Short Creek with that below. There is an inverse relationship of the thicknesses such that as the section of the Boone above the Short Creek thickens the section below thins a proportionate amount, or as the section above thins the section below thickens. It is admitted that this relationship of thicknesses may be more apparent than real, as improper or erroneous sampling could give the same result. However the amount of variation in thicknesses makes this possibility remote. If

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[15] R. C. Moore, G. M. Fowler, and J. P. Lyden, "Lead and Zinc Deposits of the Mississippi Valley Region," (Geol. Soc. Amer. Special Paper No. 24, 1939), pp. 1-12.

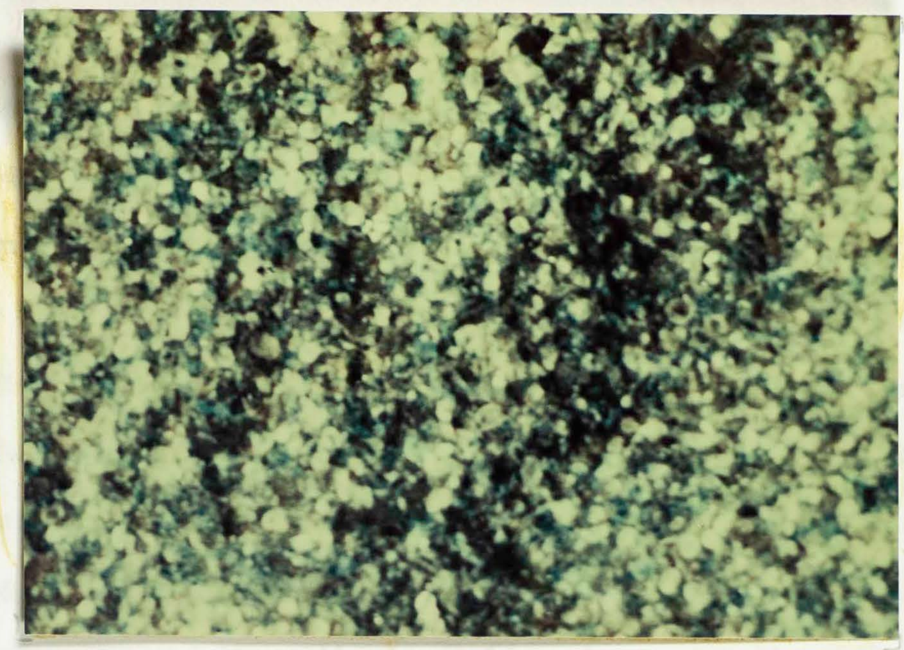

Figure 15. Detailed view of glauconitic "J" bed, quarry, Sec. 14, T. 26 N., R. 23 E. (x5)

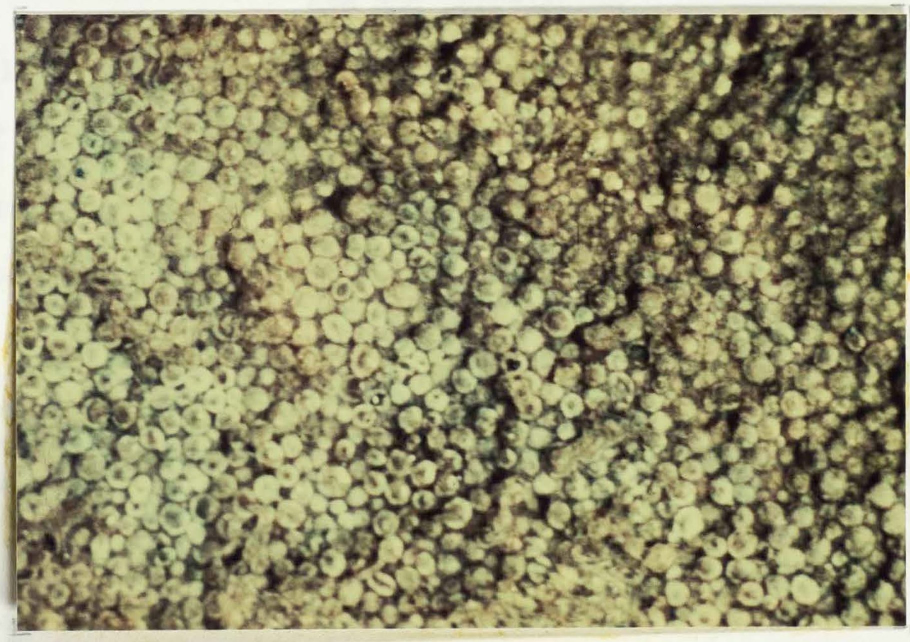

Figure 16. Detailed view of Short Creek Oolite ("M" bed), Sec. 13, T. 26 N., R. 23 E. (x5)

this is real, it may indicate the presence of an unconformity very near the base of the Short Creek. No truncation of the beds below was observed and probably would be difficult to see because of the absence of easily identifiable key beds in the section. A bed of limestone some ten to fifteen feet in thickness is found about 30 feet below the Short Creek and while this bed seems to be present in nearly all places, the interval between the two varies as much as 20 to 40 feet. Tenuous evidence seems to show that a thicker interval here coincides with a thicker interval of the Boone below the Short Creek. Too few wells have completely penetrated the Boone to justify definite conclusions as to the reality of this unconformity and the writer's field work was not directed toward this problem in time to make any contribution toward its solution.

Age and Correlation

Moore, Fowler, and Lyden[16], in their discussion of the stratigraphy of the Tri-State district as a part of the paper edited by Bastain (1939) summarize the Mississippian stratigraphy of the Tri-State region as follows:

> The total thickness of Mississippian rocks on the southwest flank of the Ozark uplift, which includes the Tri-State Mining district, is about 400 feet. Owing to erosion of varying amounts in pre-Pennsylvanian and subsequent time and to original variations, the thickness of these rocks in any one area is much less than the total maximum thicknesses of the individual formations.
>
> The stratigraphic subdivisions of the Carboniferous rocks which are recognized in the southwestern Ozark area are as follows:

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[16] R. C. Moore, George M. Fowler, and J. P. Lyden, "Tri-State District of Missouri, Kansas, and Oklahoma," Geol. Soc. Amer. Special Paper No. 24, Chap. I, pp. 1-12, (1939)

	Thickness feet
Carboniferous system	
Pennsylvanian subsystem	
Des Moines series	
Cherokee shale	
Shale, dark bluish, gray, brownish, and black. Clayey to sandy, containing sheets and lenses of medium- to fine-grained sandstone, thin discontinuous limestone beds and coal beds; generally absent in eastern part of Tri-State district; thickness up to about.	150
Important unconformity	
Mississippian subsystem	
Chester series	
Carterville or "Mayes" formation	
Shale, limestone, and sandstone, discontinuous, mostly filling solution hollows in underlying limestone, comprise the Carterville beds, recognized in the Joplin area; thickness, 0-50 feet; the so-called "Mayes limestone," consisting mostly of noncherty gray thin- to medium-bedded limestone is a fairly continuous formation in the Oklahoma-Kansas mining field; locally, as in the Miami syncline, contains ore deposits; thickness, 5 to about 80 feet	0- ± 80
Unconformity	
Meramec series	
St. Louis limestone	
Limestone, gray, dense, fine-grained; it is probable that this formation was formerly continuous over the Tri-State district but it has been eroded except in areas a short distance northeast and southeast of Joplin; it is possible that thin remnants may exist locally in the Oklahoma-Kansas mining field	0- ± 20
Unconformity	
Warsaw limestone (comprises upper part of the Boone limestone as this term is employed in the Tri-State area)	
Limestone, light-gray, medium- to coarse-grained, fossiliferous, mostly crinoidal, abundantly cherty in many places; beds mostly more than a foot thick; some beds dolomitic; contains ore deposits in some places. The	

following zones (Fowler and Lyden) are recognized in the Oklahoma-Kansas mining field.

B- Limestone and dolomite, light gray and brown; some white and blue chert; thickness variable on account of erosion. . . .	0-40
C- Chert, white and blue; gray to brown limestone; commonly more chert in basal 10 feet.	25-32
D- Chert and limestone; the chert is commonly white "cotton rock" but some of it is white and dense; limestone, light-brown; contains commercial ore bodies in some mines.	20-25
E- Chert and limestone; the chert gray and brown; limestone and locally brown dolomite; an important ore bed, containing chiefly galena	5- 8
F- Limestone, light brown; chert, white "cotton rock".	12-15
G- Limestone, gray and brown, mostly thin-bedded; chert, brown and gray to white; an important ore horizon.	10-12
H-Limestone, gray and brown; chert, brown and gray, in alternating beds mostly 2 to 5 inches thick; and important ore zone in many places	13-15
J- Limestone, brownish to very dark-gray, slightly greenish and shaly; contains some chert; very glauconitic; normal thickness about 5 feet but it is locally less than a foot, and depressions in underlying Keokuk limestone are filled with rock lithogically similar to zone J except that it is slightly more shaly than normal. Fowler and Lyden have found oolite locally in drill holes and underground workings in this horizon . . .	1-50
Total thickness of Warsaw limestone in the Tri-State district, 86 to 195 feet; normal average about.	125

<u>Unconformity</u>

Osage series (comprises middle and lower part of the so-called Boone limestone)

Keokuk limestone

Limestone, gray, medium- to coarse-grained, abundantly fossiliferous in most places; crinoidal; bryozoans common; chert light-gray to white in beds and nodules. On outcrop, four members can be differentiated readily in most places, in order from top downward, (a) Crinoidal limestone and chert, about 40 feet, (b) Short Creek oolite, about 6 feet, (c) Crinoidal limestone and chert, about 85 feet, (d) Grand Falls chert, 0 to 35 feet, discontinuous. The zones defined by Fowler and Lyden in the Oklahoma-Kansas mining field are as follows:

K- Limestone, gray, crinoidal; contains abundant nodules of chert; an important ore zone, locally absent; normal thickness	8-12
L- Limestone, gray, medium- to coarse-grained massive; massive gray chert or "cotton rock"; locally absent; normal thickness	25-30
M- Limestone, gray, the top 4 to 6 feet oolitic (Short Creek), but oolitic texture is mostly unrecognizable in areas of mineralization; chert occurs in large nodules; an important ore horizon in many places. In Oklahoma-Kansas mining field	8-22
In Oronogo, Missouri, mining field	60-85
N- Limestone, gray, massive; commonly white "cotton rock" chert and gray somewhat mottled chert, occurring locally in very large nodules (to 15 feet horizon diameter by a foot thick	20-25
O- Chert, gray, dense, in bands and round flat nodules; some limestone; an important "sheet-ground" ore zone; equivalent of upper part of Grand Falls chert.	8- 9
P- Chert, gray, in bands, and in large flat nodules; some limestone; mineralized locally	8-11
Q- Chert, gray, dense; and limestone, gray, massive; mineralized locally	17-18
Total thickness of Keokuk limestone, 80 to 130 feet; normal average about	110

Unconformity

Burlington limestone

Limestone, light-gray, coarse-grained, crinoidal, massive; contains white chert nodules and thin beds; fossiliferous; absent throughout all of mining area of Tri-State district, insofar as known, but present on its borders especially to east.	0- ±50

Unconformity

Reeds Spring limestone

Limestone, dark-bluish, medium- to fine-grained, thin to medium beds; abundantly cherty, the chert very dark, occurring as very irregular-shaped nodules and thin beds alternating with the limestone; in places, dolomitic; contains some ore deposits. This is zone R of Fowler and Lyden; its thickness southeast of the Tri-State area locally exceeds 100 feet but within the mining area it ranges from about 15-60

Unconformity (?)

St. Joe (or Pierson) limestone

Limestone, bluish-gray, fine-grained with disseminated crystalline calcite grains, medium-bedded, noncherty. The St. Joe limestone is developed typically to the south; the equivalent Pierson limestone is distinguished by its magnesian to dolomitic character and the presence of more or less common chert nodules. Both St. Joe and Pierson occur in the Tri-State district. Average thickness, about 20

Unconformity

Kinderhook Series

Northview formation

Shale, olive-green to brownish, calcareous; sandstone, soft, locally, fossiliferous, thin or absent in most of Tri-State district but in its vicinity attains thickness of more than 100 feet. Average. 5

Compton limestone

Limestone, gray to dove, very fine, dense; in thin somewhat nodular beds with calcareous shale partings; barren of ore deposits . . . 5-20

Unconformity

Chattanooga shale

Shale, black, fissile, hard; absent throughout Tri-State district, insofar as known, but borders it on west, south, and southeast. Grades locally into dark-gray shale 0-40

Important unconformity

Ordovician rocks; about 1200

.... The Keokuk limestone comprises bluish or bluish-gray fine, medium- and coarse-grained limestone and abundant chert. The limestone beds appear as comparatively even layers, some of which are only slightly crinoidal, others made up almost wholly of crinoidal remains. The beds range in thickness from less than a foot to 2 or 3 feet. The chert is mostly white to light-gray and occurs typically in the form of flat elliptical masses and as more or less continuous beds. In areas of deformation and mineralization much or all of certain zones appears to be replaced by chert. The Keokuk limestone is readily differentiated from the underlying Burlington by its fauna, especially by abundance of bryozoans which are almost entirely lacking in the Burlington beds. The Keokuk is separated also from the underlying Reeds Springs limestone by lithologic differences, both of the limestone and the chert, and by fossil evidence. The Keokuk limestone is overlain disconformably by the Warsaw limestone, the boundary as now recognized occurring about 40 feet above the Short Creek oolite. The Keokuk and Warsaw beds are very similar in lithological and faunal characters and are commonly separable only by determination of their position in relation to the thin glauconitic and phosphatic bed (J bed of Fowler and Lyden) which marks the base of the Warsaw. This zone in turn may be identified from study of its relation to the Short Creek oolite as a stratigraphic datum. In most parts of the Tri-State district, however, the glauconitic zone can be identified in drill cuttings more readily than the oolite.

The Keokuk limestone overlies the Burlington limestone disconformably in the eastern part of the southwestern Missouri Mississippian area. It rests disconformably on Reeds Spring limestone in the western part of this area which includes the Tri-State mining district. The Keokuk limestone is succeeded disconformably by the Warsaw limestone, or where Warsaw beds have been eroded by limestone of Chester (upper Mississippian) age, or by lower Pennsylvanian (Cherokee) shale and sandstone.

The average total thickness of Keokuk beds in the Tri-State mining district is about 110 feet; in adjacent part of southwestern Missouri it is commonly about 125 to 140 feet.

Named subdivisions of the Keokuk limestone are the Grand Falls chert, at the base, and the Short Creek oolite, near the top. The Grand Falls chert is an irregularly bedded mass of very dense "butcher knife" chert, mostly light-gray in color, which appears light-yellowish-brown or dark-brown in weathered exposures. Including beds below water level at Grand Falls, the type locality south of Joplin, Missouri, its thickness here measures 35 feet, but within a distance of half a mile or less to the west the chert disappears, possibly because of overlap against a local structural "high". Despite local discontinuity, the Grand Falls chert is identified over hundreds of square miles of territory in the Tri-State District. It is a zone of extensive sheet-ground mineralization in the Joplin-Webb City portion of the Tri-State district and is apparently identifiable in the deepest workings of some mines in the Oklahoma-Kansas mining field.

The Short Creek oolite is a light-gray massive oolitic limestone which rather commonly appears as a single bed 4 to 5 feet thick. It appears to be continuous throughout the southwestern Missouri area and in adjoining States wherever the proper stratigraphic horizon is present. It is one of the most valuable stratigraphic datum planes in the upper part of the Osage limestones. It is generally identified as belonging in the top portion of the M zone of Fowler and Lyden.

According to observations by Fowler and Lyden there is locally as much as 40 feet of beds above the Short Creek oolite that are assignable to the Keokuk limestone, the contact between Keokuk and Warsaw beds being drawn at the inferred horizon of disconformity at the base of the glauconitic sediments of Fowler and Lyden's zone J. The base of the J zone, that is basal Warsaw, locally extends downward to and possibly below the horizon of the Short Creek oolite.

No new information concerning the age of the Short Creek Oolite has been developed during the investigation and its assignment by Fowler and Lyden to the Keokuk member of the Boone formation is accepted.

CHAPTER IV

STRUCTURE

In preparing a structure map using the Short Creek as the datum, elevations were taken at frequent intervals along the outcrop using an aircraft altimeter and an aneroid barometer. Many bench marks and other known elevations within the limits of error of the instruments were available and in addition the surface of Grand Lake was very useful as a widespread datum level. All elevation readings were compared with a known elevation within thirty minutes or less so that the effects of pressure and temperature changes were minimized. All elevations taken by the above method were considered to be within a limit of error of five feet. Subsurface elevations were obtained from well logs and from published figures given by Weidman. In the case of wells drilled in recent years the surface elevation had been determined by an engineer's level and the elevation of the bed is considered to be within the five foot limit of error which might be caused by improper sampling. It is standard practice in this district to take samples of the cuttings at five foot intervals. In using the figures published by Weidman[17], determination of the surface elevation of the drill holes was done by

[17] S. Weidman, op. cit., 1932, p. 16.

spotting the locations on contour maps published by the U.S.G.S., which have a contour interval of ten feet. These maps are on a scale of 4" to the mile and thus show considerable detail. The topography of the northern part of the county covered by these maps is gently rolling and thus the elevations interpolated from the maps are considered to be within a limit of error of 20 feet and the elevation of the Short Creek within 25 feet.

In addition to the elevations taken on the Short Creek, the contact of the Mayes formation on the Boone was followed using Weidman's map and elevations were taken at intervals of one mile or less throughout the county. In taking these elevations along the contact no practical difference in determining the top of the Boone from that mapped by Weidman was found, and his location is considered correct. The contact is marked in many places by a chert pebble conglomerate above which no bedded cherts are ever found. Where the conglomerate is absent the top of the Boone can be distinguished by the uppermost chert bed, and where outcrops are covered by soil there is a distinct change in color from a slightly reddish soil of the Boone to a darker soil of the Mayes. The area of outcrop of the Mayes-Boone contact is generally flat or slightly rolling so that misplacing the contact by several hundred yards in horizontal location would seldom make more than ten feet difference in elevation. Where the slopes are more steep the contact is usually easily found because of the increased erosion and removal of the soil, especially along ditches on roadsides.

The interval between the top of the Boone and the top of the

Short Creek in the northern and central portions of Ottawa County, as shown by numerous well logs, varies between 110 and 145 feet with the modal interval of 120 feet. This interval was used to project the elevation of the Short Creek in subsurface. A limit of error of 25 feet was placed on these elevations.

Additional elevations were taken on the top of the Mayes and assuming an interval of 160 feet to the Short Creek, elevations were spotted and used only as a guide for contouring as it was realized the thickness of the Mayes varies from 20 to 60 feet, usually because of pre-Pennsylvanian erosion which in some cases in the mining district may have removed the Mayes entirely. Elevations obtained from the above datum were given a limit of error of 50 feet, and were used only in the western part of the county as a guide.

The structural relief of the Short Creek ranges from 1,200 or more feet above sea level in the southeastern part of the county to 450 feet above sea level in the northwestern part. (See Figure 17). The regional dip is generally northwesterly at a rate of 20 to 25 feet per mile. This is complicated by a series of gentle folds whose axes trend northeast-southwest, with dips on the flanks of 50 to as much as 150 feet per mile. In addition to these smaller folds three prominent structural features are present. These are the Horse Creek anticline, the Seneca syncline, and the Miami syncline.

In determining the structure of the Miami syncline and the Seneca syncline, sections and figures published by Weidman[18] and Fowler

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[18] S. Weidman, op. cit., 1932, p. 16.

and Lyden[19] were used to project the position of the Short Creek. The Miami syncline had been studied in the mining district where underground workings have cut it extensively. The structure of the Seneca syncline is a little more obscure in Ottawa County but interpretations based on stratigraphic sequence and dips of outcropping beds give some information.

The Horse Creek anticline, first named and described by Siebenthal[20], extends across the southern portion of the county. The fold starts a few miles southeast of Big Cabin in Craig County and trends northeastward to the mouth of Cowskin River to intersect the Seneca syncline. The axis of the fold is well exposed in the bluffs on the east side of Grand Lake at this point. From here the fold widens out and swings to the east, dying out east of Tiff City, Missouri. The dips of the beds on the north side of the fold in Ottawa County are in general from 150 to 200 feet per mile and merge with the south limb of the Seneca syncline. On the south side of the anticline the dips are much more pronounced, ranging from 5 to 10 degrees. Dips as much as 18 degrees have been reported farther south. The south limb of the fold merges into a syncline with a general east-west axis along the course of the Cowskin River, lying in Delaware County. The structure of this region was not studied in any detail by the writer. The axis of the fold plunges to the southeast and passes out of the county southeast of Afton. This

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[19] G. M. Fowler and J. P. Lyden, "The Ore Deposits of the Tri-State District," (Am. Int. Min. Metall. Eng. Tr., Vol. 102, 1932), pp. 225-229.

[20] C. E. Siebenthal, "Mineral Resources of Northeastern Oklahoma," (U. S. Geol. Survey Bull. 340, 1907), pp. 187-228.

broad anticline is responsible for the westward swing of the Mississippian beds in the southern part of the county. This fold is not only structurally but topographically the highest part of Ottawa County, the highest point in the county being reached in Sec. 27, T. 26 N., R. 24 E., with an elevation of 1,130 feet above sea level. At the point where the fold crosses Grand River the St. Joe limestone, Chattanooga shale, and upper part of the Cotter dolomite were exposed for a distance of almost a mile in the bluff and deep ravines on the east side of Grand River. This locality, which was the only exposure of these lower beds in Ottawa County, is now covered by the waters of Grand Lake.

The Seneca syncline is probably the most prominent structural feature of the extreme northeastern part of Oklahoma. It extends from a point west of Chouteau northeastward into Missouri near the town of Spurgeon. For most of its length Siebenthal[21] describes it "as a double or in places multiple fault letting down a block of Boone and younger beds into the Boone on either side. The width of the down-dropped block varies from 200 feet to more than 1500 feet, and with the strata on either side dipping more or less steeply toward the faulted block."

In Ottawa County the faulted character of the Seneca syncline is not pronounced and in most places actual faulting is absent or very small in magnitude with most the displacement due to folding. The synclinal character of the fold together with its faulted expression was well exposed in the bluffs on the west side of Grand River opposite the mouth of Cowskin River, but this is now completely covered by Grand

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[21] C. E. Siebenthal, op. cit., pp. 197-198.

Lake. Throughout most of its path across Ottawa County the syncline is somewhat obscure and marked only by slight changes in dip of the Boone along its axis. Near Seneca, Missouri, on the east line of the county, Weidman found that the fold has brought Cherokee shale down into its axis indicating as much as or perhaps more than 150 feet of displacement. Drill records and study of surface outcrops at this point indicate it is a synclinal fold and not a fault although small faulting may accompany the folding. Between the exposure on Grand River and the above mentioned place near Seneca the fold is marked usually by fracturing and slight dips in the Boone. The writer was unable to find the Short Creek exposed along the axis of the fold at any point although it should be present near Seneca in the synclinal fold there. The oolite is present less than two miles to the north where it has a thickness of 5 feet and failure to find it south of Seneca is probably due to the thick covering of chert mantle and soil which blankets the area making good outcrops a rarity.

The Miami syncline, a well-known feature of the Miami-Picher mining district, has been called the "Miami fault", "Miami trough", or the "Miami shear zone". It is undoubtedly a syncline with faulting occurring on both limbs in several places in the mining district. The syncline enters the county on the north line of Sec. 17, T. 29 N., R. 23 E., extending generally South 25° West and leaves the county one mile west of Afton. Surface indications of the fold are found just west of Blue Mound north of Picher where Weidman described the Bluejacket sandstone member of the Cherokee shale as being structurally some 200 feet lower than its outcrop on Blue Mound. The syncline is found in many mines with one of the best exposures in the Blue Goose mine southwest of Cardin. The dip of the limbs is quite variable ranging from a few degrees up to as much as seventy. The syncline extends from a point near Crestline, Kansas, southwestward into Delaware County for a distance of about ten miles. The position of the axis of the fold can be distinguished on aerial photographs in the southern part of the county and extending into Delaware County but the northern part of the fold is obscured by thick soil and alluvium. The axis of the syncline crosses the Neosho River just west of Miami and at times of extreme low water crumpled and broken strata of the Mayes can be found in the bed of the river. The Pennsylvanian beds in general do not show these contortions to the same extent; however, at the exposure west of Afton the beds including the Cherokee are highly folded so areas of more highly folded Pennsylvanian rocks elsewhere may be obscured by the absence of resistant beds in the shale. Siebenthal and others have suggested that solution of limestones in the Boone allowing slumping of the chert beds along a fault or fracture zone could account for the syncline. This theory has some merits; however, deep water wells drilled in the northeast part of Miami during 1944 along the east limb of the fold show equal displacement of the underlying Ordovician beds which would indicate that the fold is due to tectonic forces. The axis of the fold is undulating, dividing the fold into a series of basins which Fowler and Lyden[22] describe as elongate, varying in width from 1,200 to 2,500 feet and from two to three times this in length. The depth of the basins varies from 100 to 200 ft.

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[22] G. M. Fowler and J. P. Lyden, op. cit., 1932, p. 228.

In addition to the above mentioned larger structural features there are a number of smaller and more gently warped folds complicating the northwesterly dip of the Boone. These in general have an axial trend about North 45° East and dips on the limbs of from 50 to 100 feet per mile. Because of the regional westward tilting the northwest side of the small anticlines shows the steeper dips, the southeast side in many cases having dips less than 20 to 25 feet per mile. Most of these structures are not immediately apparent in the field but in several places along Spring River where the axis of a fold has been cut by the stream the dip of the northwest anticlinal limb is shown in the bluffs on the west side of the river. This is easily seen at Devil's Promenade bridge across Spring River east of Quapaw where the beds dip rapidly to the north in the form of a monocline or more likely a small syncline with the axis about one mile to the north. For purposes of identification this fold will be called the Lincolnville syncline after the abandoned mining camp in Sec. 31, T. 29 N., R. 24 E. which lies on the axis. This syncline is from one-half to one mile in width and extends North 50° East from south of Quapaw to the northeast corner of the county. The structural displacement is less than 100 feet.

A larger anticlinal fold is found to the south which in this discussion will be called the Dripping Springs anticline for its exposure south of the Dripping Springs bridge east of Miami on Spring River. The axis of this fold is in general marked by the course of Warrens Branch on the east side of Spring River. This fold is from one to two miles in width, broadening across the axis to the east. Dips are generally less than 50 feet per mile.

The southeast limb of the above mentioned anticline merges with the northwest limb of a syncline with an axis just north of Shawnee Branch extending to the northeast parallel to the axis of the Dripping Springs fold. This syncline is perhaps a mile in width with slightly sharper dips than the anticline to the north but still less than 100 feet per mile.

South of these folds the minor structures begin to be affected by the Seneca syncline and the Horse Creek anticline and their detail is lost. In the western half of the county insufficient points on the Short Creek datum level make detailed analysis of the structural picture extremely difficult. It is the opinion of the writer, however, that the minor folding of the Boone pre-dates the warping of the Pennsylvanian beds to the west. It is reasonably certain the Miami and Seneca synclines are younger than the above mentioned minor folds, and probably the Horse Creek anticline also ante-dates the folding. Whether the axial trend of these minor Mississippian folds coincides with the folds of the Ordovician beds below is not know at this time. An interesting indication that there may be some correlation of the two was shown when the writer had occasion to make a map showing the thickness of the Chattanooga shale in the northeastern counties of Oklahoma. Axes of thick and thin Chattanooga with a trend paralleling the axes of the minor folds of the Mississippian beds of Ottawa County were found. The conclusion the writer drew from this was that the almost peneplained surface of the Ordovician reflected the structure in such a way that when the Chattanooga sea flooded the area, thick sections of the shale indicated lower lands. The lower lands of the Ordovician surface may be the axes of anticlines and the higher lands axes of synclines. This surmise needs much further testing before acceptance.

CHAPTER V

SUMMARY AND CONCLUSIONS

The Short Creek Oolite is a definite mappable unit extending over a wide area of northeastern Oklahoma, southwestern Missouri, northwestern Arkansas, and southeastern Kansas. It occurs in the upper part of the Keokuk subdivision of the Boone formation. It may be distinguished from other oolites which lie near its stratigraphic position by the uniformity of texture, characteristics of weathering, absence of glauconite, and relatively constant thickness.

In Ottawa County the Short Creek serves as an excellent datum plane for structural mapping. Its outcrop may be followed easily except for local areas of obscurity caused by a covering of chert mantle (See Figure 1 in folder), and in subsurface the bed may be identified readily from cuttings. A structure map (Figure 17 in folder) drawn on the top of the Short Creek shows regional northwestward dip complicated by northeast-southwest trending folds with relatively gentle dips on the flanks. Three major folds, the Miami syncline, the Seneca syncline, and the Horse Creek anticline are mapped.

A chemical analysis shows the Short Creek to be very high in lime content. Several possible quarry sites exist where the stone may be obtained for industrial use as well as for agricultural purposes.

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