NAME AND ADDRESS	DATE
[redacted]	May 5, 1961
[redacted]	2/19/63
[redacted]	28 Dec '72

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

GEOLOGY OF THE TIAWAH AREA, ROGERS AND MAYES COUNTIES, OKLAHOMA

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

MASTER OF SCIENCE

BY

JACK L. TILLMAN

Norman, Oklahoma

1952

GEOLOGY OF THE TIAWAH AREA, ROGERS AND MAYES COUNTIES, OKLAHOMA

A THESIS

APPROVED FOR THE SCHOOL OF GEOLOGY

BY

[redacted]

[redacted]

ACKNOWLEDGMENTS

The writer wishes to express sincere thanks to Dr. Carl C. Branson for his generous assistance and constructive criticism both in the field and during the preparation of this report.

The writer is also indebted to the Oklahoma Geological Survey for furnishing aerial photographs and equipment and for providing assistance for field expenses.

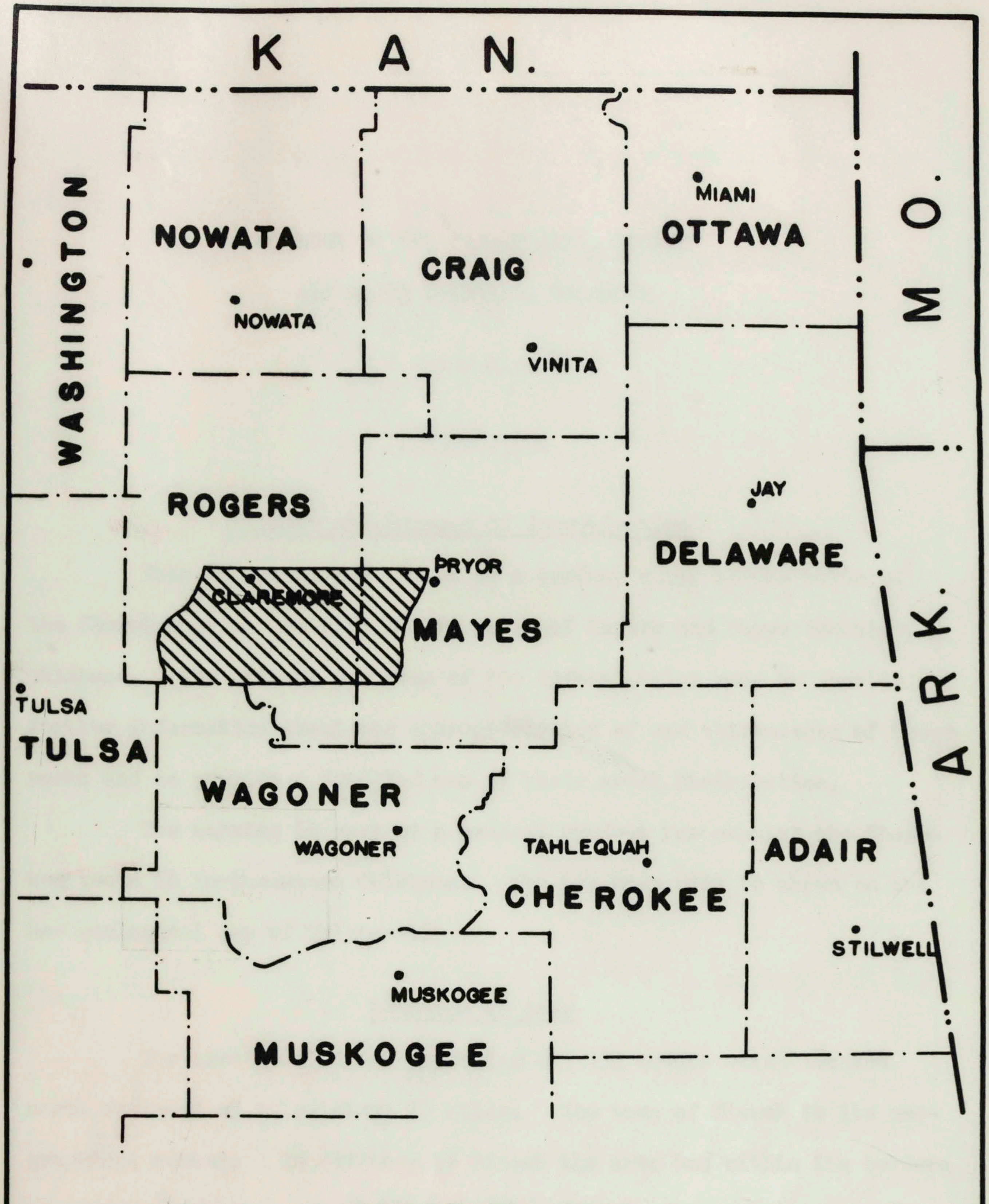
Grateful acknowledgment is made of fellowships granted to the writer by the California Oil Company and by the Superior Oil Company. Without them, neither graduate study nor the completion of this thesis would have been possible.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

PLATES

Shelved in Map Rom Case I Drawer 13I



LOCATION MAP

OF

TIAWAH AREA

FIGURE I

GEOLOGY OF THE TIAWAH AREA, ROGERS AND MAYES COUNTIES, OKLAHOMA

CHAPTER I

INTRODUCTION

Scope and Purpose of Investigation

This report is the result of a surface study of the units of the Cherokee group cropping out in parts of Rogers and Mayes Counties, Oklahoma. The primary purposes of the investigation were to provide further information about the characteristics of and thicknesses of these rocks and to provide a detailed map of their areal distribution.

The mapping is part of a general project for mapping the Cherokee rocks in Northeastern Oklahoma. The key beds will be shown on the new geological map of Oklahoma.

Location of Area

The area consists of approximately 250 square miles located north and east of Tulsa about 25 miles. The town of Tiawah is its geographical center. In addition to Tiawah the area has within its borders the towns of Catoosa, Verdigris, and Claremore. It can be entered from almost any direction by main roads. U. S. Highway 66 as well as Oklahoma Highways 88, 20, and 33 traverse the area. This road system is supplemented by many section line roads which make about 80 per cent of the area accessible by automobile. It is also served by the St. Louis and San Francisco and by the Missouri Pacific Railroads.

The area lies in Townships 20 and 21 north, Ranges 15, 16, 17, and 18 east. It is shown on the location map (Fig. 1).

Previous Investigations

The earliest geological work done in this area was by Smith.[1] His work was not published, but the results of his mapping were used in compiling the Geologic Map of Oklahoma[2] in 1926. Woodruff and Cooper[3] gave a brief description of the geology of Rogers County in 1928, as did Ireland[4] of Mayes County in 1930. In 1943 Oakes[5] worked in the area and mapped most of the units from the Chelsea sandstone to the Fort Scott limestone. Later, Austin[6] mapped the Tiawah limestone and Chelsea sandstone in part of the area in compiling his thesis on the Chelsea.

---

[1] C. D. Smith, "Geology of the Claremore Quadrangle," Unpublished manuscript map on file at the office of the Oklahoma Geological Survey, 1911.

[2] H. D. Miser, "Geologic Map of Oklahoma," U. S. Geological Survey, 1926.

[3] E. G. Woodruff and C. L. Cooper, "Geology of Rogers County," Oklahoma Geological Survey, Bulletin 40-U, p. 7, 1928.

[4] H. A. Ireland, "Geology of Mayes, Ottawa, and Delaware Counties," Oklahoma Geological Survey, Bulletin 40-NN, 1930, pp. 26-27.

[5] Malcolm C. Oakes, "Broken Arrow Coal and Associated Strata," Oklahoma Geological Survey, Circular 24, 1944.

[6] R. B. Austin, "The Chelsea Sandstone and Associated Strata, East and Northeast of Claremore, Oklahoma," Unpublished Masters Thesis, University of Oklahoma, 1946.

Present Investigation

The field work for this report was begun in July, 1951, and was carried on intermittently until May, 1952. The earlier mapping in the area was thoroughly checked and refined where necessary. A number of units not previously mapped were traced across the area.

The mapping was done on a scale of 3.1 inches per mile, which was the average scale of the aerial photographs used. The photographs in stereoscopic pairs were used both in the field and in the office. Acetate sheets were placed over the photographs, and roads and drainage were traced directly to the acetate. During the course of stereoscopic study in conjunction with field study the geological data were sketched in. When the writer had checked and rechecked his work, the mapping was transferred to a large base map on the same scale which had been prepared.

Reliable exposures in the area are few and most of them are found in road-cuts, however, much walking was done between roads for two reasons: (1) to reduce distances between control points to a minimum, and (2) to check when it was thought that sketching on the stereoscopic image might prove erroneous.

In a region where stratigraphic units change thicknesses and characteristics in short distances or grade laterally or vertically into another type of rock, it is desirable to secure as much detailed information as possible. The use of a soil map of Mayes County failed to supplement the writer's field studies; however, drillers' logs were valuable indirectly in locating several key exposures. This was accomplished by plotting the first hard rocks encountered in drilling and their depths. The writer was well enough acquainted with the area to be reasonably certain of what unit was reported. From the depth of the rock, the location of the well, the regional dip, and the topography, a calculation was made of where the rock reached the surface. A search would then be made; often with good results. Of particular interest are the limestones, which are difficult to locate, but are important in determining the identity of associated sandstones.

Sections were measured with the aid of a hand level and a steel tape. It was not possible to measure a completely continuous section across all the strata mapped. Measured sections with overlapping portions that could be correlated were used for a generalized section. The thickness of rocks in large covered areas was calculated mathematically. This was done by using the distance from one known point to another, the regional dip, and the difference in elevation.

Topography and Drainage

The topography of the region is that of a low undulating plain, broken at places by gently sloping cuestas and small buttes which rise above the plain. This results from differential erosion of more resistant sandstone and limestone layers in soft shale by subsequent streams. Although most of the streams are adjusted to the regional dip and occupy the positions of the less resistant rocks, a few of them follow fault traces for short distances. Since the regional dip is in a west-northwest direction at an average dip of about 40 feet per mile, the cuestas have eastward facing escarpments. The Bluejacket sandstone forms the most prominent of these. It rises 200 feet above a shale valley in the west half of T. 21 N, R. 18 E.

Fig. 2. 200 foot high Bluejacket sandstone ridge in sec. 8, T. 21 N., R. 18 E.

The total relief of the area is about 300 feet. Elevations range from about 550 feet where the Verdigris River flows from the area to about 850 feet on top of the Bluejacket ridges just mentioned.

The major drainage of the area is that of the Verdigris River and its three principal tributaries: Dog, Bird, and Spunky Creeks. The portion of the area which lies east of the Bluejacket sandstone outcrop is drained by Seminole, Pryor, and Chouteau Creeks. This drainage system eventually empties into Grand River to the east.

CHAPTER II

STRATIGRAPHY

Introduction

The rocks of the Cherokee group belong to the Desmoinesian series of Pennsylvanian age. The Cherokee in the area under discussion lies unconformably upon the Atoka series. It is apparently conformable with the Fort Scott limestone, which is the basal member of the Marmaton group and marks the top of the Cherokee group.

Until the present program for mapping the Cherokee group in Oklahoma was started, it was best described in Kansas, where it is predominantly shale. The sandstones and limestones are fewer in number and considerably thinner. In the Tiawah area it would be misleading to refer to this sequence of rocks as the Cherokee shale, because of the increased amount of coarser clastics.

In this area it consists of approximately 25 per cent sandstone. Many of the shale intervals are quite arenaceous. The limestones in the upper part of the Cherokee are silty.

Rocks of the same class in the Cherokee are difficult to distinguish. The limestones have much the same appearance and characteristics. The sandstones, although they vary greatly as units, all have certain common characteristics. They are quartzose and at most places contain mica and iron. Unlike the limestones, which are abundantly fossiliferous, the sandstones lack invertebrate fossils. However, many of them contain plant fragments.

The characteristics of the Cherokee sediments are ascribed to crustal unrest during the Pennsylvanian period. This unrest resulted in oscillation of the seas with repeated alternations of transgression and regression. The resulting sediments are a repetition of similar sequences of beds and lithologic characters. This is called cyclic sedimentation and the sequence of lithologic units that resulted from one advance and retreat of the sea is termed a cyclothem.

In Kansas, fifteen cyclothems have been recognized in the Cherokee. They are better developed there than in the Tiawah area, which is closer to the hinge line between what was the interior platform and the McAlester basin to the south. The cyclothems of Kansas were described by Abernathy[1] who states:

The phases of the normal cyclothem in southeastern Kansas is as follows:

Calcareous shale..............	0.8
Limestone.....................	0.7
Gray shale....................	0.6
Black shale...................	0.5
Coal..........................	0.4
Underclay.....................	0.3
Sandy shale...................	0.2
Sandstone.....................	0.1
Unconformity	

The lower phases of the cyclothem (0.1, 0.2, 0.3, and 0.4) are of continental origin, while the upper phases (0.5, 0.6, 0.7, and 0.8) are of marine origin. The continental sediments are the local accumulations that were derived by the erosion of a near-by land

[1]George A. Abernathy, "The Cherokee Group of Southeastern Kansas," Kansas Geological Society, Eleventh Annual Field Conference, 1937, p. 19.

surface. The sediments were carried by streams and deposited in the low places of the basin. There is no transition between the continental and marine phases. The coal bed, the highest phase of the continental sediments, makes a sharp contact with the overlying black shale, the lowest phase of the marine sediments. Phases 0.5, 0.6, 0.7, and 0.8 are the result of the normal advance of the sea upon a continent. The beds of black shale and gray shale (phases 0.5 and 0.6) represent the deposits formed by an encroaching sea. The limestone phase (0.7) represents the time of maximum flooding of the sea. The shale above the limestone (phase 0.8) represents the sediments deposited during the retreat of the sea in the normal sedimentary cycle.

The units covered in this report will be described in descending order, from youngest to oldest, which is approximately the order in which they were mapped.

Fort Scott Limestone

The Fort Scott limestone, named by Swallow[1] after the town of Fort Scott, Kansas, splits into two members. Only the lower Fort Scott is present here and it correlates with the Blackjack Creek limestone of Kansas. This limestone is dense, impure, massive-bedded, and fossiliferous. It apparently thickens from north to south across the area from about 5 to 8 feet. A good exposure of its entire thickness is to be seen in Bird Creek at the southwest corner of sec. 18, T. 20 N., R. 15 E. It is a light gray on fresh exposures but weathers tan.

Interval from the Fort Scott Limestone to the Breezy Hill Limestone

The rock of this interval is 4 to 5 feet of hard, black, fissile shale which contains phosphatic nodules and at many places is jointed.

---

[1] G. C. Swallow, "Preliminary Report on the Geological Survey of Kansas," Kansas Geological Survey, 1866, p. 25.

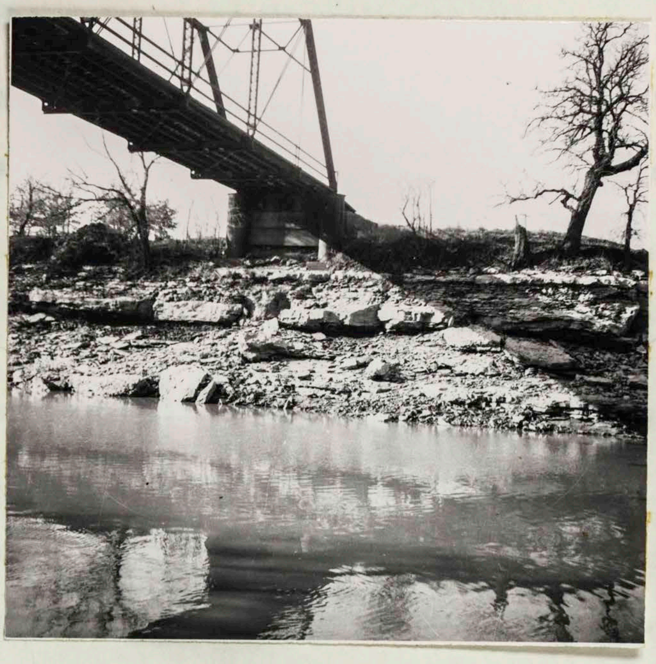


Fig. 3. Exposure of Fort Scott limestone, black shale interval, and Breezy Hill limestone on Bird Creek, sec. 18, T. 20 N., R. 15 E.

Fig. 4. Breezy Hill limestone on Highway 20, 3.3 miles west of Claremore. The pick marks the location of the Iron Post coal.

The presence of the nodules, which range in size up to about one inch in diameter, offers the best means of identifying the base of the Fort Scott. The lower few inches of this shale contains badly crushed, partially pyritized fossils at places.

Breezy Hill Limestone

The Breezy Hill limestone was named by Pierce and Courtier[1] from exposures at Breezy Hill near Mulberry, Kansas. It is gray on a fresh exposure, but weathers brown to buff. It is compact, finely crystalline, silty, and contains fossils throughout, but is most fossiliferous in its upper half. The lower half commonly has dark gray splotches which contrast sharply with the overall color. The thickness of the Breezy Hill is fairly uniform, being 10 to 11 feet across the area. In the southern part of the Tiawah area, there is a splitting off of the upper two feet by the introduction of a one foot bed of hard gray fissile shale. This was first noticed by the writer on State Highway 33 just west of Spunky Creek in the northwest 1/4 of sec. 5, T. 19 N., R. 15 E. It is also present in the bank of Bird Creek 150 yards southeast of the bridge in the southwest 1/4 of sec. 18, T. 20 N., R. 15 E.

Interval from the Breezy Hill Limestone
to the "Squirrel" Sandstone

Immediately below the Breezy Hill limestone is a dark gray,

---

[1] W. G. Pierce and W. H. Courtier, "Geology and Coal Resources of the Southeastern Kansas Coal Field," Kansas Geological Survey, Bulletin 24, 1934.

fissile shale followed by 7 to 13 inches of coal which was named the Iron Post coal by Howe.[1] The shale is not present in the south part of the area. The coal is persistent. It has been locally mined for private use, but is too thin for commercial production. An underclay is found below the coal and attains a thickness of about 15 inches.

Below the underclay of the Iron Post coal, the rocks are composed chiefly of a tan to gray shale which locally contains a thin black, fossiliferous shale along with a blue shale which weathers to a clay. In this facies it is about 15 feet thick. To the south it thickens and contains more silt in addition to a siltstone and a three and one-half foot bed of tan micaceous sandstone containing plant fossils.

"Squirrel" Sandstone

This sandstone is referred to in subsurface as the "Squirrel" or "Prue". The drillers call it the "Squirrel" because of its habit of "jumping around" in well logs. Its name was first mentioned in print by Green.[2] The "Squirrel" sandstone varies greatly in both thickness and characteristics. From place to place, it varies from a sandy zone of a foot or less to a bed 30 or more feet thick. It is a medium-grained, tan, crumbly, micaceous, and cross-bedded sandstone with shale lenses. At places it grades into a massive, medium-grained, dark ferruginous sandstone which may or may not be well indurated.

The outcrop of the "Squirrel" follows closely the course of the

---

[1]W. B. Howe, "Bluejacket Sandstone of Kansas and Oklahoma," Bulletin of the American Association of Petroleum Geologists, vol. 35, 1951, p. 2092.

[2]F. C. Green, "Oil and Gas Pools of Western Missouri," Missouri Bureau of Geology and Mines, Biennial Report No. 57, 1933, p. 16.

Fig. 5. "Squirrel" sandstone only 14 inches thick with an undetermined thickness of shale below. Northwest 1/4 sec. 23, T. 21 N., R. 15 E.

Fig. 6. "Squirrel" sandstone about 25 feet thick at the type section of the Verdigris limestone. Sec. 17, T. 20 N., R. 15 E.

Verdigris river in the northwest part of the area and forms rolling broad hills which rise above the river alluvium. These hills blend with and make extensions to those formed by the Breezy Hill and Fort Scott.

Interval from the "Squirrel" Sandstone to the Verdigris Limestone

The rocks of this interval consist of gray and tan, fissile shales which are silty at places. Generally, much of the interval is covered so that no where was it seen in its entirety. It varies from 4 feet to about 25 feet.

Fig. 7. Interval between the "Squirrel" sandstone forming hill and the dip slope of the Verdigris limestone is 4 feet. Sec. 35, T. 21 N., R. 15 E.

Verdigris Limestone

The name of this unit first appeared in print in 1928.[1] Originally it was named by Smith[2] from exposures at the Verdigris River. In addition, he designated the place for the type section which appears in this report. The Verdigris limestone is the equivalent of the Ardmore limestone of Missouri. According to R. C. Moore,[3] the name Ardmore limestone has priority, but Verdigris limestone has been more used.

The Verdigris is a compact, finely crystalline, extremely fossiliferous unit. From a dark gray on a fresh exposure, it quickly weathers to a light buff or a reddish brown, with more resistant fossils etched in relief. Upon further weathering it becomes porous and light in weight. It contains silty and argillaceous impurities. In the north 1/2 of sec. 26, T. 21 N., R. 15 E. on the east bank of the Verdigris River, many Indian arrow heads and other artifacts may be collected. The Indians made them there from chert which is locally present in the Verdigris limestone.

Normally, the lower 2 to 4 feet of this rock is all that is found in an outcrop. This lower part is best exposed in strip pits. An exposure of its entire thickness of about 12 feet is rare. Herein is a measured section at Smith's proposed type section of the Verdigris limestone. It is 3 miles southwest of Verdigris, Oklahoma, in the south bank of the Verdigris River at the location of the old U. S. Highway 66

---

[1] C. L. Cooper, "Proceedings of the Oklahoma Academy of Science," <u>University of Oklahoma Bulletin</u>, Vol. 7, 1928, p. 161.

[2] C. D. Smith, op. cit.

[3] R. C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," Kansas Geological Survey, Bulletin 22, 1936, p. 56.

bridge, southeast 1/4 of sec. 17, T. 20 N., R. 15 E.

Bed		Feet
3	"SQUIRREL" sandstone, massively cross-bedded, buff, micaceous..	34.0
2	Shale, gray..	14.0
1	VERDIGRIS:	
	Limestone, massive, dark gray, fossiliferous..	4.5
	Shale, soft..	0.7
	Limestone, gray, fractured......................	0.7
	Shale, weathered.................................	0.8
	Limestone, massive, gray, fossiliferous, base covered..	5.3

The following fossils were collected from the Verdigris limestone along the bank of the creek in the east-central part of sec. 35, T. 21,N., R. 15 E.:

- Composita subtilita (Hall)
- Juresania nebrascensis (Owen)
- Dictyoclostus americanus Dunbar and Condra
- Echinoconchus semipunctatus (Shepard)
- Marginifera muricatina Dunbar and Condra
- Neospirifer cameratus (Morton)
- Fenestrellina mimica (Ulrich)

The following fossils were collected from the Verdigris limestone at a strip pit in the northeast 1/4 of sec. 33, T. 20 N., R. 15 E.:

- Lophophyllidium profundum (Edwards and Haime)
- Neospirifer cameratus (Morton)
- Marginifera muricatina Dunbar and Condra
- Composita subtilita (Hall)
- Mesolobus mesolobus (Girty)
- Dictyoclostus portlockianus (Norwood and Pratten)
- Dictyoclostus americanus Dunbar and Condra
- Derbyia crassa Meek and Hayden

Interval from the Verdigris Limestone to the Chelsea Sandstone

Below the Verdigris limestone is about 5 feet of hard, black, fissile shale containing phosphatic nodules. Upon close examination this shale is found to contain fossils and pyrite. The iron from the pyrite causes the weathered surface to be a yellow brown. The remainder of this interval down to the Broken Arrow coal is variable. It is composed of a gray shale containing large spheroidal calcareous concretions in the south and has a thickness of about 18 feet. It gradually thickens to the north until the total interval from the Verdigris to the Broken Arrow is some 45 feet. As the shale interval thickens, it grows progressively more silty. An 8 foot sand is developed in the north and may be seen 150 yards east of the northwest corner of sec. 8, T. 21 N., R. 16 E.

The Broken Arrow coal is a consistent unit and has been mined commercially across much of the area. It is fairly uniform in thickness at about 20 inches. South of the Verdigris River its properties are more desirable than to the north where the coal readily crumbles upon being exposed. For detailed information on the Broken Arrow coal the reader is referred to the work of Oakes.[1]

Below the Broken Arrow coal lies a foot or two of underclay followed by a compact, finely crystalline, fossiliferous limestone. The limestone appears to be present throughout the area, but may be in the form of one or two layers. It is a single layer of 19 inches where it is exposed in a strip pit in sec. 26, T. 21 N., R. 15 E. In sec. 28, T. 20 N., R. 15 E. it presents itself as an upper limestone of 16 inches, separated by 33 inches of shale from another limestone layer of 14 inches.

---

[1] Malcolm C. Oakes, op. cit.

Fig. 8. About 3 feet of Verdigris limestone underlain by hard black shale and softer gray shale in strip pit. Sec. 28, T. 20 N., R. 15 E.

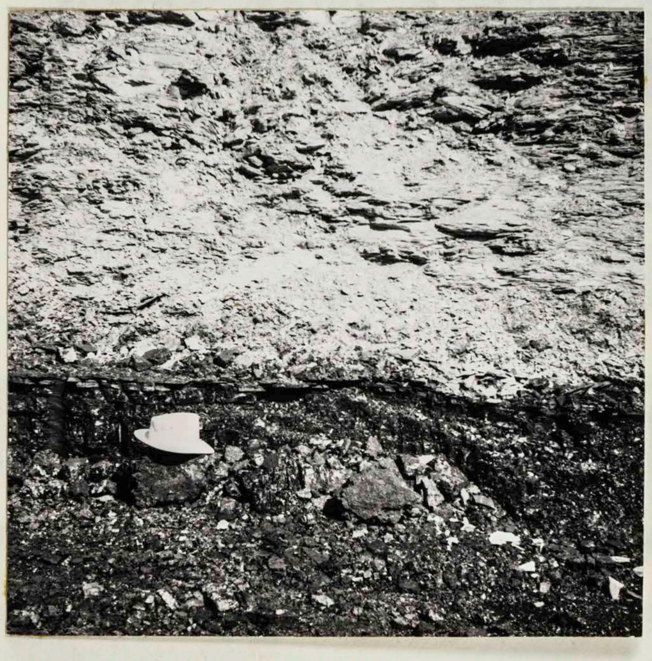


Fig. 9. Gray shale containing large calcareous concretions up to 1 foot in diameter. Below is 20 inches of Broken Arrow coal. Strip pit in sec. 28, T. 20 N., R. 15 E.

This limestone is dark gray and weathers brick red. It contains a considerable amount of silt. Oakes[1] was the first to mention this bed. It has since been called the McNabb[2] limestone.

The following fossils were collected from the McNabb limestone 50 yards north of the McNabb Coal Company powder house in sec. 28, T. 20 N., R. 15 E.:

Mesolobus mesolobus (Norwood and Pratten)
Neospirifer cameratus (Morton)

Fig. 10. McNabb limestone in sec. 28, T. 20 N., R. 15 E.

Below the McNabb limestone is a sequence of shales and silty shales with a few thin sandstone lenses. The most prominent of these lenses is just a few feet below the McNabb. It thickens at places to 8 feet or more of thin-bedded, tan, micaceous sandstone. The remainder

---

[1] Ibid., p. 11.

[2] John H. Gatchell and L. E. Fitts, "Tulsa to Spavinaw," Tulsa Geological Society, Field Trip Guide No. 3, 1950, p. 23.

of the approximately 50 to 75 feet from the McNabb to the Chelsea sandstone is covered throughout.

Chelsea Sandstone

The Chelsea sandstone was named by Ohern[1] from outcrops near Chelsea, Oklahoma. Its name first appeared in print in 1927.[2] It is one of the most prominent sandstones in the area. At many places it forms an escarpment where softer rocks below have been eroded. It caps outliers near the town of Tiawah which are over 150 feet high.

The Chelsea sandstone is composed of two lithologic zones which make a total thickness of 65 feet, more or less. The lower zone is massive, coarse, darkly ferruginous, and excessively cross-bedded. It varies from extreme hardness to friability. This zone commonly supports a dense growth of trees and has a thickness of from 25 to 45 feet; however, locally it may extend well into the irregularly bedded phase above and attain a thickness of 60 feet or more. The hill on which the Claremore Country Club is built was caused by a local thickening of the massive phase which grades laterally into thin-bedded sands and silty shales. This is in northwest 1/4 of sec. 20, T. 21 N., R. 16 E.

The upper portion of the Chelsea sandstone forms a gentle sloping to flat grass covered prairie. Due to the nature of the topography and of the underlying rocks its upper boundary is covered throughout the area

---

[1] D. W. Ohern, "Geology of the Nowata and Vinita Quadrangles," Unpublished Manuscript on file at the office of the Oklahoma Geological Survey, 1914.

[2] G. D. Clark and C. L. Cooper, "Geology of Kay, Grant, Garfield and Noble Counties," Oklahoma Geological Survey, Bulletin 40-H, 1927, Fig. 3.

Fig. 11. Chelsea sandstone capped outlier immediately west of the town of Tiawah.

Fig. 12. Top of the massive-bedded phase of the Chelsea sandstone in northwest 1/4 of sec. 6, T. 20 N., R. 16 E. Notice the very uniform pronounced cross-bedding.

It is believed to vary from 15 to 30 feet in thickness. From what could be observed in creek banks, it appears to be a series of thin-bedded, tan, micaceous sandstone lenses which grade laterally and vertically into silty shales. In mapping the top of the Chelsea, it was necessary to examine the soil characteristics across much of the area.

A coal exists, at least locally, in the top phase of the Chelsea sandstone. This was examined in a creek bank 100 feet north of the road in the southeast 1/4 sec. 36, T. 21 N., R. 15 E. Here it has developed to a thickness of 2 feet, overlain by silty shale and underlain by an underclay and an 11 foot series of thin sandstones and silty shales to the top of the massive Chelsea. Hobbs[1] reports a coal of 9 inches in the same stratigraphic position in T. 19 N., R. 15 E. Possibly this is the same coal.

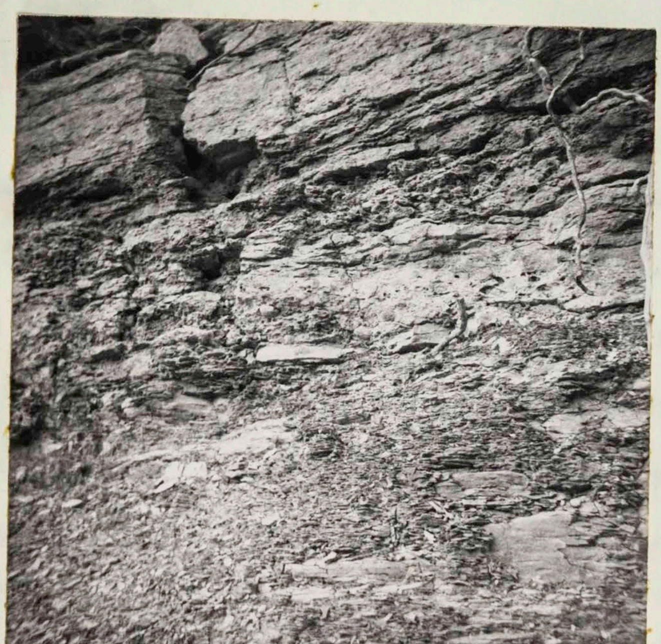


Fig. 13. Conglomeratic base of Chelsea sandstone overlying gray-black shale in sec. 4, T. 21 N., R. 17 E.

[1]Mark Hobbs, personal communication, August, 1951.

The best exposure of the base of the Chelsea sandstone is in sec. 12, T. 21 N., R. 16 E., 2-1/2 miles east of Claremore in a road-cut on Highway 20. This is the proposed type section. The undulating base as well as the rapid change in interval between it and the Tiawah limestone suggests an erosional period prior to Chelsea deposition. A coarse pebble conglomerate is present in its base at places, as on top of a Chelsea outlier west of Tiawah in secs. 27, 34, and 35, T. 21 N., R. 16 E.

Interval from the Chelsea Sandstone to the Tiawah Limestone

The rocks of this interval consist of gray-black, fissile shale to gray, silty shale. The chief characteristic of this interval is its abrupt and pronounced change in thickness. It averages about 5 feet, but varies from 2 to 15 feet.

Tiawah Limestone

The Tiawah limestone was named by Lowman[1] because of its excellent development in the hills about the town of Tiawah. It is compact and fossiliferous like most of the limestones in this section. On a fresh surface its color is gray and on exposure turns buff. It is referred to in subsurface as the "Pink"[2] limestone, because pink calcite is present in quantity. On continued exposure, it weathers rapidly to a

[1] S. W. Lowman, "Lower and Middle Pennsylvanian Stratigraphy of Oklahoma East of the Meridian and North of the Arbuckle Mountains," Tulsa Geological Society Digest, 1932, unnumbered page.

[2] L. E. Fitts, Jr. and R. A. Brant, "Pennsylvanian and Mississippian Rocks of Eastern Oklahoma," Tulsa Geological Society, Field Trip Guide, 1946.

gray, iron stained clay. At some places where the stratigraphic sequence indicates Tiawah limestone, only a bed of clay about 3 feet thick is present. Due to this rapid and complete weathering the Tiawah limestone could not be continuously mapped.

Fig. 14. Base of Chelsea sandstone and Tiawah limestone 1/2 mile east of type section.

The best exposure was found in a road-cut along Highway 20 east of Claremore and is the proposed type section of the Tiawah limestone and of the Chelsea sandstone. The section was measured 0.1 mile east of southwest corner sec. 12, T. 21 N., R. 16 E.

Bed		Feet
12.	CHELSEA sandstone, massive, cross-bedded, coarse, red-brown	31.0
11.	Shale, hard, black to gray	3.0
10.	Ironstone, hard, gray	0.25
9.	Shale, soft, fissile, gray	1.5
8.	TIAWAH limestone, hard, fossiliferous, gray with dark spots, weathers reddish brown	6.3
7.	Coal (TEBO?)	0.02
6.	Underclay, gray	0.3

Bed		Feet
5.	Shale, hard and black in lower part with phosphatic concretions, gray in upper part..............................	2.5
4.	Siltstone, gray, hard..	0.2
3.	Shale, fissile, gray..	5.0
2.	"WHITE" sandstone, fine grained, micaceous, light gray..	5.6
1.	Shale, medium hard, fissile, gray..............................	14.0

The Tiawah limestone varies in thickness, but averages about 5 feet.

Interval from the Tiawah Limestone to the Taft Sandstones

Below the Tiawah limestone lies a hard gray to black fissile shale which contains phosphatic concretions. Its thickness is at most places about 2.5 to 3 feet. It is underlain by a 4 to 8 foot gray shale which rests upon a sandstone of variable characteristics. This sandstone was first described by Austin,[1] who called it the "White" sandstone, because of its white appearance on a fresh exposure. At many places where it is exposed it is fine-grained, light gray, medium hard, and may or may not contain small brown specks. At more localities, it is medium-grained, buff to darkly ferruginous, and hard only where its iron content has formed a crust on its surface. It is because of this more common appearance and its relationship to the sandstones below, that the writer believes it may actually belong to the series of Taft sandstones. It varies in thickness from about 4 to 8 feet.

Below the "White" sandstone to the uppermost Taft sandstone which was mapped is about 20 to 40 feet of gray and tan silty shales.

---

[1] R. B. Austin, "The Chelsea Sandstone and Associated Strata East and Northeast of Claremore, Oklahoma," Unpublished Masters Thesis, University of Oklahoma, 1946, p. 5.

Fig. 15. Hill capped by Tiawah limestone with "White" sandstone in the side and silty shale below. Location is northeast 1/4 of sec. 15, T. 21 N., R. 16 E.

Taft Sandstones

The rocks composing the Taft sandstones and shales of the Tiawah area are, at least in part, equivalent to the Taft sandstone described by Wilson[1] and named for exposures near Taft, Oklahoma, in Muskogee County.

As seen in the area under discussion the Taft consists of approximately 100 to 140 feet of interbedded sandstones and shales. The strata like most of those present in the Cherokee Group are extremely variable. The stratigraphic relationships are not clearly discernible.

---

[1] C. W. Wilson, Jr., "Age and Correlation of Pennsylvanian Surface Formations and of Oil and Gas Sands of Muskogee County, Oklahoma," Bulletin of the American Association of Petroleum Geologists, Vol. 19, 1935, p. 511.

It seems that there is both lateral and vertical gradation so that no single phase occupies exactly the same stratigraphic position throughout the area. No less than three separate sandstone lenses were observed, between two of the mapped members, in a hill in sec. 25, T. 21 N., R. 16 E.

The shales in this interval range from soft and black to tan and silty with plant fragments. At places thin beds of clay-ironstone were located. Underclays are to be seen at a few places, but because of the covered nature of the area, coal was located at only one place. It is several feet below the upper sandstone in a hillside in the southwest 1/4 of sec. 26, T. 21 N., R. 16 E.

Of the sandstones in the interval, three were found to be continuous or nearly so. They are expressed topographically over considerable distances. They were differentiated and traced across the area. Their bases are shown on the geological map which accompanies this report.

The lower Taft sandstone is the best developed of the three sandstones mapped. It is, throughout much of the area, a tan, medium to coarse-grained, massive rock which weathers a dark brown. It approaches 20 feet in thickness and caps many of the Bluejacket sandstone escarpments, extending their heights another 40 or 50 feet. On the north half of an outlier which lies in secs. 16, 20, 21, and 29, T. 21 N., R. 18 E., it may be seen with different characteristics. Here it is coarse and extremely ferruginous with the purplish-brown color which is usually associated with the basal Chelsea. These same characteristics are also present in this member in sec. 6, T. 21 N., R. 18 E. This

Fig. 16. Lower Taft sandstone capping hill in sec. 26, T. 21 N., R. 17 E.

Fig. 17. Taft capped hills rising above the dip slope of the Bluejacket sandstone. Looking east from Highway 88 south of Tiawah.

Fig. 18. Weathered blocks of the upper Taft sandstone. Joints are defined by the grass. Location is top of a hill in sec. 20, T. 21 N., R. 17 E.

Fig. 19. View of the middle Taft sandstone in sec. 1, T. 20 N., R. 17 E.

sandstone as well as the other Taft sandstones are jointed in three directions. Where they are massive, they weather into blocks about a foot thick which are used throughout the area for building stone.

The lower unit in the southern part of the area appears to be more like the middle and upper units and was more difficult to map. These upper two members are at most places thin-bedded with parts of them at places being massive. They contain more mica, more plant fragments, and are more extensively ripple-marked. They are medium-grained to silty and tan in color. Their maximum thickness is about 10 feet. It was not possible to determine whether one or both may actually thin to zero feet in places, because of overburden.

Fig. 20. Upper Taft sandstone in Highway 33 road-cut in sec. 32, T. 20 N., R. 16 E. Note massive sandstone wedge in upper left part of exposure.

Interval from the Taft Sandstones to the Inola Limestone

From the lower Red Fork sandstone to the Inola limestone is some 30 feet of shale. The rocks of this interval can be examined in their entirety in a Highway 20 road-cut between secs. 7 and 18, T. 21 N., R. 18 E. The upper half consists of gray to tan silty shales with a two and one-half foot underclay near the top. No coal was found; however, a mile north a coal of 3 or 4 inches was seen at this horizon in a recently dug water well. The lower half of this interval is composed of alternating layers of black, fissile shale with relatively thin beds of clay-ironstone.

Inola Limestone

The Inola limestone was originally described and named by Lowman[1] from its presence in Inola Mound near Inola, Oklahoma. As described by Lowman, it is a single bed of gray, fossiliferous limestone about 10 inches thick. This location was visited by the writer and no additional limestone was found; however, in the area under discussion this limestone is quite thick and consists of several beds.

It apparently weathers even more rapidly than the other limestones in the Cherokee. Exposures are extremely rare and considerable time was spent searching for them. This horizon is important in distinguishing between the Bluejacket sandstone below and the lower Taft

---

[1]S. W. Lowman, "Lower and Middle Pennsylvanian Stratigraphy of Oklahoma East of the Meridian and North of the Arbuckle Mountains," Tulsa Geological Society Digest, 1932, unnumbered page.

Fig. 21. Good exposure of Inola limestone beds in sec. 7, T. 29 N., R. 17 E.

Fig. 22. View of upper Inola limestone at type section on Highway 20. Note layering effect on weathering.

sandstone above. At most localities where the Inola was found, only one bed or portions of one bed had been resistant enough to remain. It is believed by the writer that this may be the condition which exists at Lowman's[1] type locality. Three of the limestones were found to be present 5 miles north in sec. 7, T. 20 N., R. 17 E. At only one place was the Inola limestone seen in its entirety. This is in a fresh road-cut on Highway 20 a few yards east of the northwest corner of sec. 18, T. 21 N., R. 18 E. It is the proposed type section of the Inola limestone.

Bed		Feet
13.	Shale, black, soft, fissile, with interbeds of clay-ironstone......................................	16.0
12.	Upper INOLA limestone, irregularly massive bedded, fine crystalline, light gray, and fossiliferous. Weathers into gray to reddish-brown layers..........	3.5
11.	Coal..	0.2
	Underclay, soft, gray..	1.5
10.	Shale, soft, light gray..	2.5
9.	Second INOLA limestone, gray to red, rich in iron, silty, fossiliferous......................................	0.5
8.	Shale, gray to tan, silty......................................	4.0
7.	Third INOLA limestone, gray, compact, fossiliferous, weathers quickly to an ironstained clay.............	2.1
6.	Underclay, gray..	1.5
5.	Shale, soft and fissile, becomes more silty towards top....................................	3.0
4.	Lower INOLA limestone, light gray with dark gray spots, compact, fossiliferous—contains fusulinids, weathers rapidly........................	9.9
3.	Coal..	0.04
2.	Underclay, gray..	1.0
1.	Shale, light gray, calcareous..................................	2.0
	BLUEJACKET sandstone...	55.0

The second Inola limestone bed apparently is only a local lens, since it is not present in any other known exposure.

The following fossils were collected from the Inola limestone beds along Highway 20 between secs. 7 and 18, T. 21 N., R. 18 E.

---

[1] *Ibid.*, unnumbered page.

The lower Inola limestone contains:

Chonetes granulifer Owen
Dictyoclostus portlockianus (Norwood and Pratten)
Marginifera haydenensis Girty
Marginifera muricatina Dunbar and Condra
Composita subtilita (Hall)
Phricodothyris perplexa (McChesney)
Fusulina leei Skinner[1]
Wedekindellina henbesti (Skinner)[1]
Eoschubertella gallowayi (Skinner)[1]

The third Inola limestone contains:

Caninia torquia (Owen)
Lophophyllidium profundum (Edwards and Haime)
Composita subtilita (Hall)
Chonetes granulifer Owen
Dictyoclostus portlockianus (Norwood and Pratten)
Dictyoclostus americanus Dunbar and Condra
Mesolobus mesolobus (Norwood and Pratten)
Neospirifer dunbari King
Marginifera muricatina Dunbar and Condra
Marginifera haydenensis Girty

The upper Inola limestone contains:

Caninia torquia (Owen)
Lophophyllidium profundum (Edwards and Haime)
Composita subtilita (Hall)
Phricodothyris perplexa (McChesney)
Marginifera muricatina Dunbar and Condra

Interval from the Inola Limestone to the Bluejacket Sandstone

The rocks of this interval consist of a very thin coal, an underclay, and a gray calcareous shale where they are best seen. The interval varies from 2 to 8 feet. The rocks constitute the lower units of the cyclothem of which the lower Inola limestone is the cap-rock.

---

[1]John W. Skinner, "Primitive Fusulinids of the Mid-Continent Region," Journal of Paleontology, Vol. 5, 1931, pp. 253-259.

Bluejacket Sandstone

The Bluejacket sandstone is one which has received considerable attention and is by far the most prominent sandstone in the Cherokee group. In subsurface, it is commonly known as the "Bartlesville" sandstone. A considerable portion of the oil produced in this region is from the "Bartlesville".

This sandstone was named by Ohern[1] for exposure 2 miles west of Bluejacket, Oklahoma. Howe[2] redefined the limits of the type section in 1951, because the original description included several other sandstones.

In the area under discussion, this sandstone is massive where it is best seen, however, it grades laterally into thin beds of sandstone alternating with thin micaceous siltstones and shales. The latter phase is generally covered and little can be seen. Where massive, it is cross-bedded, medium to coarse-grained and light brown. It weathers the same color. As is the case with most of the sandstones in the section, no fossils were found except for plant fragments. Stigmaria was noted in the Bluejacket.

Due to the lithologic variations it was not everywhere possible to measure its total thickness; and also, much difficulty was encountered in mapping.

The best exposure of it was measured on Highway 20 in the northwest 1/4 of sec. 17, T. 21 N., R. 18 E. At this locality it is 55 feet thick, and the base is a coarse, medium-hard, quartzitic sandstone de-

---

[1] D. W. Ohern, op. cit.

[2] W. B. Howe, op. cit., p. 2088.

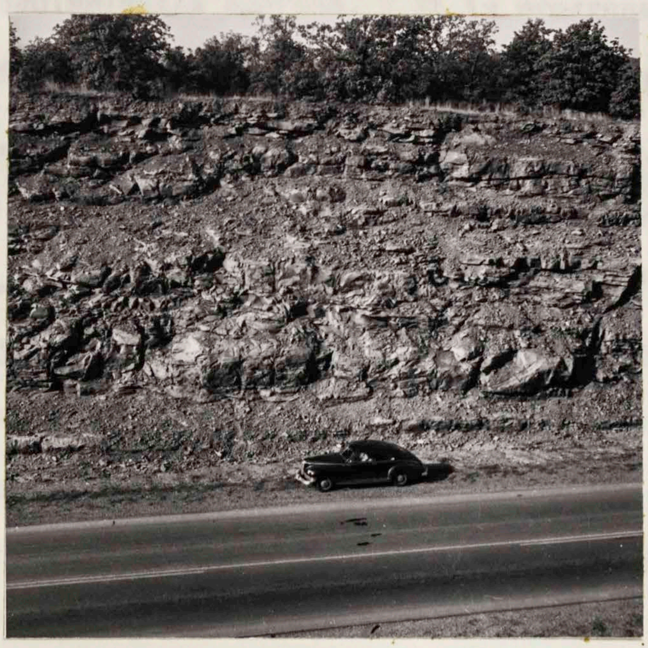


Fig. 23. Best exposure of massive phase of Bluejacket sandstone in Tiawah area. Photo taken in Highway 20 road-cut in sec. 17, T. 21 N., R. 18 E.

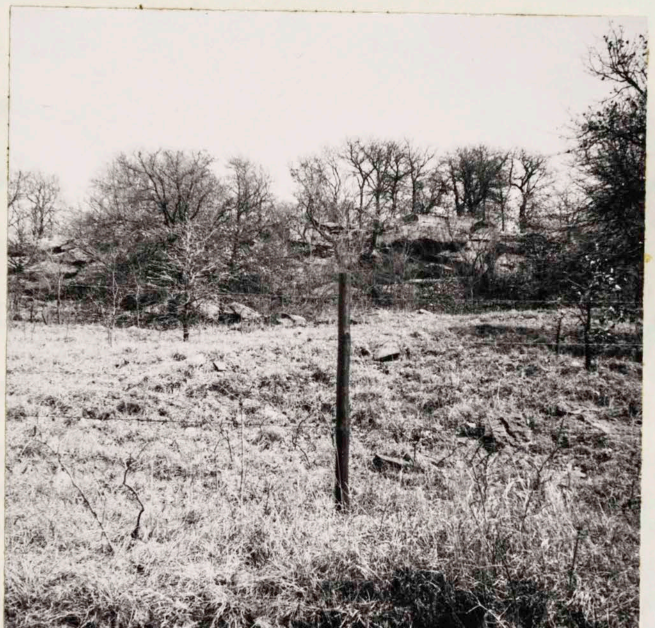


Fig. 24. Bluejacket sandstone in massive phase where it caps a high hill in secs. 12 and 13, T. 20 N., R. 18 E.

posited on an irregular shale surface. It is progressively finer-grained and more ferruginous toward the top with increasing numbers of thin shale lenses. Two miles north, in sec. 6, T. 21 N., R. 18 E., it is considerably thinner, very micaceous, and ripple marks are developed on bedding planes.

The Bluejacket sandstone ridges and buttes are the sharpest, most prominent features of the area's topography. Over much of the area they are made even higher by the hard lower Taft member. In the southern part of the area, where the Taft has been removed, the dip slope of the Bluejacket is irregular because of differential erosion of its softer phases.

An intensive study was made of the characteristics and distribution of the Bluejacket sandstone by Weirich[1] who states about its surface outcrop:

> Thickness of the Bluejacket is variable. In most places the Bluejacket is a silty, discontinuous sandstone, massive sandstone beds being absent along the entire outcrop. The bed may be recognized only by its greater resistance to erosion as compared to adjacent shale beds.

Mr. Weirich[2] has the following to say about the Bluejacket sandstone in subsurface:

> The sand body occurs as a comparatively wide sheet 100-200 feet thick extending from its outcrop to Washington County, Oklahoma. The sheet attains width of 50 miles on the south but narrows northward until it ends near Copan, Oklahoma. Again in Montgomery County, Kansas, sand reenters the section and continues as a definite body. . . . In Nowata and Rogers Counties, Oklahoma, the sand is present as outlying stringers and small isolated patches.

---

[1]T. E. Weirich, "Petroleum Geology of Nowata and Washington Counties, Oklahoma," Kansas Geological Society, Eleventh Annual Field Conference, 1937, p. 90.

[2]*Ibid.*, p. 90.

Here the sand body is comparatively thin, averaging 20 feet in thickness.

Many of the authors writing about the Bluejacket assume it to be a series of offshore bars. This explains very well its characteristics of having shale adjacent to sandstone bodies, but does not explain its large areal extent. Mr. Weirich is one who apparently considers it a sheet sand of varying thickness with its lensing characteristics more common along its eastern margin and approximately parallel to the present outcrop. This idea seems more nearly to explain the wide area over which it is known to exist.

Interval from the Bluejacket Sandstone to the Little Cabin Sandstone

Little is known about this interval in the area because of the covered slopes of the Bluejacket scarp, and the thick top soil and alluvium in the valley to the east. Exposures are rare. Where they are seen, not enough strata are present to be placed correctly in the section. The interval is about 210 feet to 250 feet.

The upper part of this interval is best known from a road-cut on Highway 20 in sec. 17, T. 21 N., R. 18 E. The Bluejacket lies on the uneven surface of hard black platy shale about 14 inches thick. Below the shale is a 4 inch bed of gray, fossiliferous limestone which weathers as nodules, and is in turn underlain by a 5 inch coal. This coal has an underclay. The next 65 feet of this section consists of gray-green, gray, and silty tan shales with several thin beds of fossiliferous ironstone. Three more coals with their associated underclays are present. The best developed of these is one foot thick and is thought to be equivalent to the Rowe coal of Kansas. It is about 45 feet below the Bluejacket sandstone. It does not have a cap-rock at this locality, although another exposure of what is believed to be the Rowe coal is overlain by its associated limestone. This bed was named the Doneley limestone by Chrisman[1] from exposures northwest of Vinita, Oklahoma. It is exposed in the Tiawah area in the Spavinaw water line ditch, 30 feet east of the road, and 1/3 of a mile south of the northwest corner of sec. 35, T. 21 N., R. 17 E. At this place the Doneley limestone is 2 to 7 inches of dark gray, compact, fossiliferous limestone which is discontinuous and weathers a red-brown. It is underlain by 10 inches of coal with calcite seams.

The remainder of the interval to the Little Cabin sandstone was calculated mathematically to be approximately 165 feet. The rocks are mostly dark shale with a few thin beds of sandstone, several coals, and two "brown" limestones. None of the strata is both hard and thick enough to be mapped successfully in the Tiawah area.

The upper "brown" limestone was named the Sam Creek limestone by Lowman[2] for exposures on Sam Creek in Muskogee County, Oklahoma. It is approximately 130-140 feet below the Bluejacket sandstone. The

---

[1]Louie P. Chrisman, Unpublished Masters Thesis, University of Oklahoma, 1951.

[2]S. W. Lowman, "Lower and Middle Pennsylvanian Stratigraphy of Oklahoma East of the Meridian and North of the Arbuckle Mountains," Tulsa Geological Society Digest, 1932, unnumbered page.

Fig. 25. Medium hard, black, fissile shale overlain by 12 inches of "brown" limestone believed to be Sam Creek. Location is on Seminole Creek in sec. 4, T. 21 N., R. 18 E.

Fig. 26. Example of the type of talus and slump fill which covers much of the Tiawah area. It is especially thick near Bluejacket sandstone escarpments.

lower "brown" limestone was named the Spaniard limestone by Lowman[1] from outcrops on Spaniard Creek in Muskogee County. It was not possible to differentiate between the two limestones except where they are both present at the southeast corner of sec. 5, T. 20 N., R. 18 E. At this place the Spaniard limestone floors Chouteau Creek and is deeply weathered. It is a hard, dark gray, fossiliferous, calcareous, silty rock. A coal was found below. The writer believes that ordinarily it would appear the same as the Sam Creek which is 14 feet above. It is a compact, dark gray, abundantly fossiliferous limestone, which weathers a characteristic red-brown.

Other places where "brown" limestone exposures are known to exist are:

1. In the south bank of Seminole Creek at west section line road, sec. 4, T. 21 N., R. 18 E.

2. In the south bank of creek 1/3 mile south and 1/4 mile west of northeast corner of sec. 16, T. 21 N., R. 18 E.

3. In road-cut on Highway 20 at the northwest corner of sec. 14, T. 21 N., R. 18 E.

4. In bank of creek 1/4 mile east and 100 yards south of the northwest corner of sec. 24, T. 21 N., R. 18 E.

5. Flooring creek 20 yards northwest of bridge on north section line of sec. 36, T. 21 N., R. 18 E.

---

[1] S. W. Lowman, "Cherokee Structural History in Oklahoma," Tulsa Geological Society Digest, 1933, p. 31.

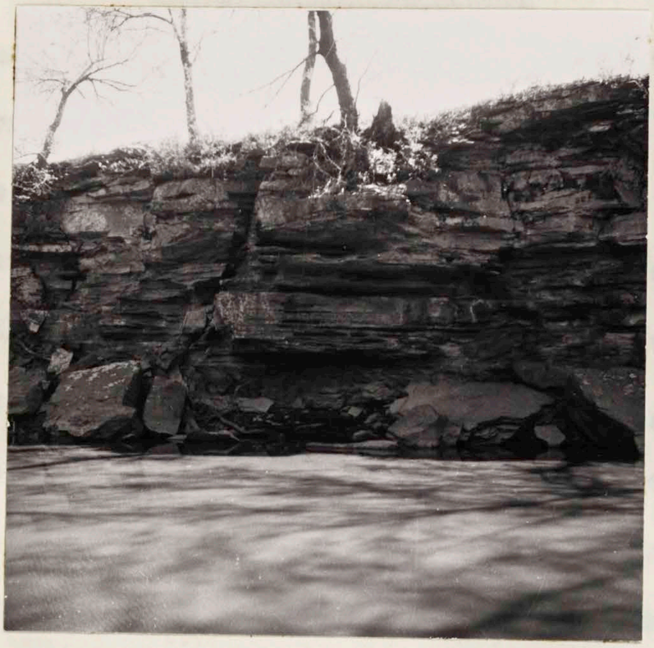


Fig. 27. Exposure of 14 feet of massive-bedded Little Cabin sandstone in sec. 15, T. 20 N., R. 18 E.

Fig. 28. 6 feet of thin-bedded Little Cabin sandstone exposed in Highway 33 road-cut. Sec. 33, T. 20 N., R. 18 E.

Little Cabin Sandstone

This sandstone is the first conspicuous stratum below the Bluejacket. It forms a low escarpment and rolling hills which give relief to the otherwise flat plain in the vicinity. In the southeastern part of the area a part of the Seneca fault system disrupts the outcrop pattern of the Little Cabin, and at the same time introduces sandstones foreign to the section. Because of a lack of outcrops, it is not possible to differentiate at all places between these sandstones. The base of the Little Cabin was mapped where identification was reasonably certain.

The Little Cabin sandstone was named by Ohern[1] for exposures on Little Cabin Creek in Craig County, Oklahoma. It has since been traced south and is known as the Warner sandstone member of the McAlester formation south of the Arkansas River.

The thickness of the sandstone at measured outcrops ranges from 6 to 14 feet. These were all measured at places where the top was covered by soil. In characteristics the Little Cabin is a typical Cherokee sandstone. It is medium-grained, brown to buff, and contains considerable mica. It varies from irregular, massive beds as seen in sec. 15, T. 20 N., R. 18 E., to irregular, thin beds as seen in sec. 33, T. 20 N., R. 18 E. At most places it is medium-hard, but locally is almost quartzitic.

A very thin coal and associated underclay is present below the Little Cabin and locally a clay-ironstone is about 12 feet below. Otherwise, little can be seen of the estimated 50 to 60 feet of black, fissile Cherokee shale which underlies the Little Cabin.

---

[1]Ohern, <u>op. cit.</u>

CHAPTER III

REGIONAL GEOLOGY

The rocks of Cherokee age extend both northerly and southerly from the Tiawah area in an arcuate pattern which outlines the western periphery of the Ozark uplift. They extend northward in a broad belt across southeastern Kansas, across Missouri and into south-central Iowa. South of the Tiawah area, in the McAlester basin, the Cherokee group has a total thickness in excess of 6000 feet[1] where it has its widest areal extent.

These sediments in the McAlester basin were deposited in a miogeosyncline, developed by Springeran time, which extended from northeastern Texas across east-central Oklahoma and thence eastward across central Arkansas.[2] Kay[3] describes the characteristics of a miogeosyncline as follows:

> The miogeosynclines with peripherally coarsening graywacke must have been associated with rising lands opposite the craton, and thus be true downfolds between the platform of the craton and linear welts that were the sources of the debris. . . . Along the trend of

---

[1] Malcolm C. Oakes and M. M. Knechtel, "Geology and Mineral Resources of Haskell County, Oklahoma," Oklahoma Geological Survey, Bulletin 67, 1948, pp. 25, 30, 49, and 55.

[2] Marshall Kay, "North American Geosynclines," Geological Society of America, Memoir 48, 1951, plate 10.

[3] Ibid., p. 15.

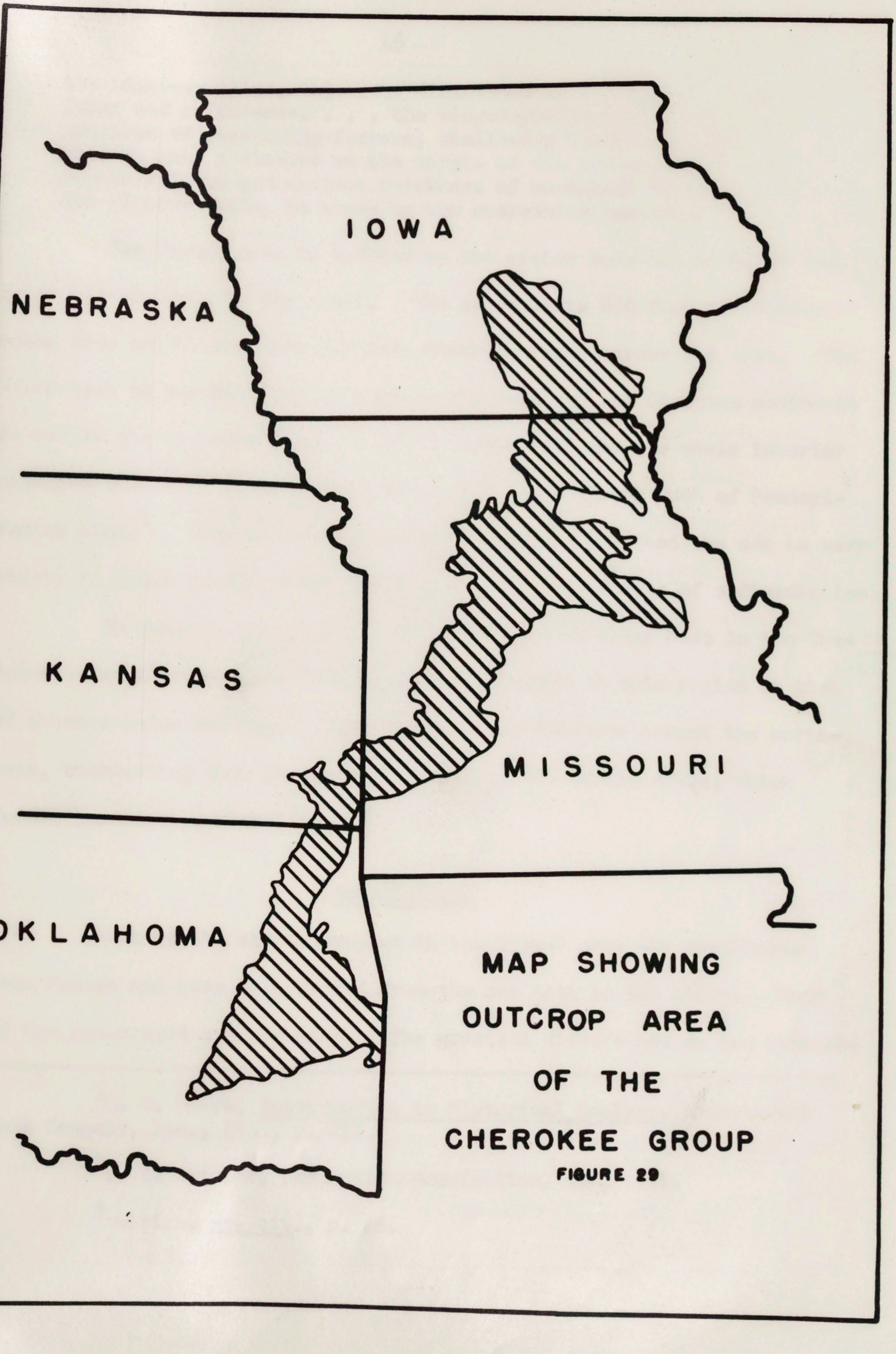

IOWA
NEBRASKA
KANSAS
MISSOURI
OKLAHOMA
MAP SHOWING
OUTCROP AREA
OF THE
CHEROKEE GROUP

FIGURE 29

the miogeosyncline, thickness diminishes as the facies become finer and calcareous. . . . the miogeosynclinal belt had a progression of developing furrows, shallowing longitudinally, passing into a flexure on the margin of the craton, and having greatest depth and maximum thickness of contained detritus near the highest lands, as shown by the coarsening textures.

The Tiawah area is located on the craton somewhat north of the geosynclinal basin to the south. The approximate 850 feet of Cherokee rocks does not thicken greatly from north to south across the area. The depression in northeastern Oklahoma which received the Cherokee sediments is called the Cherokee Basin. It was never deep and the whole interior platform must have stood just about at sea level during much of Pennsylvanian time.[1] Very slight changes of sea level permitted the sea to vary widely in areal extent, thus resulting in the cyclic type of sedimentation.

In general the relationship of younger to older beds in the Cherokee as well as in other Pennsylvanian sediments in this region is that of transgressive overlap.[2] The Cherokee sea advanced toward the northwest, encroaching upon the eastern flanks of the Nemaha ridge, which formed the western shoreline.[3]

Correlations

Most of the strata present in the Tiawah area are continuous into Kansas and have been traced from the one area to the other. Many of the names used are the same. The greatest differences in the Cherokee

---

[1]R. C. Moore, Introduction to Historical Geology, McGraw-Hill Book Company, Inc., 1949, p. 211.

[2]T. E. Weirich, personal communication, May, 1951.

[3]Weirich, op. cit., p. 86.

group between the two places are in the thinning of the group, in the lesser percentage of sandstone, and in the better developed cyclothems of Kansas.

These continuous units are the Lower Fort Scott limestone, Breezy Hill limestone, "Squirrel" sandstone, Verdigris (Ardmore) limestone, Broken Arrow (Croweburg) coal, Tiawah limestone, Bluejacket sandstone, Doneley limestone, Rowe coal, and the Little Cabin sandstone. In Kansas the Tiawah limestone is the cap-rock of the Tebo coal, and the Doneley limestone is known to be the cap-rock of the Rowe coal.

The Chelsea sandstone, Taft sandstones, and Inola limestones play out northward from the Tiawah area, and are not present in Kansas.[1]

In the McAlester Basin south of the Tiawah area and south of the Arkansas River, the sediments of the Cherokee group are thick. They are predominately clastics deposited in a deep synclinal basin. Correlations in time as well as by certain traceable units have been accomplished between the basin and the shelf sediments.

The Fort Scott limestone, the lowest unit of the Marmaton group, is equivalent to part of the Calvin sandstone.[2] Oakes, in his recent work on this part of the section, considered the Breezy Hill limestone as a part of the Fort Scott limestone. Therefore, the Breezy Hill limestone also is equivalent to the Calvin sandstone in the McAlester basin. In work still in progress, the Breezy Hill limestone of Kansas has been traced south as far as Wagoner County. It was found to be a

---

[1]Carl C. Branson, personal communication, April, 1952.

[2]Malcolm C. Oakes, personal communication, May, 1952.

unit long designated as the lower Fort Scott in Oklahoma.[1]

The Senora formation is equivalent to the Cherokee sediments from the base of the Breezy Hill limestone to an horizon below the Tiawah limestone.

The Thurman and Stuart formations of the McAlester basin are not represented, because they pinch out south of the Tiawah area.[2]

The Boggy formation, as it has been defined, includes those sediments from the base of the Tiawah limestone to an horizon immediately above the Sam Creek limestone. This horizon is occupied by a unit called the "Spiro" sandstone in the McAlester basin. The "Spiro" is not recognized in the Tiawah area.

The Oklahoma Geological Survey proposes to raise the base of the Boggy formation to the base of the Bluejacket sandstone.[3] The strata affected in the reclassification include the Doneley limestone and Rowe coal which will be placed in the Savanna formation. These units are probably equivalent to the "lower Boggy" coal and the persistent limestone above mentioned by Newell.[4] For purposes of simplification, the newly proposed classification is used in this work. The Boggy formation as redefined includes the Taft sandstones, the Inola limestone and the Bluejacket sandstone.

---

[1]Carl C. Branson, personal communication, May, 1952.

[2]Malcolm C. Oakes, personal communication, May, 1952.

[3]R. H. Dott, personal communication, May, 1952.

[4]C. W. Wilson and N. D. Newell, "Geology of the Muskogee—Porum District, Muskogee and McIntosh Counties, Oklahoma," Oklahoma Geological Survey, Bulletin 57, 1937, p. 53.

The Savanna formation is represented in the Tiawah area by the "brown" limestones, Sam Creek and Spaniard, and now by the intervening strata to the base of the Bluejacket sandstone.

The McAlester formation is present in the Tiawah area as the rocks in the interval between the "brown" limes and a horizon in the shale below the Little Cabin sandstone.

It is generally known that a paleontological break occurs between the Tiawah and Inola limestones. Marginifera missouriensis and Marginifera haydenensis occur below the break and are Pottsville forms. Above the Inola, Marginifera muricatina is abundant. It is primarily an Allegheny form. Mesolobus mesolobus, a form more abundant in Allegheny rocks than in older ones, is abundant above the Inola. Large thick-shelled species of Fusulina are found in the Tiawah limestone and higher in the section.

A tectonic break closely coincides with the paleontological break. The rocks of the Tiawah area that are Taft and older in age are faulted considerably, while those above are not affected by these same faults. This fault system, post-Taft and pre-Chelsea, is related to the Ozark faulting.

Structure

The prevailing feature of the structure of the Tiawah area is a regional dip of about 40 feet per mile in a west-northwest direction. This dip is generally quite constant. Local variations are at most places due to fault drag and small tear faults. These small tear faults are numerous in the pre-Chelsea rocks. They are to be seen at many

Fig. 30. Small faulted anticline in the middle Taft member. Located in sec. 1, T. 20 N., R. 16 E.

places where the rocks are exposed.

The larger faults mapped in the area, in general, trend in a northeast-southwest direction. Although it was not possible to be certain, they are assumed to be normal faults. An accurate amount of throw cannot be determined for any of them, because of the nature of the sediments. The part of the section in which most occur is predominantly shale. The evidence for mapping these faults was one or more of the following: visible displacement, fault drag, or interruption of the outcrop pattern. It is impossible to map all the small displacements which are present in the area, so only those large enough to show on aerial photographs were mapped.

One mapped fault in the area departs from the common trend. It strikes in a northwest-southeast direction through sections 26, 22, 21,

Fig. 31. Fault line scarp formed by base of Bluejacket sandstone. It dips to the southeast at 35 degrees. Located in sec. 28, T. 21 N., R. 17 E.

Fig. 32. Breezy Hill limestone drag folded by a fault in the Verdigris River in sec. 15, T. 21 N., R. 15 E.

16, and 17 of T. 20 N., R. 17 E. Its entire length is not known, but it is in excess of three miles. It alters the outcrop pattern of the lower Taft and the Bluejacket sandstone.

Apparently some faulting took place after Breezy Hill time. One fault was noted, but because it could not be traced it was not mapped. Four tenths of a mile west of the southeast corner of sec. 15, T. 21 N., R. 15 E., the Breezy Hill limestone is faulted out of place in the Verdigris River bed. Where measured, the strike of the limestone is north 10 degrees east and the dip is 44 degrees east.

A rather broad low anticlinal fold was noted several miles east of Claremore, where the strike of the strata can be noticed on the map to depart from its general north-northeast to an east-west direction. The strata in sections 4, 5, and 6 of T. 21 N., R. 17 E., have a northward dip. In section 7, T. 21 N., R. 17 E., a small outlier is capped by Tiawah limestone. The Tiawah at this place is somewhat higher in elevation than the overlying Chelsea sandstone one mile to the north. It is probable that this structure can be measured in tens of feet.

A small dome is present in the northeast part of sec. 16, T. 20 N., R. 18 E. Its extent or size is not known. It is associated with the Seneca fault system and the surface rocks are very near the base of the Cherokee. Chouteau Creek as it flows across this structure exposes a Mississippian limestone, overlain by Atoka sandstone and limestone. The flanks of the structure are covered by Little Cabin sandstone and Cherokee shale.

CHAPTER IV

ECONOMIC GEOLOGY

Water Supply

Aerial photographs of the Tiawah area made in 1941 show 165 bodies of standing surface water. Most of these are small ponds that were made by damming of creeks. With one exception, the larger lakes of the area are located on the Verdigris River flood plain, and most of these occupy positions of former stream channels. Claremore Lake which extends north of the area, is the largest lake present. It was formed by placing a dam across Dog Creek in sec. 3, T. 21 N., R. 16 E. It furnishes the water supply for Claremore.

The major streams of the area, with particular emphasis on the Verdigris River, are dependable sources of surface water.

In general, the locating of good water wells in the area is difficult. There are many fine wells, but because of the nature of the sediments present, their distribution is erratic. Locally, ground water present contains a large percentage of gas and is unfit for use.

Several artesian wells have been drilled in the vicinity of Claremore. A pervious Mississippian unit serves as the aquifier. It receives its water from the Ozark region and the westward dip gives the hydrostatic head to the wells. The depth of the wells is approximately

1100 feet at Claremore. Since the water obtained from these wells contains a considerable amount of sulphur and other dissolved minerals, it is reputed to have certain curative values. It is utilized by sanatoriums in Claremore in the form of hot baths.

Gravel

There are scattered deposits of an impure mixture of sand, silt and gravel in the area. At only one place is it shown on the map. This is along Highway 33 in sections 35 and 36, T. 20 N., R. 16 E. It is used as a source of gravel locally. Gravel pits are common south of this place in T. 20 N., R. 15 E.

Building Stone

There is an adequate supply of building stone for local use in the area. The sandstones of the Cherokee, especially the Taft sandstone, commonly weather into joint controlled blocks. At some places ground water solutions have made them very hard--almost quartzitic. These sandstone blocks cover the ground, forming rocky slopes. At some places they are of a size that can be used without being cut.

Coal

A great many beds of coal occur in the Cherokee group. Most of them are thin and of no economic importance. At least three of the coals in the Tiawah area have been strip-mined at places for local use, but only one of these has a broader market.

The most important coal in the area is the Broken Arrow coal. The McNabb Coal Company is actively engaged in stripping it at the present time. The localities where it has been mined are shown on the geologic map which accompanies this report. In general, the Broken Arrow coal is persistent and averages about 20 inches in thickness. It is a relatively hard, bituminous coal with good burning qualities.

The other two coals which are used only locally are: the Iron Post coal which is present in the western part of the area, and the Rowe coal which is present in the eastern part of the area. Both of these coals are commonly somewhat less than one foot in thickness. It is not feasible to mine them commercially; however, they are used by farmers in the area.

Oil and Gas

The Cherokee group contains some of the principal oil and gas yielding strata of the Mid-Continent region. The irregular form of the sandstone bodies surrounded by shale makes them excellent reservoirs. The presence of structural closure is not necessary for accumulation of oil and gas under these conditions.

Since the Tiawah area is at the outcrop of the Cherokee sediments, most production from them is located farther in the down-dip direction. The producing horizons are too near the surface in this area for any large production from the Cherokee. However, hundreds of shallow wells have been drilled in the area, and many of them yielded oil or gas or both. Few of these wells exceeded 10 barrels of oil per day, and more often were considerably less. The number that is maintained on pumping operations at the present time is small.

The most concentrated drilling in the area has been at the East

Claremore pool, 6 miles east of Claremore, on the low broad anticline mentioned in the section on structure. The Corporation Commission has a record of no less than 60 wells drilled in sec. 9, T. 21 N., R. 17 E. The production is from two horizons. Gas is produced from the Bluejacket sandstone which crops out only two miles east. Oil and gas are produced from the Little Cabin sandstone.

The Catoosa pool located southeast of Catoosa in T. 20 N., R. 15 E., is principally a producer of gas. This is from two horizons: the Little Cabin sandstone and the "Mississippi" limestone.

Most of the drilling done in the area in the past 20 years has been to produce gas for farm consumption. One such well was just completed in the northeast 1/4 of sec. 26, T. 21 N., R. 15 E. Gas production was successful from the Bluejacket sandstone at a depth of 410 feet.

The prospect for future production in the area seems small. Most of the area has been drilled and further exploration for commercial production abandoned. Evidently the close proximity of basement rocks at places in the area has discouraged much exploratory drilling in Mississippian and older strata. However, it is believed by the writer that any future commercial production will have to come from the older rocks. Perhaps the small dome in sec. 16, T. 20 N., R. 18 E. is a possibility.

CHAPTER V

SUMMARY

The rocks that crop out in the Tiawah area belong to the Cherokee group of the Desmoinesian series of Pennsylvanian age.

The Cherokee group is unconformable with underlying rocks and is apparently conformable with overlying rocks.

The cyclic type of sedimentation prevails in the Tiawah area, but is not as well developed as farther north.

The surface sediments of the Tiawah area were deposited in a shallow basin on the craton.

The prevailing structural feature of the area is a gentle westward dipping homocline.

The major faulting of the area is post-Taft, pre-Chelsea in age and trends in a northeast-southwest direction.

Economic resources of the area are water, gravel, building, stone, coal, and oil and gas. They are locally important.

The type sections of the Chelsea sandstone, the Tiawah limestone, and the Inola limestone are designated in this report. A measured stratigraphic section of the Verdigris limestone at the place previously designated as the type section is presented.

The principal contributions of this work are: a detailed geologic map of the area, and a further study of the sediments of the Cherokee group in Oklahoma.

BIBLIOGRAPHY

Abernathy, George A., "The Cherokee Group of Southeastern Kansas," Kansas Geological Society, Eleventh Annual Field Conference, 1937, pp. 18-23.

Austin, R. B., "The Chelsea Sandstone and Associated Strata East and Northeast of Claremore, Oklahoma," Unpublished Masters Thesis, University of Oklahoma, 1946.

Chrisman, Louis F., "Geology of the Big Cabin Creek Area, Craig County, Oklahoma," Unpublished Masters Thesis, University of Oklahoma, 1951.

Clark, G. C., and Cooper, C. L., "Geology of Kay, Grant, Garfield, and Noble Counties," Oklahoma Geological Survey, Bulletin 40-H, 1927.

Cooper, C. L., "Proceedings of the Oklahoma Academy of Science," University of Oklahoma Bulletin, vol. 7, 1928, pp. 158-168.

Cooper, C. L., and Woodruff, E. G., "Geology of Rogers County," Oklahoma Geological Survey, Bulletin 40-U, 1928.

Fitts, L. E., Jr., and Brant, R. A., "Pennsylvanian and Mississippian Rocks of Eastern Oklahoma," Tulsa Geological Society, Field Trip 1946.

Gatchell, John H., and Fitts, L. E., "Tulsa to Spavinaw," Tulsa Geological Society, Field Trip Guide No. 3, 1950, pp. 18-24.

Green, F. C., "Oil and Gas Pools of Western Missouri," Missouri Bureau of Geology and Mines, Biennial Report, No. 57, 1933.

Howe, W. B., "Bluejacket Sandstone of Kansas and Oklahoma," Bulletin of the American Association of Petroleum Geologists, Vol. 35, 1951, pp. 2087-2094.

Ireland, H. A., "Geology of Mayes, Ottawa, and Delaware Counties," Oklahoma Geological Survey, Bulletin 40-NN, 1930.

Kay, Marshall, "North American Geosynclines," Geological Society of America, Memoir 48, 1951.

Lowman, S. W., "Lower and Middle Pennsylvanian Stratigraphy of Oklahoma East of the Meridian and North of the Arbuckle Mountains," Tulsa Geological Society Digest, 1932.

__________, "Cherokee Structural History in Oklahoma," Tulsa Geological Society Digest, 1933, pp. 31-34.

Miser, H. D., "Geological Map of Oklahoma," U. S. Geological Survey, 1926.

Moore, R. C., "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," Kansas Geological Survey, Bulletin 22, 1936.

__________, Introduction to Historical Geology, McGraw-Hill Book Company, Inc., 1949.

Oakes, Malcolm C., "Broken Arrow Coal and Associated Strata," Oklahoma Geological Survey, Circular 24, 1944.

Ohern, D. W., "Geology of the Nowata and Vinita Quadrangles," Unpublished Manuscript on file at the office of the Oklahoma Geological Survey, 1914.

Pierce, W. G., and Courtier, W. H., "Geology and Coal Resources of the Southwestern Kansas Coal Field," Kansas Geological Survey, Bulletin 24, 1937.

Skinner, John W., "Primitive Fusulinids of the Mid-Continent Region," Journal of Paleontology, Vol. 5, 1931, pp. 253-259.

Smith, C. D., "Geology of the Claremore Quadrangle," Unpublished Manuscript Map on file at the office of the Oklahoma Geological Survey, 1911.

Swallow, G. C., "Preliminary Report on the Geological Survey of Kansas," Kansas Geological Survey, 1866.

Weirich, T. E., "Petroleum Geology of Nowata and Washington Counties, Oklahoma," Kansas Geological Society, Eleventh Annual Field Conference, 1937, pp. 85-92.

Wilson, C. W., Jr., "Age and Correlation of Pennsylvanian Surface Formations and of Oil and Gas Sands of Muskogee County, Oklahoma," Bulletin of the American Association of Petroleum Geologists, Vol. 19, 1935, pp. 503-520.

Wilson, C. W., Jr., and Newell, N. D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma," Oklahoma Geological Survey, Bulletin 57, 1937.

APPENDIX

MEASURED STRATIGRAPHIC SECTIONS

1. Sec. 14, T. 21 N., R. 15 E. Measured in road-cut 1/3 mile west of northeast corner of sec. 14.

Bed		Feet
7	FORT SCOTT limestone, compact, gray, fossiliferous, top eroded and gravel covered	8.0
6	Shale, gray, fissile, jointed	3.5
5	Shale, black, very hard, fissile, contains phosphate nodules	1.5
4	BREEZY HILL limestone, compact, dark gray, fossiliferous, silty	10.0
3	Shale, dark, fissile	0.8
2	IRON POST coal, impure	1.1
1	Clay, gray, sticky, lower part covered	1.2

2. Sec. 2, T. 21 N., R. 15 E. Measured in road-cut 1/4 mile east of the northwest corner of sec. 2.

Bed		Feet
11	BREEZY HILL limestone, top weathered	3.0
10	Shale, silty, fossiliferous	2.0
9	IRON POST coal	0.6
8	Clay, gray, iron stained	0.3
7	Siltstone, tan	0.7
6	Shale, gray	2.5
5	Shale, black, fossiliferous	0.2
4	Shale, gray silty, weaters tan	5.5
3	Shale, blue, soft, fossiliferous	2.5
2	Shale, dark gray, silty	6.0
1	"SQUIRREL" sandstone, fine-grained, brown, thin-bedded, micaceous, lower part covered	6.0

3. Sec. 35, T. 21 N., R. 15 E. Measured from creek in east part of section to east section line, thence north to top of hill.

Bed		Feet
6	BREEZY HILL limestone	not measured
5	Covered, presumably shale	12.0
4	"SQUIRREL" sandstone	13.0

Bed		Feet
3	Shale, gray..	4.0
2	VERDIGRIS limestone, jointed..............................	10.0
1	Shale, hard, black, contains phosphate nodules.........	2.0

4. Sec. 23, T. 21 N., R. 15 E. Measured in bank 1/4 mile east of northwest corner of sec. 23.

Bed		Feet
4	BREEZY HILL limestone, weathered, and upper part covered	3.0
3	Shale..	10.0
2	"SQUIRREL" sandstone, medium-grained, weathers dark brown..	1.2
1	Shale, gray to tan and silty, covered below............	10.0

5. Sec. 18, T. 20 N., R. 15 E. Measured on Bird Creek under bridge in southwest 1/4 of sec. 18.

Bed		Feet
3	FORT SCOTT limestone, gray, massive-bedded, fossiliferous covered on top................................	9.0
2	Shale, hard, black, contains phosphatic nodules........	4.0
1	BREEZY HILL limestone..	10.0

6. Sec. 17, T. 20 N., R. 15 E. Measured in south bank of Verdigris River at location of old Highway 66 river bridge in southeast 1/4 of sec. 17.

Bed		Feet
4	"SQUIRREL" sandstone, tan, massive, cross-bedded, medium, upper part covered.........................	25.0
3	Shale, gray, silty...	7.5
2	VERDIGRIS limestone, hard, gray, fossiliferous, 0.5 foot shale break in middle......................	9.5
1	Covered, presumably shale, about.........................	20.0

7. Sec. 33, T. 20 N., R. 15 E. Measured in Broken Arrow coal strip pit in northeast 1/4 of sec. 33.

Bed		Feet
4	VERDIGRIS limestone, gray, weathers tan, fossiliferous, upper part weathered into soil....................	4.0
3	Shale, hard, black, jointed, weather yellow-brown, contains pyrite and crushed fossils..............	6.0
2	Shale, light gray, platy to massive, contains large calcareous concretions some of which are fossiliferous...	18.0
1	BROKEN ARROW coal...	1.8

8. Sec. 28, T. 20 N., R. 15 E. Measured in drainage ditch located 50 yards north of McNabb Company Powder house in the southwest 1/4 of sec. 28.

Bed		Feet
5	Upper McNABB limestone, compact, gray, fossiliferous, weathers dark brown..........................	1.4
4	Shale, covered..	2.8
3	Lower McNABB limestone, abundantly fossiliferous.....	1.2
2	Shale, covered..	4.0
1	Sandstone, thin-bedded, micaceous.....................	1.0

9. Sec. 5, T. 19 N., R. 15 E. Measured on Highway 33 immediately west of Spunky Creek.

Bed		Feet
7	FORT SCOTT limestone, compact, light gray, fossiliferous, partially covered......................	4.2
6	Shale, hard, black, fissile, contains phosphatic concretions and badly crushed, partially pyritized fossils..	4.0
5	BREEZY HILL limestone, light gray, compact shale, gray, fissile limestone, massively bedded, fossiliferous..	8.0
4	Coal..	1.2
3	Clay, gray..	0.9
2	Sandstone, medium hard, micaceous.....................	3.5
1	Shale, soft, gray, silty, contains pyrite, several thin beds of hard gray to tan micaceous siltstone..	18.0

10. Sec. 7, T. 21 N., R. 16 E. Measured going south and up hill from creek on sec. road in northwest 1/4 of sec. 7.

Bed		Feet
5	BREEZY HILL limestone, gray, weather..................	8.0
4	Covered, shale..	8.0
3	SQUIRREL sandstone, poorly exposed....................	5.0
2	Covered...	25.0
1	VERDIGRIS limestone, massive, tan on weathered surface, exposed..	5.0

11. Sec. 13, T. 21 N., R. 16 E. Measured in road-cut on Highway 20 in northwest 1/4 of sec. 13.

Bed		Feet
12	CHELSEA sandstone, massive, coarse to medium-grained, friable to hard, cross-bedded, very ferruginous, dark reddish brown............................	20.0
11	Shale, hard, black to gray............................	3.0
10	Ironstone, hard, gray, weathers brick red............	0.25
9	Shale, soft, fissile, gray............................	1.5
8	TIAWAH limestone, light gray with dark gray spots, fossiliferous, weathers a reddish tan, variable in thickness...	6.3

Bed		Feet
7	Coal	0.02
6	Clay, gray	0.3
5	Shale, hard and black in lower part with phosphatic concretions, bray in upper part	2.5
4	Siltstone, gray, hard	0.2
3	Shale, fissile, gray	5.0
2	"WHITE" sandstone, fine, gray	5.6
1	Shale, medium hard, gray	14.0

12. Sec. 35, T. 21 N., R. 16 E. Measured west up hill from intersection of section road and Highway 88 1/4 mile north of Tiawah.

12	TIAWAH limestone, gray, hard, weathered, partially exposed	3.5
11	Covered	7.0
10	"WHITE" sandstone, massive, fine, micaceous, light brown with dark brown specks	7.5
9	Sandstone, thin-bedded, micaceous	5.0
8	Covered	45.0
7	TAFT sandstone, massive, hard in upper part grading into thin-bedded silty tan sandstone	14.5
6	Shale, gray, medium soft	7.0
5	Coal	0.3
4	Clay, gray, soft	2.0
3	Shale, tan and silty, weathers tan	20.0
2	Sandstone, medium hard, ferruginous	1.0
1	Covered	20.0

13. Sec. 7, T. 20 N., R. 16 E. Measured from creek below Missouri Pacific Railroad bridge up hill to the west in southeast 1/4 of sec. 7.

5	Lower TAFT sandstone, weathered and partially covered.	6.0
4	Covered, mostly silty shale	23.0
3	INOLA limestone, fossiliferous limestone beds alternating with shale	12.0
2	Shale, soft, badly covered	3.0
1	BLUEJACKET sandstone, soft, tan, medium-grained, deeply weathered and partially exposed in creek..	6.0

14. Secs. 9 and 10, T. 21 N., R. 17 E. Measured going west up hill and starting 1/4 mile west of the northeast corner of sec. 10.

10	CHELSEA sandstone, coarse, soft, ferruginous	23.0
9	Shale, gray-black	3.0

Bed		Feet
8	Clay, gray, soft, may be weathered residue of TIAWAH limestone....................................	3.0
7	Shale, tan, silty..	15.0
6	"WHITE" sandstone..	5.0
5	Covered, shale..	18.0
4	Upper TAFT sandstone, fine, tan, micaceous, thin-bedded.	6.0
3	Covered, silty shales..	60.0
2	Middle TAFT sandstone, lower half is thin-bedded, fine quartzitic sandstone with mottled appearance. Upper half is hard and massive........................	9.0
1	Covered, shale..	32.0

15. Secs. 17 and 18, T. 21 N., R. 18 E. Measured going up hill west on Highway 20. Measurements started below Bluejacket escarpment in sec. 17 and ended in northwest 1/4 of sec. 18.

Bed		Feet
34	Lower TAFT sandstone, medium, ferruginous, upper part covered..	12.0
33	Covered..	3.0
32	Clay, gray, soft..	2.5
31	Shale, tan, silty..	3.0
30	Shale, gray..	2.5
29	Shale, black, soft, contains several layers of ironstone beds about 0.3 foot each............................	16.0
28	Upper INOLA limestone, light gray, massive-bedded.......	3.5
27	Coal..	0.2
26	Clay, gray, soft..	1.5
25	Shale, soft, gray..	2.5
24	Second INOLA limestone, gray to red, silty, fossiliferous	0.5
23	Shale, gray to tan, silty....................................	4.0
22	Third INOLA limestone, fossiliferous, weathers quickly to an iron stained clay............................	2.1
21	Clay, grey, soft..	1.5
20	Shale, soft and fissile, becomes more silty towards the top..	3.0
19	Lower INOLA limestone, light gray with dark gray spots, fossiliferous, contains fusulinids................	1.9
18	Coal..	0.04
17	Clay, gray..	1.0
16	Shale, light gray, calcareous................................	2.0
15	BLUEJACKET sandstone, massive-bedded, coarse to medium, jointed, tan..	55.0
14	Shale, hard, black, platy....................................	1.2
13	Limestone, hard, dense, medium-gray, fossiliferous, weathers nodular.....................	0.4
12	Coal..	0.4

Bed		Feet
11	Clay, light gray, soft..	1.0
10	Covered, silty shale...	18.0
9	Coal...	0.6
8	Clay, gray...	3.0
7	Shale, medium-hard, gray, with several thin layers of fossiliferous ironstone..................................	22.0
6	Coal...	0.1
5	Clay, light gray...	2.5
4	Shale, soft and gray with thin ironstone concretionary layers..	7.5
3	Coal...	1.05
2	Clay, soft..	2.5
1	Shale, gray-green to tan and silty with ironstone......	18.0

16. Sec. 4, T. 21 N., R. 18 E. Measured in south bank of Seminole Creek in southwest 1/4 of sec. 4.

2	SAM CREEK (?) limestone, compact, fossiliferous, dark gray, weathers a rusty brown................	1.0
1	Shale, medium-hard, dark gray, fissile..................	12.0

17. Sec. 14, T. 21 N., R. 18 E. Measured going west on Highway 20 in the northwest 1/4 of sec. 14.

10	Limestone, dark gray, fossiliferous, weathers to a silty ironstone....................	0.7
9	Coal...	0.5
8	Clay, gray, sticky..	0.7
7	Shale, white to light green, soft, silty..................	2.0
6	Silstone, white to buff, micaceous.......................	4.5
5	Coal...	0.5
4	Clay, gray, soft..	1.0
3	Silstone, light gray, micaceous, cracks filled with ferruginous material..................	2.2
2	Shale, soft, light gray...	3.0
1	Shale, gray-black, soft, with several thin layers of ironstone...............................	23.0

18. Sec. 15, T. 20 N., R. 18 E. Measured in creek bank 500 yards east of bridge in northwest 1/4 of sec. 15.

2	LITTLE CABIN sandstone, brown, fine-grained, massive-bedded, upper portion covered...........	14.0
1	Shale, black, fissile, lower part covered by water in creek..	8.0

Bed		Feet
	19. Sec. 13, T. 21 N., R. 18 E. Measured up hill from creek west to top of hill.	
4	LITTLE CABIN sandstone, fine, light brown, micaceous, massive to thin-bedded, upper part covered.....	6.0
3	Shale, black, soft....................................	12.0
2	Clay-ironstone, reddish-brown.........................	0.3
1	Shale, black, fissile, medium hard....................	6.0
	20. Sec. 33, T. 20 N., R. 18 E. Measured in Highway 33, road-cut in southeast 1/4 of sec. 33.	
4	LITTLE CABIN sandstone, massive to thin-bedded, fine, tan....................................	6.0
3	Shale, hard, black, contains small concretions........	1.1
2	Coal..	0.025
1	Clay, gray, lower part covered........................	1.2