378.76
O4G
C131g
cop.3

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

GEOLOGY OF THE BLACK DOG AREA, OSAGE COUNTY, OKLAHOMA

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

MASTER OF SCIENCE

BY

JOSEPH BUFORD CARL

Norman, Oklahoma

1957

UNIVERSITY OF OKLAHOMA
LIBRARY

Downloaded from SHAREOK. Persistent Handle URL: https://hdl.handle.net/11244/331242

378.76
Ok0
C191g
cop.3

GEOLOGY OF THE BLACK DOG AREA, OSAGE COUNTY, OKLAHOMA

A THESIS

APPROVED FOR THE SCHOOL OF GEOLOGY

BY

[redacted]

Geology

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to Dr. Carl C. Branson for his supervision during the preparation of this report.

Thanks are extended to Dr. Philip A. Chenoweth and Dr. Reginald W. Harris for reading the manuscript and for offering constructive criticism.

Acknowledgment is also presented the Oklahoma Geological Survey for financial assistance and for furnishing airplane photographs of the area.

TABLE OF CONTENTS

		Page
LIST OF ILLUSTRATIONS		vi
Chapter		
I.	INTRODUCTION	1
II.	STRATIGRAPHY	8
	Missouri Series	8
	Skiatook Group	9
	Coffeyville Formation	9
	Hogshooter Formation.	14
	Lost City limestone member . . .	14
	Winterset limestone member . . .	15
	Nellie Bly Formation.	17
	Dewey Formation	23
	Ochelata Group	26
	Chanute Formation	27
	Iola Formation.	29
	Paola limestone member	30
	Muncie Creek shale member. . . .	32
	Avant limestone member	33
	Wann Formation.	34
	Clem Creek sandstone member. . .	36
	Barnsdall Formation	38
	Okesa sandstone member	39
	Unnamed shale member	40
	Wildhorse dolomite lentil. . . .	42
	Tallant Formation	45
	Bigheart sandstone member. . . .	46
	Virgil Series	48
	Douglas-Shawnee Group.	49
	Vamoosa Formation	49
	Cheshawalla sandstone member . .	50
	Kiheki sandstone member.	52
	Cochahee sandstone member. . . .	54
	Wynona sandstone member.	55
	Kanwaka shale member	57
	Elgin sandstone member	58
	Quaternary Deposits.	60

Page

III. HISTORICAL GEOLOGY 63

IV. STRUCTURAL GEOLOGY 66

V. ECONOMIC GEOLOGY 70

BIBLIOGRAPHY. 72

APPENDIX. 77

Measured Stratigraphic Sections in the Black Dog and Adjacent Areas 78

LIST OF ILLUSTRATIONS

Plate — Page

I. Geologic Map of the Black Dog Area, Osage County, Oklahoma . . . . . Pocket

II. Composite Section of the Upper Pennsylvanian Rocks in the Black Dog Area, Osage County, Oklahoma . . . . . "

Figure

1. Location Map of the Black Dog Area 2

2. One of the best exposures of the lower shale of the Coffeyville formation 13

3. Exposure of the upper sandstone zone of the Coffeyville formation. 13

4. The thinnest occurrence of the Winterset limestone member of the Hogshooter formation and the upper coal of the Coffeyville formation. . 16

5. Winterset and Lost City limestone members of the Hogshooter formation and the upper coal of the Coffeyville formation 16

6. Thick exposure of the Lost City limestone underlain by coal bed of the Coffeyville formation. 16

7. Cross-bedding and contorted bedding typical of the middle part of the Nellie Bly formation 21

8. Contorted bedding in the middle part of the Nellie Bly formation 21

9. An excellent exposure of the Iola formation and part of the Chanute formation. 31

10. Wavy bedding typical of the Avant limestone. . 31

Figure		Page
11.	Lenticular sandstone beds of the Okesa sandstone member of the Barnsdall formation.	41
12.	Massive sandstone beds near the base of the Okesa sandstone.	41
13.	Wavy bedding typical of the Wildhorse dolomite	44
14.	Escarpment capped by the Wildhorse dolomite.	44
15.	Exposure of the Kiheki sandstone displaying ripple marks and filled shrinkage cracks . .	53
16.	Kiheki sandstone displaced by small normal fault.	53
17.	Interbedded siltstone, sandstone and shale of the Wynona sandstone.	56
18.	Lower sandstone bed of the Wynona sandstone member	56
19.	Escarpment capped by the upper bed of the Elgin sandstone.	59
20.	Alluvium standing in nearly vertical walls .	61
21.	Alluvial deposits along Boar Creek	61

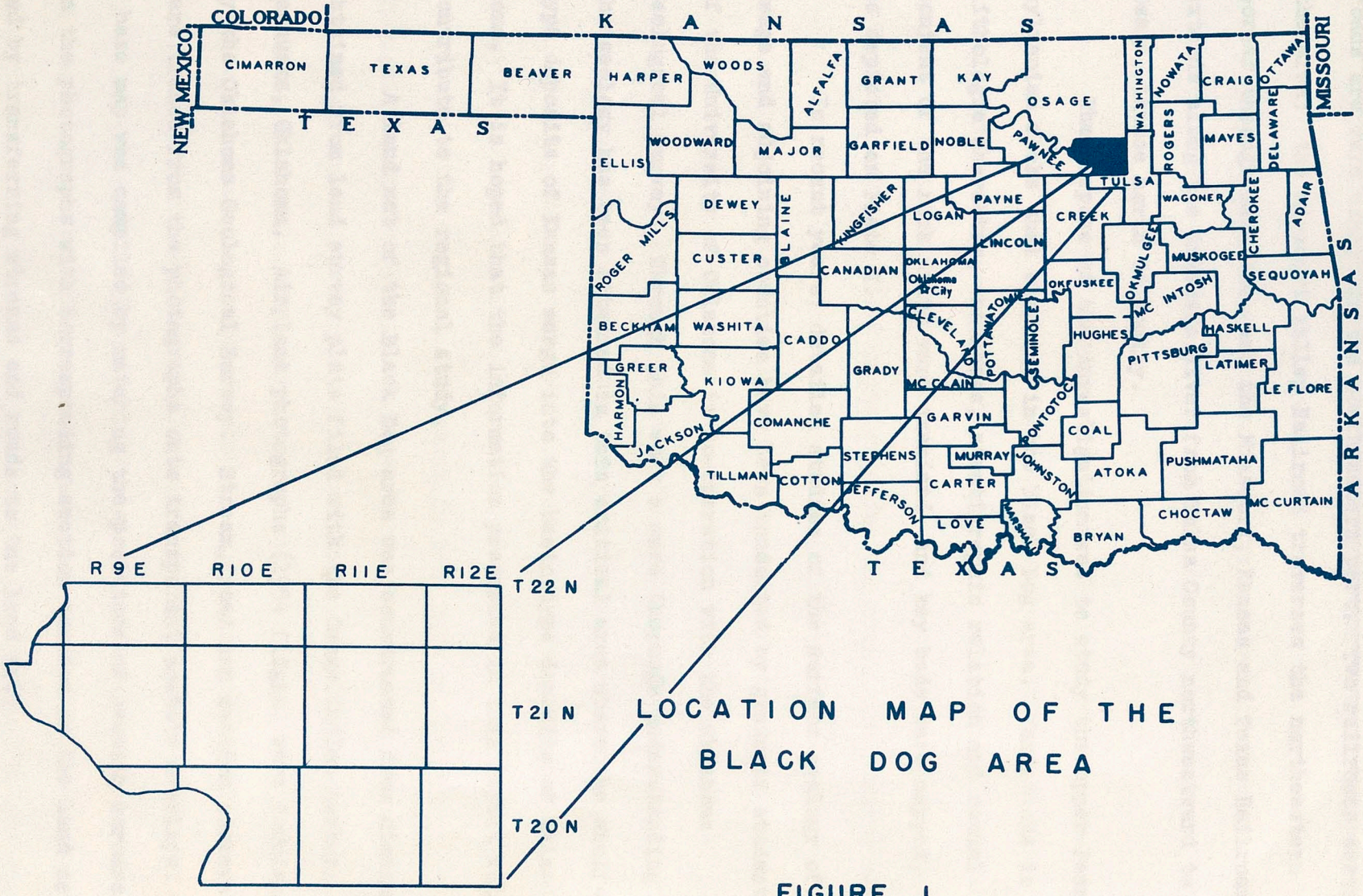
GEOLOGY OF THE BLACK DOG AREA, OSAGE COUNTY, OKLAHOMA

CHAPTER I

INTRODUCTION

The area considered in this report will be referred to as the Black Dog area, after the name of the school district which includes most of the mapped area. It comprises approximately 290 square miles in southeastern Osage County (Fig. 1). The area includes those parts of T. 20 N., Rs. 9, 10, 11 and 12 E.; T. 21 N., Rs. 9, 10, 11, 12 and part of 8 E.; and the south one-half of T. 22 N., Rs. 9, 10, 11, 12 and part of 8 East, which lie within Osage County. It is bounded on the southwest by the Arkansas River, which establishes the Osage-Pawnee County line, and on the south and east by Tulsa County. The area extends northward to the center of T. 22 N. and westward to the position of a bed near the middle of the Elgin sandstone member of the Vamoosa formation in Tps. 21 and 22 N., R. 8 E.

The towns of Skiatook, Osage and Prue are situated within the area, and an unincorporated suburb of Tulsa occupies the southeastern corner of T. 20 N., R. 12 E. Oklahoma State Highway 20, which connects Skiatook and Hominy, nearly parallels the northern boundary. Secondary roads are maintained throughout most of the area, though section-line



LOCATION MAP OF THE
BLACK DOG AREA

FIGURE 1

roads are rare except in the southeastern part. Two railroads serve the area: the Missouri Valley Railroad traverses the northeastern corner through Skiatook, and the Missouri, Kansas and Texas Railroad extends along the Arkansas River from Tulsa County northwestward to Osage, thence north to Hominy.

The purpose of the investigation was to study the upper Pennsylvanian rocks that crop out in the Black Dog area. Variations in lithologic character, thickness, stratigraphic relation and faunal content of the rock units were examined, and key beds were mapped, as depicted on Plate I.

In recent years, detailed studies of the surface geology of Osage and adjoining counties have been conducted by graduate students of the University of Oklahoma in co-operation with the Oklahoma Geological Survey. Through this work a more thorough understanding of the geology has been attained in this critical area where the shelf-type deposits of Kansas merge into the basin-type deposits of Oklahoma. It is hoped that the information presented in this report will contribute to the regional study.

A land net of the Black Dog area was constructed from dimensions obtained from land survey plats filed with the Osage Indian Agency, Pawhuska, Oklahoma. Airplane photographs (1954 flight) were furnished by the Oklahoma Geological Survey. Stream, road and section corners were traced from the photographs onto transparent acetate overlays. A base map was compiled by matching the positions of section corners on the photographs with corresponding section corners on the land net, and by transferring streams and roads to the land net.

The photographs were stereoscopically examined, and traceable beds, alluvial material, eolian deposits, linears and faults were traced onto the acetate overlays. After being checked and corrected in the field when necessary, this information was transferred to the base map.

Field work was accomplished during the interval from January to June, 1956. This work consisted of measuring sections, describing lithologies, checking airplane photographs and collecting fossils and samples of certain units for detailed study. Insoluble residue tests were made on all limestone units crossing the area. The results of the tests are included in the discussion of the various units in Chapter II. Sections were measured by Brunton compass, hand level and six-foot steel tape. The regional dip, which was approximated at 50 feet per mile, was not considered in the measurement of most of the sections; however, sections were corrected where measured in areas of high local dip or where measured over a considerable distance in a direction across the strike.

The Black Dog area is located in that part of the Great Plains known as the Sandstone Hills (Snider, 1917, p. 80). The area lies in a belt of alternating sandstone, shale and thin limestone beds, which dip gently in a direction slightly north of west. Through differential erosion, the more resistant sandstone beds form cuestas, with steep escarpments to the east and rather broad, gentle slopes to the west. Commonly, the western slope (or back slope) is dissected by numerous northward and southward flowing streams, thus producing a rough and broken topography. The low dip of the beds make the cuesta development

difficult to recognize. Areas where sandstone or sandy shale crop out are, at most places, covered with a heavy growth of scrub oak. If sufficiently thick, the shale beds form a grass-covered prairie topography. Generally, the limestones display little or no topographic relief within the area.

Four bands of the dissected cuesta type topography, alternating with four bands of the prairie type, trend from slightly east of north, southward across the Black Dog area. From east to west, the four prairie belts are developed on thick shale beds in the following formations: Coffeyville, Chanute and Muncie Creek shale of the Iola formation, unnamed shale member of the Barnsdall formation, and upper part of the Wynona sandstone member and Kanwaka shale of the Vamoosa formation. Alternating with the shale beds above, massive sandstone in the following formations produces the dissected cuesta type topography: Nellie Bly, Wann formation and Okesa sandstone of the Barnsdall formation, Tallant and the lower part of the Vamoosa formation, and the Elgin sandstone of the Vamoosa formation.

The lowest elevation in the area, slightly less than 620 feet above sea level, occurs in sec. 3, T. 21 N., R. 12 E. where Hominy Creek crosses the Osage County line; the highest elevation, more than 1,150 feet, occurs in sec. 15, T. 21 N., R. 9 E., resulting in a maximum relief of more than 530 feet.

The area is drained by three major eastward flowing, consequent streams. Hominy Creek, flowing across the northeastern corner of the area, and its main tributaries, Rock, Quapaw, Tall Chief and Boar Creeks, drain approximately 128 square miles of the northern part of the area.

The Arkansas River, which establishes or closely parallels the southern boundary, and its main tributaries, Shell and Mud Creeks, drain approximately 109 square miles of the southern part of the area. Delaware Creek, in the east-central part of the area, drains 64 square miles. The divide that separates the drainage basins of the Arkansas River and Delaware Creek to the east, and Hominy Creek to the west, trends practically parallel to the Arkansas River.

The Arkansas River, Hominy Creek, Delaware Creek and the larger tributaries flow through well-developed valleys, the floors of which are generally covered with a veneer of alluvium. These larger streams possess meandering courses and gradients of only a few feet per mile. The smaller tributaries are intermittent, normally with dendritic patterns and high gradients. Many of the smaller streams flow in a direction parallel to the dominant joint and fault trend, i.e., N. 20° W. to N. 50° W.

The only sizable reservoir is in the south-central part of the area, where Shell Creek has been impounded to provide municipal water for the town of Sand Springs. In recent years, the yield of water has been insufficient and the town has sought another source. Numerous man-made ponds occur on ranches throughout the area.

Several previous geologic studies have been conducted in part of the Black Dog area. In 1917 and 1918 the eastern and southern parts were mapped by several geologists of the United States Geological Survey under the direction of K. C. Heald (White, 1922). This work was part of an accelerated program to locate possible oil-bearing structures and to increase the nation's petroleum supply and reserve during World War I.

Accordingly, only "key beds" were mapped and described and, unfortunately, few beds were mapped across adjacent townships. Nevertheless, this investigation has provided a valuable foundation for succeeding work.

Beckwith (1928) combined the aforementioned work with information obtained from oil companies and other commercial sources into a complete report concerning Osage County.

Mohler (1942) mapped and described the Iola formation of Osage and Tulsa Counties.

Perhaps the greatest contribution to the present understanding of the geology of the region has been made by M. C. Oakes of the Oklahoma Geological Survey. His Washington (1940) and Tulsa (1952) County reports have been utilized extensively in the preparation of this thesis. The eastern part of the Black Dog area was mapped by Oakes (1952) in conjunction with his work in Tulsa County.

Adjacent areas in Osage and adjoining counties have been studied recently by Greig (1954), Russell (1955), Tanner (1956) and Gardner (1956).

CHAPTER II

STRATIGRAPHY

GENERAL STATEMENT

The stratigraphic sequence exposed in the Black Dog area is of Upper Pennsylvanian age. Pennsylvanian beds range upward from the Coffeyville formation of the Missouri series into the Elgin sandstone member of the Virgil series. The sequence is approximately 1,700 feet thick and consists of alternating beds of shale, sandstone and limestone.

MISSOURI SERIES

The name Missouri series was first applied by Keyes (1893, p. 85) to upper Pennsylvanian strata as typically developed in northwestern Missouri. The series in north-central Oklahoma is defined as the strata occurring above the unconformity at the top of the Des Moines series and below the unconformity at the base of the Virgil series.

Missourian beds below the Coffeyville formation are not exposed in the Black Dog area. The series above the Coffeyville consists of gray and maroon shales, thin to massive sandstones and thin, locally developed sandy limestones, with a total thickness of approximately 1,200 feet.

The Missourian series has been subdivided into the Skiatook group below and the Ochelata group above.

Skiatook Group

The term Skiatook was originally applied by Ohern (1910, pp. 35-36) to the section occurring between the Checkerboard and the Dewey limestones. Subsequently, the name was not employed until Moore (1937, pp. 39-40) proposed the present usage for strata extending upward from the unconformity at the base of the Missourian series to the unconformity beneath the Chanute formation.

That part of the Skiatook group that crops out in the Black Dog area consists essentially of gray shales, with lesser amounts of interbedded, locally thick sandstones, and thin, lenticular to persistent limestones. Many of the units display abrupt lithologic variations when traced along strike. Southward, the formations display a marked increase in thickness and in ratio of sandstone to shale. Exposures of the Skiatook group within the Black Dog area have an aggregate thickness of 600 feet.

Coffeyville Formation.

Definition. The Coffeyville formation was named by Schrader and Haworth (1905, p. 448) from exposures in the vicinity of Coffeyville, Kansas. The name was applied originally to the rocks of the interval between the base of the Drum and the top of the Parsons (Lenapah) limestones. As redefined by Moore (1937, p. 42), the term is applied to the sandstone-shale sequence lying between the Checkerboard and the Hogshooter formations.

Distribution and thickness. The outcrop of the Coffeyville extends southward from the Kansas-Oklahoma line to the southwestern corner of Okfuskee County.

It was impossible to measure a complete section of the Coffeyville at any given locality; however, composite sections indicate a thickening of the formation from 295 feet in the southern part of T. 21 N., R. 12 E. to 323 feet in the southern part of T. 20 N., R. 12 E. The basal 30 feet of the formation does not crop out in the area.

Character and subdivisions. The Coffeyville formation in the Black Dog area consists essentially of gray and blue shales containing two lenticular sandstones.

The lower 100 feet of the formation is predominantly shale. At the base, resting upon the Checkerboard limestone, is a black, fissile shale, 7 feet thick, which contains small, black phosphatic nodules. This black shale is overlain by approximately 93 feet of blocky to fissile, gray shale which contains thin, wavy-bedded siltstone layers, which grade upward into the lower sandstone. Exposures of the lower shale do not occur in the Black Dog area, but there is an excellent exposure along Flat Rock Creek, secs. 13 and 14, T. 20 N., R. 12 E., Tulsa County (Fig. 2).

The lower sandstone, which averages 23 feet in thickness, consists of several lenticular beds each normally less than 3 feet thick, grading laterally and vertically into wavy-bedded siltstone and shale. The sandstone is buff, essentially fine-grained, thin-to medium-bedded, ripple-marked, and moderately cross-bedded. Along the Tulsa-Sperry

road immediately south of Flat Rock Creek in sec. 14, T. 20 N., R. 12 E., this lower sandstone may be examined conveniently.

The lower sandstone grades upward into a thick sequence of gray to dark blue, thin to blocky shale. Along the road in the SE¼ sec. 15, T. 20 N., R. 12 E., a complete section (112 feet) is exposed. Other good exposures are along the Tulsa-Sperry road on the northern side of Turley Mountain, secs. 35 and 36, T. 21 N., R. 12 E., and along the east-west road on the eastern side of Reservoir Hill in the SE¼ sec. 22, T. 20 N., R. 12 E.

In the NW¼ sec. 4, T. 20 N., R. 12 E., a local limestone bed occurs in the upper part of the middle shale interval lying approximately 20 feet below the upper sandstone. The limestone is a foot thick, dark brown in color, sandy and weathers to brick-red. Large crinoid stems are common and stand out in relief on the weathered surfaces.

The upper sandstone (Fig. 3) of the Coffeyville formation forms a rather prominent and easily traceable escarpment from the alluvium in sec. 10, T. 21 N., R. 12 E. southward to the southwestern corner of T. 20 N., R. 12 E. The zone, similar to the lower sandstone zone, consists of buff to dark tan, fine to medium, thin to massive sandstone, commonly ripple-marked and cross-bedded. Both lateral and vertical gradation into siltstone and shale are common. Easily accessible exposures occur along the Tulsa-Sperry road on the northern side of Turley Mountain, sec. 36, T. 21 N., R. 12 E. and along the paved road in the NW¼ sec. 6, T. 19 N., R. 12 E.

The upper part of the formation consists of approximately 40 feet

of light gray to dark blue shale containing at least two thin coal beds. The lower portion of the unit is generally silty; the upper portion is clayey. Locally, thin underclays are associated with the coal beds. The lower coal bed lies 17 to 20 feet below the Hogshooter formation and consists of a single bed, normally less than 0.3 feet thick, associated with underclay. In the SE$\frac{1}{4}$ sec. 17, T. 20 N., R. 12 E., the coal has a thickness of 0.2 feet and is underlain by 0.2 feet of underclay containing numerous plant fragments preserved as carbonaceous film. North of T. 20 N., R. 12 E., the bed was not found. The upper coal bed lies approximately a foot below the Hogshooter formation (Figs. 4-6) and consists of one or more beds, each ranging from a film to 0.2 feet thick, occurring in a zone not exceeding 0.3 feet in thickness. Above and below this coal bed is thin blue-gray, clay shale, resembling an underclay and containing carbonaceous plant fragments. North of T. 20 N. this coal is absent, but it does persist at least as far southward as the center of T. 19 N., R. 11 E. An easily accessible locality for study is along the paved road in the NW$\frac{1}{4}$ sec. 6, T. 19 N., R. 12 E.

Stratigraphic relationships and correlation. The Coffeyville formation rests conformably upon the Checkerboard formation and is overlain conformably by the Hogshooter formation.

The Coffeyville formation is equivalent to the rocks of the Kansas section lying between the Checkerboard limestone and the Dennis (Hogshooter) formation. This interval includes the Hertha limestone, Ladore shale, Swope limestone and Galesburg shale. It is correlative with the lower part of the Francis formation of south-central Oklahoma.



Figure 2. One of the best exposures of the lower shale of the Coffeyville formation, along the Tulsa-Sperry road, NE$\frac{1}{4}$ sec. 14, T. 20 N., R. 12 E.



Figure 3. Exposure of the upper sandstone zone of the Coffeyville formation along the Tulsa-Sperry road, NW$\frac{1}{4}$ sec. 36, T. 21 N., R. 12 E.

The upper sandstone has been correlated with the Dodds Creek sandstone of Kansas and the subsurface Layton sandstone of Creek County, Oklahoma (Oakes, 1952, p. 59).

Paleontology. No fossils were found in the formation except the aforementioned plant fragments.

Hogshooter Formation

Definition. The Hogshooter formation was first mapped by Adams (1903, pp. 62-63) as the lower Drum limestone. Ohern (1910, pp. 28-29) named the formation from exposures along Hogshooter Creek, Nowata County, Oklahoma, and described the unit as follows:

> ...essentially...a single bed of limestone. This in its northern extension is heavily bedded and massive but to the southward it is thin bedded and argillaceous. Usually fossils are fairly abundant.

Distribution and thickness. The Hogshooter formation has been mapped from northern Nowata County southward to the central part of Okfuskee County. In the Black Dog area, the formation emerges from a position beneath the alluvium in sec. 15, T. 21 N., R. 12 E. and trends southwestward to the southeastern corner of T. 20 N., R. 11 E. Heavy sandstone debris conceals the outcrop over an extensive part of the area.

The formation thickens from an average of 2 feet in T. 21 N., R. 12 E., to 16.5 feet in the southeastern corner of T. 20 N., R. 11 E.

Character and subdivisions. In the Black Dog area, the Hogshooter has been subdivided into the Lost City limestone member below and the Winterset limestone member above.

Lost City limestone member. The lower member of the Hogshooter

was named by Gould (1911, p. 179) from exposures near Lost City, in west-central Tulsa County, where the member attains a maximum thickness of 50 feet. In the Black Dog area, the member thickens from 4.5 feet in sec. 17, T. 20 N., R. 12 E., to 15 feet in sec. 36, T. 20 N., R. 11 E. It is absent north of sec. 8, T. 20 N., R. 12 E. The gray-blue limestone is dense, massive and weathers light gray. It is sparsely fossiliferous. A good exposure occurs along the paved road in the NW¼ sec. 6, T. 19 N., R. 12 E.

Insoluble residue tests reveal the Lost City limestone of the Black Dog area with an average composition of 88.5 per cent carbonate, 0.3 per cent residue and 11.2 per cent decanted clay size material. The residue consists essentially of extremely fine, subangular quartz grains with traces of selenite, orthoclase and lignitic material.

Winterset limestone member. The name was first applied by Tilton in 1897 to a sequence of limestone and sandstone in Madison County, Iowa (Wilmarth, 1938, p. 2355). Moore (1932, p. 91) restricted the term to the upper limestone of the Dennis formation of the Kansas section.

In the Black Dog area, the Winterset member ranges in thickness from 0.3 to 3.0 feet, averaging 2 feet. It is continuous and its character is consistent throughout the area. The member consists of gray to dark brown, highly argillaceous, sandy limestone which weathers yellow and contains rounded phosphatic nodules. An abundance of crinoidal debris is characteristic of the member. Commonly, the limestone weathers into a yellow, granular mass composed almost entirely of crinoidal fragments.



Figure 4. The thinnest occurrence of the Winterset limestone member of the Hogshooter formation and the upper coal (point of hammer) of the Coffeyville formation, SW¼ sec. 5, T. 20 N., R. 12 E.



Figure 5. Winterset (IPhw) and Lost City (IPhlc) limestone members of the Hogshooter formation overlying the upper coal (head of hammer) of the Coffeyville formation, NW¼ sec. 6, T. 19 N., R. 12 E.

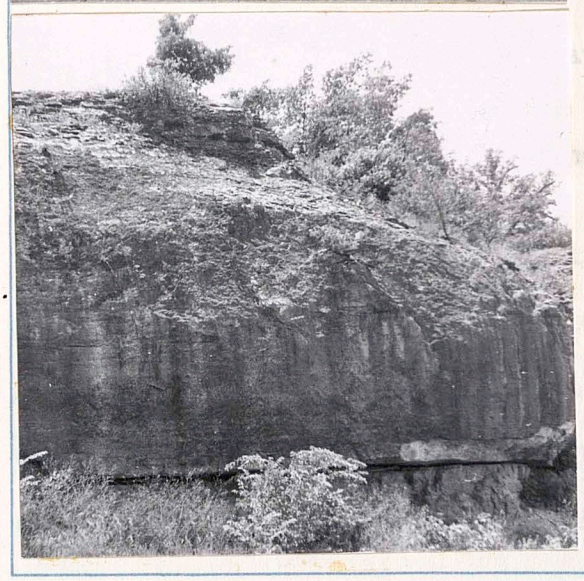


Figure 6. Thick exposure of Lost City limestone underlain by coal bed of the Coffeyville formation, SE¼ sec. 15, T. 19 N., R. 11 E.

Insoluble residue tests indicate that the composition of the Winterset limestone ranges from 84.0 per cent carbonate, 2.4 per cent residue and 13.6 per cent decanted clay size material in sec. 32, T. 21 N., R. 12 E., to 72.0 per cent carbonate, 7.0 per cent residue and 21.0 per cent decanted clay size material in sec. 6, T. 19 N., R. 12 E. The residue is essentially rounded, fine, siltstone fragments and silicified organic remains.

Stratigraphic relationships and correlation. The Hogshooter formation conformably overlies the Coffeyville formation and is overlain conformably by the Nellie Bly formation.

The Hogshooter is equivalent to the Dennis formation of Kansas and to the middle part of the Francis formation of south-central Oklahoma (Oakes, 1952, p. 64).

Paleontology. Fossils of the Hogshooter include the following:

Protozoa
Triticites sp.

Anthozoa
Lophophyllidium sp.

Crinoidea
Columnals and plates

Bryozoa
Fenestrate and encrusting forms

Nellie Bly Formation

Definition. According to Gould (1925, p. 74), the Nellie Bly formation was named by D. W. Ohern (in an unpublished manuscript) from exposures along Nellie Bly Creek, Washington County, Oklahoma. Gould, quoting partially from Ohern, described the formation as follows:

UNIVERSITY OF OKLAHOMA
LIBRARY

> "Alternating shale and hard, gray sandstone, the latter ranging in thickness from a few inches to several feet" from 15 feet on the Kansas line to 200 feet in southeastern Osage County....Rests on the Hogshooter and is overlain by the Dewey limestone.

Distribution and thickness. The Nellie Bly crops out in an irregular band from the Kansas-Oklahoma line in Nowata County southward to the northern part of Pontotoc County (Tanner, 1956, p. 71). The formation occurs in the northeastern corner of the Black Dog area in a band three to four miles in width. Southward, in the eastern part of T. 21 N., R 11 E., the outcrop narrows to approximately two miles because of the increase in the westward dip of the beds on the northwestern flank of the Delaware anticline. The formation becomes thicker and the width of outcrop increases to six miles in the southern part of the area. As the ratio of sandstone to shale increases from north to south, the low prairie developed on the outcrop in the north becomes rugged and hilly southward.

In Washington County, Oakes (1940, p. 48) discovered the thickness of the formation to increase from 80 feet (north) to 180 feet (south). The thickness increases from approximately 230 feet in T. 21 N., R. 11 E., to approximately 300 feet in T. 20 N., R. 11 E. across the Black Dog area.

Character and subdivisions. The Nellie Bly consists of dark-colored, sandy to clayey shales, lenticular to persistent sandstones, thin siltstones and, at least one thin limestone bed. Two of the more persistent sandstone units have been mapped (Plate I).

In the southern half of T. 22 N., R. 12 E., the formation is poorly exposed because of the low relief. Alluvial deposits of Hominy

Creek cover much of the Nellie Bly.

In T. 21 N., R. 12 E., the lower 35 to 40 feet of the formation consists of dark gray, clayey shale which weathers to a dark soil. A local thin limestone bed, colloquially termed the "Turley Mountain Stray" limestone (Murray, 1941), occurs within the lower shale unit. Lying 22 feet above the Hogshooter formation, the limestone is exposed on the northern side of Turley Mountain in the SW¼ sec. 36, T. 21 N., R. 12 E. The bed is a foot thick, dark blue to rust-colored, argillaceous and weathers bright yellow. Southward, the lower shale of the Nellie Bly increases to a thickness of approximately 100 feet and contains much interbedded thin sandstone in T. 20 N., R. 11 E.

In the east-central part of the area, a sandstone, colloquially termed the "Hominy Falls" sandstone and mapped (Plate I) as the lower sandstone, occurs approximately 35 feet above the base of the formation. This unit, best developed on the outlying hills south of Delaware Creek, consists of up to 25 feet of yellow, fine to medium, thick to massive sandstone, interbedded with thin, silty shale partings. Northward, the zone thins and is covered by alluvium north of sec. 9, T. 21 N., R 12 E.; southward, the identity of the unit is lost as it merges into a complex sandstone-shale sequence in the northwestern part of T. 20 N., R. 12 E. and the northeastern part of T. 20 N., R. 11 E. The lower sandstone zone is well exposed above the "Turley Mountain Stray" limestone at the aforementioned locality.

In the southern part of the area, the lower shale of the formation grades upward into the aforementioned complex sandstone-shale sequence. Ranging up to 100 feet in thickness, the sequence consists

essentially of gray to buff, fine-grained, laminated to massive, locally highly contorted sandstone (Figs. 7 and 8), interbedded with gray to tan, micaceous siltstones and gray, lignitic shales. The beds are exceedingly lenticular, and channeling is commonly observed. Many of the bedding surfaces are ripple-marked and display a variety of trails. Unusually high dips (for this region) of up to six degrees were noted and, although beds were observed dipping in different directions at different localities, the prevalent dip is two to five degrees to the northwest. Several authors have considered these beds as deltaic deposits of a northward flowing stream. Lloyd and Mathers (White, 1922, p. 122) described the sequence as:

> ...a thick series of shale and sandstone which was deposited in the delta of a northward-flowing stream. The series consists in greater part of shale but includes a number of very prominent massive sandstone beds, which are, however, very lenticular and, at least for the most part, are foreset delta deposits. ...The deltaic origin of the rocks is shown by the lenticularity of the beds and by their generally northward dips, which do not correspond with the structure of overlying and underlying rocks.

As the sandstones are, in general, not particularly resistant, benches are poorly developed and, because of the lenticularity of the beds, are traceable but a short distance. In the northern part of T. 20 N., R. 11 E., this "deltaic" sequence apparently descends in the section and splits into several thin sandstone beds traceable for a short distance northward. The lower sandstone (as mapped on Plate I) is possibly a northern continuation of the lower part of the "deltaic" sequence. This part of the formation may be examined along the paved road extending westward from Sand Springs, Tulsa County, and along



Figure 7. Cross-bedding and contorted bedding typical of the middle part of the Nellie Bly formation, NW¼ sec. 9, T. 19 N., R. 11 E.



Figure 8. Contorted bedding in the middle part of the Nellie Bly formation, NW¼ sec. 9, T. 19 N., R. 11 E.

Delaware Creek in T. 21 N., R. 11 E.

In the upper part of the Nellie Bly formation is a persistent sandstone zone colloquially termed the "Shell Creek" sandstone from exposures along Shell Creek in T. 20 N., R. 11 E. This sandstone is best developed in the southern part of the area, where it is 70 to 90 feet thick. Here the lower bed of the unit is a buff to dark tan, fine-to medium-grained, massive-bedded, friable sandstone which is banded with various shades of yellow limonitic stain. This bed is 20 to 30 feet thick and is the only unit of the Nellie Bly formation with distinctive lithologic character that permits accurate field identification. Overlying the basal sandstone is a sequence of alternating ferruginous sandstones and dark shales. Northward in T. 21 N., Rs. 11 and 12 E., the ratio of sandstone to shale decreases, and the unit is essentially sandy shale.

South of Delaware Creek, the base of the upper sandstone unit was mapped with difficulty. At many places, the unit rests directly upon lower sandstones, and the contact, as drawn on airplane photographs, is difficult to determine in the field; nevertheless, it is believed that the contact as portrayed on Plate I is essentially correct. The upper sandstone may be examined along the east-west road through secs. 29 and 30, T. 20 N., R. 11 E. or along the north-south road in the eastern part of T. 20 N., R. 11 E.

Stratigraphic relationships and correlation. In the Black Dog area, the Nellie Bly is conformably underlain by the Hogshooter formation and conformably overlain by the Dewey formation.

Paleontology. No fossils were discovered in the Nellie Bly

formation.

Dewey Formation

Definition. The formation was first mapped by Adams (1903, pp. 62-63) as the Drum limestone. Ohern (1910, p. 30) named the formation from exposures near Dewey, Washington County, and described the formation as follows:

> The Dewey lens is a bluish, semi-crystalline limestone, usually somewhat shaley but often massively bedded. On weathering it gives surface fragments which abound in seams of calcite which resist solution more effectively than the non-crystalline mass. Wherever examined the Dewey abounds in fossils, Campophyllum torguim [Caninia torquia] being especially abundant.

Distribution and thickness. In Oklahoma the formation has been traced from T. 28 N., R. 14 E., Nowata County, to southern Okfuskee County. Its southern equivalent, the Belle City limestone, continues southward to central Pontotoc County (Oakes, 1952, p. 68).

In Nowata and Washington Counties, the formation is generally 10 feet thick (Oakes, 1952, p. 68). Southward in sec. 33, T. 23 N., R. 12 E., a thickness of 20.5 feet was reported by Gardner (1956, personal communication). In the Black Dog area, the thickness ranges from 16.5 feet in sec. 28, T. 21 N., R. 11 E., where the upper part is presumably removed by pre-Chanute erosion, to 52 feet in sec. 31, T. 22 N., R. 12 E.

Character and subdivisions. The Dewey consists of from one to three thin limestone beds separated by dark, calcareous shale.

Along the north-south road a quarter mile south of the northwestern corner of sec. 20, T. 22 N., R. 12 E., the upper 15 feet of

the Dewey is exposed. The upper 3 feet consists of blue, dense, somewhat wavy-bedded, argillaceous limestone containing poorly preserved fossils. Beneath the upper limestone is 12 feet of highly calcareous, marly shale containing knobby nodules of limestone and poorly preserved fossils, including Caninia torquia (?) (Owen).

Southward on the outlying hill in the SW¼ sec. 31, T. 22 N., R. 12 E., the Dewey consists of 50 feet of dark gray, calcareous shale overlain by 2.5 feet of yellow, highly argillaceous, fossiliferous limestone.

Near the northwestern corner of sec. 24, T. 21 N., R. 11 E., the basal bed of the Dewey is a limestone, colloquially termed the "Cowbarn" limestone (Murray, 1941). The bed is 2 to 3 feet thick, gray to rust-colored, medium crystalline, argillaceous, and sandy. It weathers to a light gray or yellow color. The upper bed of the formation consists of 3 feet of yellow to light brown, medium-bedded, argillaceous limestone which weathers to a dirty yellow color. Separating the two limestones is 30 feet of dark gray, calcareous shale.

In sec. 28, T. 21 N., R. 11 E., only the lower 16 feet of the Dewey is present; the upper part is presumed to have been removed by pre-Chanute erosion. The formation is represented here by two thin limestones, one to 3 feet thick, separated by 12 feet of thin sandstone and shale. From this point southward, these two limestones persist in the lower part of the Dewey and can be distinguished at most places by the color of their weathered surfaces. The lower limestone weathers to light gray; the upper limestone (of the lower part of the formation)

weathers to yellow or rust-color.

In secs. 24 and 25, T. 20 N., R. 10 E., all three limestones of the Dewey are present. The two lower beds, exhibiting the above-mentioned weathering characteristics, are exposed on the western shore of Shell Lake in the SE$\frac{1}{4}$ sec. 24, T. 20 N., R. 10 E. The beds are not exposed in place, but their presence is indicated by large float fragments resting upon the upper persistent sandstone of the Nellie Bly formation. Along the north-south road approximately one quarter mile south of the north line of sec. 25, T. 20 N., R. 10 E., the upper limestone bed is 4 feet thick and consists of blue-gray, medium crystalline, thick-bedded limestone which weathers to a yellow color. Here the middle part of the formation expresses itself as a grass-covered slope of low relief. The estimated thickness of the formation is 30 to 35 feet. South of this locality, the major part of the Dewey is concealed by eolian material.

Insoluble residue tests reveal the composition of the upper limestone bed of the Dewey formation ranging from 74.9 per cent carbonate, 2.4 per cent residue and 22.7 per cent decanted clay size material in sec. 31, T. 22 N., R. 12 E., to 93.0 per cent carbonate, 0.2 per cent residue and 6.8 per cent decanted clay size material in sec. 25, T. 20 N., R. 10 E.

Stratigraphic relationships and correlation. The Dewey is conformably underlain by the Nellie Bly formation. In Nowata and Washington Counties, the Dewey is overlain unconformably by the Chanute formation (Oakes, 1952, p. 73). In most of the Black Dog area, there is no direct evidence of an unconformity at the Dewey-

Chanute contact; however, the absence of the upper limestone bed and the rather abrupt thinning of the formation in the south-central part of T. 21 N., R. 11 E., indicates that the unconformity continues southward, at least to that area.

The Dewey formation is correlative with the Cement City member of the Drum limestone in Kansas, and the formation probably correlates with the Belle City limestone of central Oklahoma (Oakes, 1954, p. 74).

Paleontology. In general, fossils occurring in the Dewey formation are poorly preserved. Fragments of Caninia torquia (?) (Owen) occur in sec. 20, T. 22 N., R. 12 E., but were not discovered farther south. Triticites sp. is numerous in the lower limestone in the central part of the area. Various poorly preserved specimens of brachiopods, corals and crinoid columnals are present throughout the formation.

Ochelata Group

The name Ochelata was first applied by Ohern (1910, p. 38) to beds lying between the Dewey and Avant limestones. Several different meanings were attached to the name until Moore (1937, pp. 39-43) proposed the name Ochelata as a group name for strata lying between the base of the Chanute formation and the base of the Nelagoney formation. Oakes (1952, pp. 74-75) extended the upper limit to include the Tallant formation and to coincide with the Missouri-Virgil unconformity.

In the Black Dog area, the Ochelata group is approximately 625 feet thick and, in order of predominance, consists of gray and maroon shales, thin to massive sandstones, locally thick limestones, and a

lenticular dolomite. Most of the sandstones are lenticular, with rather rapid lateral lithologic changes into shale; yet, some of the shale units persist across the area with little or no change in character or thickness.

On the basis of lithology, the Ochelata group has been subdivided into five formations; they are (ascending): Chanute, Iola, Wann, Barnsdall and Tallant.

Chanute Formation

Definition. The Chanute formation was named by Haworth and Kirk in 1894 from exposures in the vicinity of Chanute, Neosho County, Kansas (Wilmarth, 1938, p. 399). The term was introduced into Oklahoma stratigraphy by Moore (1937, p. 43) as "The lowermost formation of the Ochelata group....It is normally underlain by the Drum [Dewey] limestone and overlain by the Iola (includes Avant) limestone".

Distribution and thickness. The formation is first encountered in Oklahoma in northwestern Nowata County where it trends southwestward to the North Canadian River in Okfuskee County. In the Black Dog area, the formation crops out in a narrow band on the steep side of an eastward facing escarpment capped by the Avant limestone and lenticular sandstones of the Wann formation. The outcrop is generally covered by debris from the overlying formations.

The thickness of the formation is quite uniform throughout the area, ranging from 32 to 40 feet.

Character and subdivisions. In the mapped area, the formation consists of dark gray shales, silty sandstones and one or more thin

coal beds. According to Oakes (1952, p. 76):

> In southern Washington County the Chanute consists of three members: a basal unnamed shale member; the Thayer coal member; a sandstone member, correlated with the Cottage Grove sandstone of Kansas; and an upper coaly shale member only a few inches thick.

All four members described by Oakes are represented in the northern part of the area, but due to the nature of the exposures, it is difficult to define the limits of the members or, at places, the limits of the formation.

The lower shale member, though poorly exposed, is the most persistent member of the Chanute in the area. The Thayer coal was discovered in place at only one locality in the northern part of the area, but, according to Oakes (1952, p. 77), the member has been identified as far south as sec. 14, T. 21 N., R. 11 E. The Cottage Grove sandstone member is somewhat diverse in character and thickness. It is best developed in the north and was not discovered south of sec. 28, T. 21 N., R. 11 E. Although the "coaly" shale member is not exposed south of Oklahoma State Highway 20, it is probably represented in various places by a covered interval occurring between the Cottage Grove sandstone and the Paola limestone member of the Iola formation.

By far the best exposure of the Chanute occurs along Oklahoma State Highway 20 immediately west of Quapaw Creek in sec. 24, T. 22 N., R. 11 E. (Fig. 9). The Thayer coal, exposed at road level, consists of a bed of coal 0.4 feet thick. Resting upon the coal, the Cottage Grove sandstone member is 14 feet thick and is composed of gray to buff, fine-grained, thin-bedded sandstone. The bed is very silty and micaceous, and it contains a few lignitic streaks near the top which may represent the

~~the~~ upper "coaly" shale member.

On the eastern end of the outlying hill in the SW¼ sec. 31, T. 22 N., R. 12 E., the lower shale member (overlying the upper limestone bed of the Dewey formation) is a dark gray, non-fossiliferous, clay shale. The member is 22 feet thick. A well-defined bench marks the outcrop of the Cottage Grove sandstone member. The sandstone is dark brown, fine-grained, massive and resistant in the lower part, laminated and less resistant near the top. The upper surface is deeply pitted. The Cottage Grove is 4 feet thick and is separated from the Paola limestone by 6 feet of covered interval, probably representing the upper "coaly" shale member.

South of sec. 28, T. 21 N., R. 11 E., the Cottage Grove is not recognizable, and the formation is predominantly shale, with possible thin coal seams.

Stratigraphic relationships and correlation. The Chanute formation rests unconformably upon the Dewey formation and is overlain conformably by the Paola limestone member of the Iola formation.

The Chanute formation of the Black Dog area is a direct continuation of the Chanute formation of Kansas. A part of the Hilltop formation of Seminole County may represent a southern equivalent of the Chanute formation (Tanner, 1956, p. 84).

Paleontology. The Chanute formation is essentially non-fossiliferous in the Black Dog area.

Iola Formation

Definition. The Iola formation was named originally by Haworth

and Kirk in 1894 from exposures at Iola, Kansas (Wilmarth, 1938, p. 1017). Newell (Moore, 1932, p. 92) subdivided the formation at the type locality into three members, all of which are recognizable in the Black Dog area.

Distribution and thickness. The Iola outcrop is first encountered in northern Oklahoma in the northwestern corner of Nowata County and is traceable southward to T. 15 N., R. 9 E., Creek County. South of this point, the formation has been removed by pre-Barnsdall erosion (Oakes, 1952, p. 78). In the Black Dog area, the Avant limestone, the upper member of the formation, caps a prominent eastward facing escarpment and is readily traceable throughout the area. The lower members, the Muncie Creek shale and Paola limestone, are largely concealed and are traceable only by their position in relation to the superjacent Avant limestone. For this reason, the Avant is mapped as the Iola formation, and that part of the formation occurring below the Avant is included as the upper part of the Chanute interval (Plate I).

The thickness of the formation ranges from 46 feet in sec. 28, T. 21 N., R. 11 E., to 76 feet in sec. 24, T. 22 N., R. 11 E.; it averages 65 feet.

Character and subdivisions. In the Black Dog area, the formation is subdivided (as at the type locality in Kansas) into the Paola limestone member, the Muncie Creek shale member and the Avant limestone member.

Paola limestone member. The Paola limestone was named by Newell (Moore, 1932, p. 92) from exposures at the type locality near Paola, Kansas.



Figure 9. An excellent exposure of the Iola formation and part of the Chanute formation, along Oklahoma State Highway 20, NE$\frac{1}{4}$ sec. 24, T. 22 N., R. 11 E.



Figure 10. Wavy bedding typical of the Avant limestone, SW$\frac{1}{4}$ sec. 26, T. 22 N., R. 11 E.

In the Black Dog area, the member is an extremely calcareous sandstone, averaging generally less than 3 feet thick. The unit is largely concealed by the overlying Muncie Creek shale, but its presence is usually indicated by a slight bench which at many places supports a growth of persimmon trees.

An excellent exposure of the Paola member occurs in the road cut of Oklahoma State Highway 20 in the NE$\frac{1}{4}$ sec. 24, T. 22 N., R. 11 E., (Fig. 9). At this locality, the member consists of 1.5 feet of dark gray, extremely calcareous, non-fossiliferous sandstone, which weathers to a dark rust color.

An insoluble residue test reveals the Paola limestone from the aforementioned locality composed of 32.9 per cent carbonate, 54.1 per cent residue and 13.0 per cent decanted clay size material. The residue consists essentially of fine, subangular quartz grains with a trace of muscovite and carbonaceous material.

Muncie Creek shale member. The Muncie Creek shale member was named by Newell (Moore, 1932, p. 92) from exposures at the type locality along Muncie Creek, Wyandotte County, Kansas.

Within the Black Dog area, the member thins from 63 feet in sec. 24, T. 22 N., R. 11 E., to 26 feet in sec. 16, T. 20 N., R. 11 E. This thinning of the Muncie Creek south of sec. 33, T. 21 N., R. 11 E. results in considering a bench located approximately mid-way between the Paola and Avant limestones to be equivalent to the lower part of the Avant at the type locality. This relationship is not evident in the Black Dog area, but it has been supported by the work of Oakes (1952, pp. 82-83) south of the Arkansas River in Tulsa County.

The Muncie Creek consists of dark to light gray, fissile to blocky shale containing small, phosphatic nodules. It also contains thin zones of oval ironstone concretions, many of which have calcite-filled shrinkage cracks. The shale weathers to an olive-yellow. The member in its entirety may be examined at the aforementioned road-cut along Oklahoma State Highway 20, sec. 24, T. 22 N., R. 11 E. (Fig. 9).

Avant limestone member. The Avant limestone, which corresponds to the Raytown limestone of Kansas and Missouri, was named by Ohern (1910, pp. 31-32) from outcrops in the vicinity of Avant, Osage County, Oklahoma.

The member thins from 53 feet (Gardner, 1956, personal communication) near Avant, to 15 feet in sec. 24, T. 22 N., R. 11 E. Southward, the member generally displays a thickness of 10 feet.

In the NE$\frac{1}{4}$ sec. 24, T. 22 N., R. 11 E. the member is gray to light pink, dense to finely crystalline, thick-to wavy-bedded (Fig. 10), fossiliferous limestone. It weathers to gray, wavy fragments of approximately 0.2 feet in thickness. Insoluble residue tests reveal the member at this locality containing only 7.3 per cent insoluble material, of which 6.7 per cent is clay size.

Southward, thin interbedded sandstone comprises an increasingly large percentage of the interval, and the limestone component becomes increasingly arenaceous and argillaceous. Along the east-west road in the northwestern corner of sec. 36, T. 20 N., R. 10 E., the Avant is composed of three units: a lower bed (4 feet thick) of gray, finely crystalline, sandy limestone; a middle bed (6 feet thick) of buff to gray, fine-grained, medium-bedded sandstone; and an upper bed (2 feet

thick) of gray, dense, finely crystalline, sandy limestone. The lower bed weathers to a deep maroon. Insoluble residue tests reveal the above-mentioned limestone with an average composition of 80.2 per cent carbonate, 8.5 per cent residue and 11.3 per cent decanted clay size material. The residue consists of extremely fine, well-sorted, sub-angular quartz grains.

Stratigraphic relationships and correlation. The Iola formation rests conformably upon the Chanute formation and is overlain conformably by the Wann formation.

The Iola formation of the Black Dog area is a direct continuation of the Iola formation of Kansas.

Paleontology. The following fossils were collected from the Avant limestone in scattered localities throughout the area:

Protozoa
Triticites sp.

Brachiopoda
Dictyoclostus sp.
Echinoconchus semipunctatus (Shepard)
Linoproductus sp.
Meekella striatocostata (Cox)
Neospirifer dunbari King

Pelecypoda
Myalina sp.

Wann Formation

Definition. The name Wann was originally assigned by Ohern (1910, p. 28) to a sequence of sandstone, shale and limestone exposed near the town of Wann, Osage County, Oklahoma. The term was seldom employed until Oakes (1940, p. 74) redefined the unit as the interval

...between the top of the Iola formation, below, and

> the base of the Torpedo sandstone, above, or the base of the Birch Creek limestone where the Torpedo sandstone was removed by pre-Birch Creek erosion.

In the Black Dog area, the southern equivalent of the Birch Creek limestone member, the Okesa sandstone member of the Barnsdall formation, overlies the Wann.

Distribution and thickness. The Wann extends from the Kansas-Oklahoma line southward to Creek County, where it is completely removed by pre-Chanute erosion (Oakes, 1952, p. 84). The formation crosses the central part of the area as a rugged, tree-covered terrain from four to eight miles in width.

Because of the excessive width of the outcrop, no complete single exposure was discovered, but composite sections indicate a slight thinning of the formation from 325 feet in the north, to 275 feet to the south.

Character and subdivisions. According to Oakes (1952, p. 84):

> The Wann formation is notable for its heterogeneous rock types which intergrade both laterally and vertically. In this area the Wann consists dominantly of shale and sandstone with limestone and limy sandstones present in small amounts and only locally....thick sandstones are prominent in Tps. 20 and 21 N....

In the Black Dog area, the lower part of the formation is a thick shale sequence; the middle part consists of massive sandstones; the upper part is predominantly shale.

The lower shale thins from 170 feet in T. 22 N., R. 11 E., to 100 feet along the Arkansas River in T. 20 N., R. 10 E. This shale is gray to dark blue, blocky, fossiliferous and contains numerous lenticular sandstone beds, some quite thick.* Locally the shale contains thin,

* Contains the spectacular deltaic development mainly east of Tall Chief Cr. in T 21 N

fossiliferous, limy zones, many of which are literally packed with Triticites sp. The "Fusulinid-bearing sandstone", which was mapped by Goldman and others (White, 1922, p. 355), occurs near the top of the lower shale unit. A complete section of the lower shale may be observed along the road through the NE¼ sec. 31, T. 21 N., R. 11 E. Another good exposure occurs in the SW¼ sec. 21, T. 20 N., R. 10 E., where fossiliferous limy zones occur within the shale.

Overlying the lower shale is a thick section of massive sandstone and interbedded shale, averaging 100 feet in thickness. This sandstone section forms steep cliffs along Hominy Creek and is traceable southward, where it produced precipitous bluff overlooking the Arkansas River. The upper persistent sandstone bed in this sandstone interval is mapped as the Clem Creek sandstone member (Plate I), and in the southern part of the area, the lower part of the sandstone interval is colloquially termed the "Washington Irving" sandstone (Oakes, 1952, p. 85).

Clem Creek sandstone member. The name was applied by Emery (White, 1922, p. 3) to

> ...a series of massive medium-grained sandstones and thin lenticular shales aggregating 60 to 65 feet in thickness and are exposed along Clem Creek in the northwestern part of T. 23 N., R. 11 E. This formation is limited below by the red limestone....

Unfortunately, the red limestone is not recognizable south of T. 23 N., R. 11 E.* (Gardner, 1956, personal communication), and southward from this point the location of the base of the Clem Creek member is somewhat arbitrary. In Tps. 21 and 22 N., the upper persistent sandstone was mapped as the Clem Creek sandstone member. Its equivalence with the

Clem Creek of the type locality is doubtful; therefore, the contact is indicated by a dashed line. South of T. 21 N., the base of the Clem Creek merges into the thick "Washington Irving" sandstone, and the contact is, at best, a doubtful equivalent of the Clem Creek sandstone as mapped to the north.

The Clem Creek and the underlying sandstone are well exposed along Oklahoma State Highway 20, secs. 23 and 24, T. 22 N., R. 10 E. The member consists of 29 feet of buff, fine-to medium-grained, massive sandstone. Underlying the member is 75 feet of alternating thick to massive sandstones and gray shales.

In sec. 14, T. 20 N., R. 10 E., the Clem Creek sandstone, occurring 189 feet above the base of the formation, is buff, fine-to medium-grained, massive and ferruginous. It weathers light brown and contains considerable interbedded maroon shale. Below the member is 85 feet of massive sandstone interbedded with maroon shale.

Overlying the Clem Creek is a shale unit which ranges in thickness from 50 to 60 feet throughout the area. Along Oklahoma State Highway 20, in sec. 23, T. 22 N., R. 10 E., the unit consists of 50 feet of dark gray to maroon shale with several thin sandstone beds. These sandstones, generally less than 2 feet thick, are buff to yellow, essentially fine-grained, with fucoids and ripple marks.

In secs. 27 and 34, T. 21 N., R. 10 E., the Clem Creek is separated from the overlying Okesa sandstone by approximately 60 feet of maroon to olive-yellow shale containing considerable sandstone, especially near the top. This sandstone is buff, thin-to thick-bedded, silty and weathers orange.

Stratigraphic relationships and correlation. The Wann formation is underlain conformably by the Iola formation. According to Oakes (1952, p. 87), the Wann is overlain unconformably by the Okesa sandstone member of the Barnsdall formation. No evidence of the unconformity was discovered in the Black Dog area.

The Wann is equivalent to the strata in Kansas lying above the Iola formation and below the upper limestone member, probably the South Bend limestone member, of the Stanton limestone (Oakes, 1940, p. 80).

Paleontology. Fossils collected from the lower shale of the Wann formation in the SW$\frac{1}{4}$ sec. 21, T. 20 N., R. 10 E. include the following:

Protozoa
Triticites sp.

Anthozoa
Lophophyllidium coniforme Jeffords

Crinoidea
Columnals and plates

Bryozoa
Fenestrate forms

Brachiopoda
Linoproductus sp.

Chordata
Petalodus destructor (Newberry and Worthen)

Barnsdall Formation

Definition. The Barnsdall formation was named by Oakes (1951, p. 120) from exposures near the town of Barnsdall, Osage County, Oklahoma. The name was applied to the rocks of the interval from the base of the Birch Creek limestone upward to the base of the Tallant formation.

Southward from the type locality, the basal Birch Creek limestone grades laterally into the Okesa sandstone, which is considered the basal member of the formation in the area under consideration.

Distribution and thickness. The formation extends from the Kansas-Oklahoma line in northwestern Nowata County southward to the North Canadian River in Okfuskee County (Ries, 1954, p. 76). The outcrop of the formation crosses the Black Dog area in an irregular band from one to six miles in width.

The Barnsdall maintains a fairly constant thickness of 165 feet in the area.

Character and subdivisions. Oakes (1954, p. 89), in describing the formation, states:

> The Barnsdall formation is heterogeneous and contains shale, sandstone, dolomitic limestone and dolomite. It has several members, probably none of which is co-extensive with the formation, unless it is the shale member at the top which apparently is present all along the outcrop.

In the Black Dog area, the formation is subdivided into the lower Okesa sandstone member and the upper unnamed shale member, which contains the Wildhorse dolomite lentil.

Okesa sandstone member. The Okesa sandstone was mapped with difficulty because of the lenticular nature of its individual sandstone beds and the lack of lithologic criteria which allow them to be distinguished from sandstones in the upper part of the Wann formation. Where the unnamed shale member is present, the base of the Okesa is established at the base of the second well-developed sandstone below the overlying shale prairie; where the shale member is absent (due to

recent erosion), the contact is somewhat uncertain and is indicated by a dashed line.

The member is composed of several lenticular, thin to massive sandstone beds alternating with maroon and gray shales and thin silty zones (Fig. 11). This sequence grades upward into the upper unnamed shale member.

The Okesa sandstone is typically developed along Wildhorse Creek in the SE¼ sec. 32, T. 22 N., R. 10 E., where the member is 85 feet thick and consists of alternating sandstone, siltstone and shale. The lower part of the member (Fig. 12) consists essentially of buff, fine-to medium-grained, thin to massive, somewhat cross-bedded sandstone interbedded with thin, gray to maroon shale. Upward, the percentage of sandstone decreases, and the topmost 36-foot section is predominantly maroon and gray shale with three to four beds of buff, silty sandstone, each less than 3 feet thick.

Another good exposure is along the north-south road in the NW¼ sec. 5, T. 20 N., R. 10 E., and the SE¼ sec. 31, T. 21 N., R. 10 E.

Unnamed shale member.* The upper shale of the Barnsdall formation persists across the area with little change in thickness or character. The member averages 80 feet in thickness and is composed of dark gray, fissile to blocky, fossiliferous shale with local, thin calcareous zones. North of sec. 18, T. 21 N., R. 10 E. the upper part of the shale contains the Wildhorse dolomite lentil.

Along Oklahoma State Highway 20 in the NW¼ sec. 21, T. 22 N., R. 10 E., a calcareous zone occurs approximately 35 feet below the Wildhorse dolomite. Abundant fossils occur in this zone and in the

* see note p. 100.

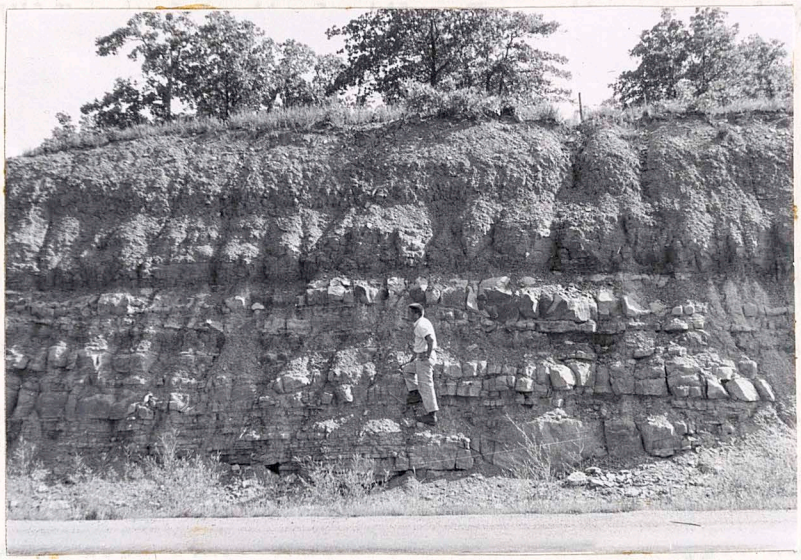


Figure 11. Lenticular sandstone beds of the Okesa sandstone member of the Barnsdall formation, NW¼ sec. 20, T. 22 N., R. 10 E.



Figure 12. Massive sandstone beds near the base of the Okesa sandstone, SW¼ sec. 33, T. 22 N., R. 10 E.

overlying shale. In sec. 18, T. 21 N., R. 10 E., several fossiliferous calcareous zones occur in the upper 50 feet of the member.

Wildhorse dolomite lentil. The unit was named by Greene (1918, pp. 121-122) from exposures along Wildhorse Creek in the western part of T. 22 N., R. 10 E. The northernmost exposure occurs in the southern part of sec. 22, T. 23 N., R. 10 E. (Gardner, 1956, personal communication). From this point southward, the Wildhorse increases in thickness to a maximum of 20 feet in T. 22 N., R. 10 E. Continuing southward, the lentil thins at a fairly uniform rate of one foot in the NW¼ sec. 18, T. 21 N., R. 10 E. South of this locality, the Wildhorse is indistinguishable from other calcareous zones in the upper Barnsdall shale. In the north, the lentil forms the most distinctive escarpment in the Black Dog area.

Near the county road in the SE¼ sec. 30, T. 22 N., R. 10 E., the Wildhorse dolomite is at least 16 feet thick (base covered) and consists of dark gray to blue, medium crystalline dolomite (Fig. 13). The upper and lower few feet are thin and wavy-bedded - similar to the upper part of the Avant limestone - and weather into dark, platy fragments. The middle 3-foot section is more evenly bedded and is thicker bedded, with large solution cavities. Large blocks of the dolomite litter the underlying shale slope. It is separated from the overlying Bigheart sandstone by a few feet of shale.

Along the southeastward flowing stream in the NW¼ sec. 18, T. 21 N., R. 10 E., the Wildhorse is one foot thick and lies 20 feet below the Bigheart sandstone. It is dark blue, argillaceous, and occurs in wavy beds less than 3 inches thick. Numerous Triticites sp.

stand out in relief on the weathered surface.

Insoluble residue tests indicate the composition of the Wildhorse dolomite ranging from 92.9 per cent carbonate, 0.1 per cent residue and 7.0 per cent decanted clay size material in sec. 19, T. 22 N., R. 10 E., to 81.3 per cent carbonate, 2.1 per cent residue and 16.6 per cent decanted clay size material in sec. 18, T. 21 N., R. 10 E. The residue is composed essentially of silt size quartz grains and silicified organic remains.

Stratigraphic relationships and correlation. The Barnsdall formation rests unconformably upon the Wann formation. This relationship is not evident in the Black Dog area, but southward in Creek County, Oakes (1952, p. 92) has discovered the Wann and Iola formations to have been removed by pre-Barnsdall erosion, and the Barnsdall rests upon the Chanute formation in T. 15 N., R. 9 E. The Barnsdall is overlain conformably by the Tallant formation.

The lower part of the formation in the Black Dog area grades northward into the Birch Creek limestone member, which is equivalent to the South Bend limestone member of the Stanton limestone in southern Kansas. The upper part of the Barnsdall is equivalent to the lower part of the Weston shale of Kansas (Oakes, 1952, p. 92). According to Tanner (1956, p. 86), the Barnsdall probably corresponds to part of the Hilltop formation south of Okfuskee County.

Paleontology. Fossils collected from the unnamed shale member in the NW¼ sec. 21, T. 22 N., R. 10 E. include:

Anthozoa
Lophophyllidium sp.



Figure 13. Wavy bedding typical of the Wildhorse dolomite, SE$\frac{1}{4}$ sec. 30, T. 22 N., R. 10 E.



Figure 14. Escarpment capped by the Wildhorse dolomite, SW$\frac{1}{4}$ sec. 16, T. 22 N., R. 10 E.

Crinoidea
Columnals and plates

Echinoidea
Spines

Bryozoa
Encrusting forms

Brachiopoda
Orbiculoidea missouriensis (Shumard)

Pelecypoda
Astartella concentrica Conrad
Myalina (Myalina) glossoidea Newell
Nuculana sp.

Gastropoda
Euphemites carbonarius (Cox)
Glabrocingulum grayvillense (Norwood and Pratten)
Trepospira depressa (Cox)
Worthenia tabulata (Conrad)

Scaphopoda
Dentalium sp.

Cephalopoda
Pseudorthoceras knoxense (McChesney)

Tallant Formation

Definition. Above the Barnsdall formation in southern Osage County is a complex sequence of sandstone and shale. Prior to work by Oakes, the lower bed of this sequence, the Bigheart sandstone, was considered the southern equivalent of the Tonganoxie sandstone, the basal bed of the Virgil series of Kansas (Moore, 1949, pp. 122-131). However, subsequent work by Oakes has demonstrated that the Cheshawalla sandstone, the upper persistent bed of the aforementioned sequence, corresponds with the Tonganoxie sandstone of Kansas. That part of the sandstone-shale sequence below the Cheshawalla sandstone and above the Barnsdall formation was reassigned to the Missouri series and named

Tallant from exposures near the town of Tallant in central Osage County (Oakes, 1951, p. 121).

Distribution and thickness. The Tallant extends from the Kansas-Oklahoma line in northwestern Nowata County southward to the northwestern part of Okfuskee County, where the formation is truncated by the Vamoosa formation of the Virgil series (Ries, 1954, p. 78).

The Tallant is 250 feet thick in T. 24 N., R. 10 E. (Tanner, 1956, p. 32). Southward, progressive truncation by pre-Virgil erosion has reduced the thickness to 190 feet in the northern part of T. 23 N., R. 10 E., 126 feet in the southern part of T. 23 N., R. 10 E. (Gardner, 1956, personal communication), and 60 to 80 feet in the Black Dog area.

Character and subdivisions. Oakes (1951, p. 121) described the Tallant formation as follows:

> In Osage County...there are two principal, named, sandstone members, the Bigheart and the Revard in ascending order, but the several geologists who have written about them are not in accord as to their limits except, fortunately, that all agree on the base of the Bigheart, the basal member of the Tallant.

It is probable that the Revard sandstone member, or its southern equivalent, has been removed by pre-Virgil erosion in the Black Dog area and that all of the Tallant within the area could be correlated with the Bigheart sandstone in T. 24 N., R. 10 E., where it is 114 feet thick (Tanner, 1956, p. 36). However, as the upper limit of the Bigheart has not been defined, a persistent basal sandstone has been designated arbitrarily as Bigheart in the Black Dog area.

Bigheart sandstone member. The member was first named by

Hutchison (1907, p. 89) from exposures near the town of Bigheart (now Barnsdall). The sandstone is well exposed along Oklahoma State Highway 20 in the SW¼ sec. 18, T. 22 N., R. 10 E. Here the member is buff to tan, fine-to medium-grained, massive, ferruginous sandstone which weathers orange. It is 21 feet thick.

Near the center of the N½ sec. 30, T. 22 N., R. 10 E., the Bigheart is exposed 10 feet above the Wildhorse dolomite in the eastward flowing stream. It consists of 25 feet of buff, fine-to medium-grained sandstone which weathers to a rusty-yellow. The lower part is medium-bedded; the middle and upper parts are massive and ferruginous.

In the NW¼ sec. 18, T. 21 N., R. 10 E., the sandstone is 27 feet thick, buff to tan, fine-to coarse-grained, massive, moderately contorted, with a clay pebble conglomerate near the base.

In the NW¼ sec. 30, T. 21 N., R. 10 E., the Bigheart is 25 feet thick. The lower 6 feet is a buff, essentially fine-grained, thick-bedded sandstone with characteristic iron staining. The middle 15 feet consist of a buff, highly contorted, readily eroded, ferruginous sandstone. Capping the sequence is a ledge of resistant, buff, fine-grained sandstone with a thickness of 4 feet. The weathered surface of the member is deeply pitted. South and west of this exposure the Bigheart is partially covered by eolian deposits.

The part of the Tallant formation above the Bigheart sandstone member consists of interbedded lenticular sandstone and gray to maroon shale. Along Oklahoma State Highway 20 in the SW¼ sec. 13, T. 22 N., R. 9 E., the unit is 48 feet thick and consists predominantly of gray to maroon shale and smaller amounts of buff, thin to massive,

locally silty sandstone.

Stratigraphic relationships and correlation. The Tallant formation rests conformably upon the Barnsdall formation. It is overlain unconformably by the Cheshawalla sandstone, the basal member of the Virgil series. No physical evidence of an unconformity was observed, and the rocks, without exception, bear no distinguishing lithologic characteristic which permits field identification. Nevertheless, the rather abrupt thinning of the formation southward indicates that the Tallant is progressively truncated by pre-Virgil erosion.

The Tallant is equivalent to the upper part of the Weston shale of southern Kansas (Oakes, 1952, p. 95).

Paleontology. The Tallant formation is essentially non-fossiliferous in the Black Dog area.

VIRGIL SERIES

The Virgil series derives its name from the town of Virgil in Greenwood County, Kansas. As defined by Moore (1932, p. 96), it includes all of the upper Pennsylvanian beds from the unconformity at the base of the Tonganoxie sandstone upward to the unconformity at the base of the Indian Cave sandstone. Where the Indian Cave is absent, the top of the Brownville limestone marks the top of the Virgil series.

Moore (1951, pp. 51-73) subdivided the Virgil of Kansas into the Douglas, Shawnee and Wabaunsee groups. In central Oklahoma the Virgil series is subdivided into three formations which are, in ascending order, the Vamoosa, Ada and Vanoss formations. As the Virgil beds in Osage County are transitional between the cyclic

deposits of Kansas and the coarse clastic deposits of central Oklahoma, local terminology of both areas has been combined in the classification in this report.

The Virgil series in the Black Dog area is represented by approximately 460 feet of maroon to dark gray shales, thin to massive sandstones and a few thin lenticular limestone beds. This sequence is equivalent to the Douglas and the lower part of the Shawnee groups of Kansas, and the lower and middle parts of the Vamoosa formation of central Oklahoma.

Douglas-Shawnee Group

The terms Douglas and Shawnee were employed originally as formational names in southern Kansas. Moore (1932, p. 96) proposed the currently accepted definitions. The Douglas group includes the section lying in the interval above the Missouri-Virgil unconformity and below the base of the Oread limestone. The Shawnee group includes the section from the base of the Oread limestone to the top of the Topeka limestone. Since the Oread limestone (or an equivalent bed) is not present in the Black Dog area, no division is possible, and the two groups are considered as a single unit.

Vamoosa Formation

Definition. The Vamoosa formation was named by Morgan (1924, p. 125) from exposures near the town of Vamoosa, Seminole County, Oklahoma. In Osage County the name is applied to the rocks of the interval between the base of the Virgil series and the base of the Pawhuska formation (Shannon, 1954, p. 24). The upper part of the

formation is absent in the area.

Distribution and thickness. The Vamoosa extends from northern Pontotoc County northward to Osage County, where the formation intergrades with the cyclic deposits of the units of the Kansas classification. In southern Pontotoc County, the formation has been truncated by erosion. In the Black Dog area, the Vamoosa crops out in a band approximately ten miles in width, covering the major part of Tps. 21 and 22 N., R. 9 E. and the southeastern part of T. 21 N., R. 8 E.

Tanner (1956, p. 93) reported a thickening of the formation in Seminole County from 125 feet in the south, to 550 feet in the north. In Okfuskee County Ries (1954, p. 83) reported a maximum thickness of 690 feet. Approximately 460 feet of the lower and middle part of the Vamoosa formation is present in the Black Dog area.

Character and subdivisions. The formation was described by Morgan (1924, p. 126) at the type locality as cherty conglomerates, massive sandstones and red shales. North of the type locality, the formation changes facies, the conglomerates and coarse clastics grade into fine-grained deposits. In the Black Dog area, the sequence consists of thin to massive sandstone, maroon to dark gray shales and (at places) thin, lenticular limestone. Six members were recognized and mapped in the area (Plate I).

Cheshawalla sandstone member. The Cheshawalla sandstone was named by Winchester, Heald and others (White, 1922, p. 61) from exposures along Cheshawalla Creek, T. 25 N., R. 10 E. and described as

> The first heavy bed below the Labadie limestone.... The lithology of the Cheshawalla sandstone is not distinctive enough to permit its identification by

> this means. It is fine grained, moderately well cemented, rather soft, and cross-bedded....This sandstone is 20 to 50 feet thick and along most of its outcrop in this township appears as a single heavy bed without interbedded shale.

The member crops out in the Black Dog area approximately half way up the steep, rugged slope formed by heavy sandstones in the underlying Tallant formation and in the overlying Vamoosa formation. Exposures of the member are generally poor; at most places it is covered by sandstone debris.

The member consists of a single massive sandstone bed ranging from 10 to 35 feet in thickness. It is well exposed along Oklahoma State Highway 20 in the SE$\frac{1}{4}$ sec. 13, T. 22 N., R. 9 E. Here the Cheshawalla consists of 35 feet of buff, fine-to medium-grained, massive sandstone. It weathers light yellow to light purple and is ferruginous, especially near the middle. Some shale partings are observed.

In the SE$\frac{1}{4}$ sec. 19, T. 21 N., R. 10 E.,the Cheshawalla exceeds 20 feet in thickness (top eroded). At this locality, it is buff to orange, massive, rather soft, moderately cross-bedded and weathers red. Here the uppermost sandstone of the Tallant formation lies 20 feet below the Cheshawalla.

The strata of the interval above the Cheshawalla sandstone (Fig. 16) consist of gray to maroon shale interbedded with thin siltstone beds, generally less than 2 feet thick. The thickness of the unit averages 31 feet throughout the area. The best exposure occurs along Oklahoma State Highway 20 in the SW$\frac{1}{4}$ sec. 13, T. 22 N., R. 9 E. Here the interval is 32.5 feet and the unit is composed of gray-green to

maroon, blocky shale containing three to four thin, light-colored, silty sandstone beds, each less than 2.5 feet thick.

Kiheki sandstone member. The Kiheki was named by Tanner (1956, p. 45) from exposures near a railroad siding of the same name in sec. 3, T. 25 N., R. 10 E. Tanner describes the unit as "A single more-or-less continuous sandstone ledge, five to 25 feet thick, ...in the shale interval between the Cheshawalla and the Labadie members". Because of its massive, resistant character and its position between two thick, persistent shale intervals, the Kiheki forms a conspicuous, readily traceable bench in the northern and central part of the area. Near the Arkansas River, its outcrop is largely concealed by sandstone debris and eolian deposits.

In the northern part of the area, the member consists of two sandstone beds separated by a wedge of maroon shale. In the central part of T. 21 N., R. 9 E., the wedge of shale thins and the two sandstone beds merge to form a single prominent unit.

The best exposure occurs along the north-south road in the NW$\frac{1}{4}$ sec. 30, T. 22 N., R. 10 E. At this locality, the lower bed is 10 feet thick and is yellow to orange, fine-to coarse-grained, thick-bedded sandstone. A clay pebble conglomerate in a coarse sand matrix occurs near the base; cross-bedding is common. The upper sandstone bed is 23 feet thick, light buff to yellow, essentially fine-grained, massive, with considerable interbedded siltstone and shale. Separating the two sandstone beds is 17 feet of gray and maroon shale.

The unit above the Kiheki sandstone member consists of gray and maroon shale with thin, lenticular beds of light-colored siltstone and



Figure 15. Exposure of the Kiheki sandstone showing ripple marks and filled shrinkage cracks, SE¼ sec. 14, T. 22 N., R. 9 E.



Figure 16. Kiheki sandstone (left and upper right of picture) displaced by small normal fault along Oklahoma State Highway 20, SE¼ sec. 14, T. 22 N., R. 9 E.

fine-grained sandstone. North of the central part of T. 21 N., R. 9 E., the interval below the Cochahee sandstone member averages 40 feet. South and west of this locality, where the Cochahee is absent and the interval extends upward to the base of the Wynona sandstone member, it is 76 to 81 feet in thickness. In the SW¼ sec. 20, T. 21 N., R. 9 E., a bed of limestone occurs 26 feet above the Kiheki sandstone. The limestone is ferruginous, arenaceous, one foot thick and weathers to a rust color.

Cochahee sandstone member. The member was named by Winchester, Heald, and others (White, 1922, p. 60) from exposures on Cochahee Creek in the southwestern part of T. 25 N., R. 10 E. It was described as ranging from 3 to 25 feet in thickness and "... is massive, hard, and fossiliferous and has a peculiar weathered surface suggesting turkey tracks". According to Gardner (1956, personal communication) the Cochahee sandstone of the Black Dog area is equivalent to the lower bed of the Four Mile sandstone member.

In the Black Dog area, the Cochahee extends from sec. 23, T. 22 N., R. 9 E. southward to sec. 22, T. 21 N., R. 9 E. (Plate I). It thins southward and is not mappable in the southern part of the area. The member consists of a single bed of massive, locally contorted sandstone, generally less than 6 feet in thickness. In the SW¼ sec. 15, T. 22 N., R. 9 E., the member consists of 6 feet of buff, fine-to medium-grained sandstone; ripple marks are common. The lower 4 feet are highly contorted; the upper 2 feet form a resistant ledge which breaks along joints into large, rectangular blocks.

The strata in the interval above the Cochahee sandstone and

below the Wynona sandstone are exposed along the lease road in the NW¼ sec. 2, T. 21 N., R. 9 E. They consist of 33 feet of maroon and gray shale with an occasional light-colored siltstone or thin sandstone bed.

Wynona sandstone member. The Wynona sandstone was named by Heald (White, 1922, p. 17) from exposures at and near the town of Wynona in T. 24 N., R. 9 E. At the type locality the member is a single bed of sandstone 15 to 20 feet thick. In the Black Dog area, all strata from the base of the first persistent sandstone above the Cochahee upward to the base of the Kanwaka shale were mapped as the Wynona sandstone member. Although the member, as considered in this report, probably represents a thicker stratigraphic interval than that originally described by Heald, it does conform with the Wynona as described and mapped by Beckwith (1923, pp. 22-23), Tanner (1956, p. 50) and Gardner (1956, personal communication).

In the area of investigation, the thickness of the Wynona increases from approximately 100 feet in T. 22 N., R. 9 E., to 129 feet in sec. 20, T. 21 N., R. 9 E. The member consists of maroon shale, thin, light- colored siltstone and thin to massive sandstone. Two sandstone beds of the member were mapped (Plate I). The member is exposed in its entirety along the east-west road in the S½ sec. 20, T. 21 N., R. 9 E. The lower sandstone bed, the basal unit of the member, is buff, thick to massive, somewhat contorted and contains considerable interbedded maroon shale. The bed is 27 feet thick and is overlain by 21 feet of maroon shale. Resting upon this shale is the upper sandstone bed of the Wynona. Here the bed is 15.5 feet thick, buff to light maroon, massive-to cross-bedded, essentially fine-grained, with clay pebble conglomerates commonly occurring near the base. Overlying the upper sandstone bed is

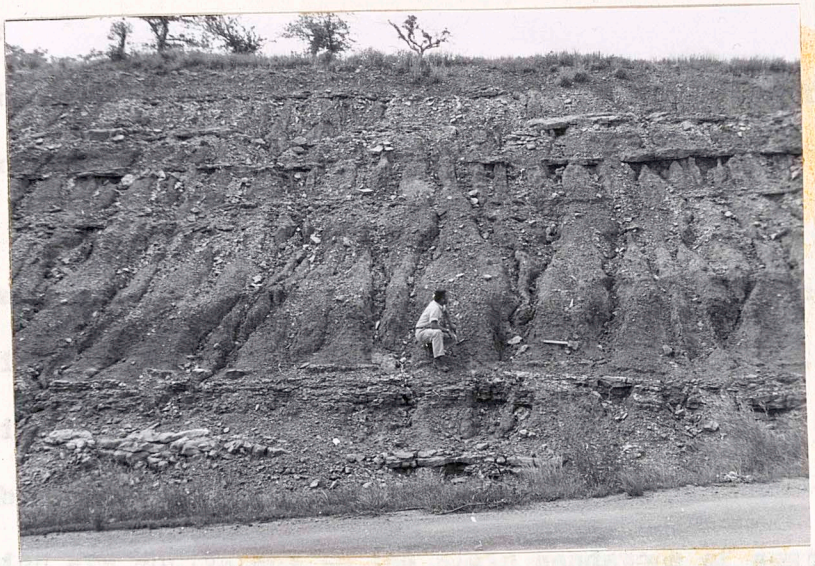


Figure 17. Interbedded siltstone, sandstone and shale of the Wynona sandstone exposed along Oklahoma State Highway 20, center sec. 6, T. 22 N., R. 9 E.



Figure 18. Lower sandstone bed of the Wynona sandstone member, NE¼ sec. 16, T. 22 N., R. 9 E.

66 feet of maroon shale with thin light-colored siltstones grading upward to dark shale with thin, silty sandstones.

North of the center of T. 21 N., R. 9 E., the upper sandstone bed loses much of its massive character and splits into several thin sandstones. As the outcrop is difficult to identify with certainty, it is indicated on Plate I with a dashed line.

Kanwaka shale member. The name was proposed by Adams (Adams, Girty, and White, 1903, p. 45) for the shale between the top of the Oread limestone and the base of the Lecompton limestone. The name was derived from exposures in Kanwaka Township, Douglas County, Kansas. The member is predominantly dark shale containing massive sandstone beds which are equivalent to the Elgin sandstone of southern Kansas. Only that part of the Kanwaka which occurs between the top of the Wynona sandstone and the base of the Elgin sandstone as mapped by Russell (1955) is considered in this report.

The Oread limestone, which defines the base of the Kanwaka shale, does not extend south of T. 23 N., R. 9 E. (Gardner, 1956, personal communication); consequently, mapping the Wynona-Kanwaka contact in the Balck Dog area was complicated by the lack of a suitable datum. In the southwestern part of T. 22 N., R. 9 E., the contact is indicated where the maroon shale of the Wynona grades upward into the dark gray shale of the Kanwaka. The change in color occurs 55 feet below the lower sandstone bed of the Elgin and 38 feet above the upper sandstone bed of the Wynona. In T. 21 N., Rs. 8 and 9 E., a distinctive, thin, calcareous, ferruginous sandstone bed occurs 50 to 60 feet below the lower Elgin sandstone and 60 to 65 feet above the upper

Wynona sandstone. This bed is packed with molds of small pelecypods resembling Nuculana. Possibly a southern equivalent of the Oread limestone, this pelecypod-bearing bed was assumed to mark the base of the Kanwaka shale since no maroon shale occurs above the bed, the underlying shale is maroon or grades downward to maroon within a few feet and the bed maintains a consistent stratigraphic position relative to mapped sandstone units above and below.

Good exposures of the Kanwaka are few in the area. Eroded remnants cap several outlying hills, but the main body crops out on the steep, eastward facing escarpment capped by the upper bed of the Elgin sandstone (Fig. 19). The shale averages 170 feet in thickness throughout the area. The lower 60 feet, between the base and the lower bed of the Elgin, consists of dark, clay shale with thin, interbedded sandstone beds normally only a few inches in thickness. The ratio of sandstone to shale displays a marked increase southward. The interval between the two mapped Elgin sandstones averages 112 feet and consists of dark, clay shale with considerable sandstone in the upper part. Weathering of the Kanwaka produces dark, locally sandy soil.

Elgin sandstone member. The name was applied by Haworth (1898, p. 64) at the suggestion of Adams to sandstones occurring within the Kanwaka shale near the town of Elgin, in southern Kansas.

The western boundary of the Black Dog area is delineated by the base of the Elgin sandstone as mapped by Russell (1955). This main body of sandstone was mapped in this report (Plate I) as the upper bed of the Elgin, but it was not studied in detail and will not be discussed. Occurring from 110 to 117 feet below the upper bed is a rather persistent



Figure 19. Escarpment capped by the upper bed of the Elgin sandstone, SE$\frac{1}{4}$ sec. 36, T. 22 N., R. 8 E.

sandstone, designated herein as the lower bed of the Elgin sandstone (Plate I). Throughout the area, the bed averages 6 feet in thickness and is yellow to orange, medium-grained, massive sandstone. It is (in places) highly contorted. The bed weathers into large, irregular blocks which litter the lower Kanwaka shale slope.

Stratigraphic relationships and correlation. The Vamoosa formation rests unconformably upon the truncated surface of the Tallant formation; it is overlain conformably by the Pawhuska formation.

The Vamoosa is equivalent to the Douglas and the lower part of the Shawnee groups of Kansas. Southern Oklahoma equivalents of the formation have apparently been removed by erosion.

Paleontology. Other than the aforementioned pelecypod molds occurring at the base of the Kanwaka shale, no fossils were found in the Vamoosa. In adjacent areas, however, abundant fossils were collected from the Kanwaka by Shannon (1954, p. 19), Greig (1954, p. 33) and Russell (1955, p. 15).

Quaternary Deposits

Widespread deposits of eolian and terrace material occur in the southern part of the area. These deposits form a veneer over extensive upland areas adjacent the flood plain of the Arkansas River, occurring at places as far as four miles from the river and 250 feet above the river. This material is unstratified, and sieve analyses reveal it to consist essentially of silt and fine to medium sand grains. The grains are essentially quartz and are subangular to well rounded; many of the grains have frosted surfaces. The deposits are buff to light orange and

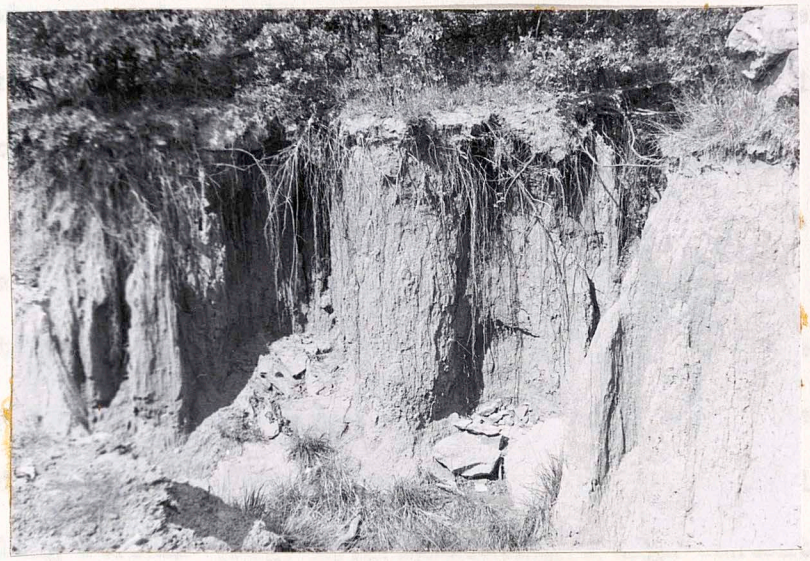


Figure 20. Alluvium standing in nearly vertical walls along Wildhorse Creek, SW¼ sec. 33, T. 22 N., R. 10 E.



Figure 21. Alluvial deposits along Boar Creek, NW¼ sec. 24, T. 22 N., R. 9 E.

form practically vertical walls, similar to those characteristic of loess, where cut by roads or streams. These deposits were probably blown from the flood plain of the Arkansas River to their present location during the Pleistocene and Recent epochs.

The valleys of the Arkansas River, Hominy Creek, Delaware Creek and their larger tributaries are partially filled with alluvium. This material is similar to the eolian deposits described above. It is essentially unstratified, buff to orange, and is composed of clay, silt and sand. It displays, in addition, the same characteristic of vertical banks along streams (Fig. 20), indicating a high content of loessal material. The origin of this alluvial material is probably a combination of fluviatile and eolian deposition during the Pleistocene and Recent epochs.

CHAPTER III

HISTORICAL GEOLOGY

Osage County is located on the western flank of the Ozark Plateau in a region known as the Prairie Plains homocline. Upper Pennsylvanian rocks form long parallel bands of outcrop which may be traced from central Oklahoma northward into Kansas and Nebraska. The regional dip of the strata is, in general, to the west at less than one degree.

Upper Pennsylvanian rocks of Kansas were deposited in shallow water on an oscillating continental platform. They consist of marine and nonmarine beds of limestone, coal, shale and sandstone which alternate in a cyclic manner. The repeated alternation of marine deposits of limestone and shale with continental deposits of sandstone and coal attests to the repeated advance and retreat of shallow seas. Though thin, many of the units persist for great distances, indicating that the conditions of deposition were uniform over broad areas. Deposition occurred on a nearly featureless surface where slight changes in sea level caused extensive advances and retreats of the sea.

During the Pennsylvanian period, southern Oklahoma was subjected to intermittent crustal unrest. Mountains were repeatedly uplifted and eroded, thus supplying vast amounts of clastic debris that filled

adjacent low areas. Consequently, the Upper Pennsylvanian rocks of central Oklahoma are essentially clastic, with conglomerates, sandstones and shales predominating. As rock units are traced from Kansas southward into Oklahoma, a rather striking change occurs; the formations thicken and marine nonclastic deposits thin or grade laterally into clastic deposits.

The Black Dog area is situated near the southern edge of the platform of Kansas. Rocks within the area reflect both of the aforementioned contrasting environments, with the marine nonclastic deposits similar to those of Kansas interfingering and grading into near shore clastic deposits similar to those of central Oklahoma. Environments reflected in sediments in the area vary from shallow marine, to deltaic, to continental. As in the shallow basin of Kansas, the surface of deposition was apparently a fairly featureless floor. Minor fluctuations of either the sea or the land surface resulted in widespread inundation or emergence, and each pulsation in the mobile belt in southern Oklahoma caused extensive deposition of clastic material.

During the Missourian epoch, periods of extensive encroachment of the sea are indicated by gray marine shale and thin, wavy-bedded limestone. Many of these marine units are traceable into Kansas, where they are recognized in the cyclic deposits. Tanner (1956, p. 16) interprets the wavy-bedded character of the limestones and siltstones as indicating the gentle scouring and winnowing common in many shallow seas. Temporary withdrawal of the seas is indicated by coal beds in the Coffeyville and Chanute formations. Lignitic shales and siltstones associated with ripple marks, channeling and trails help to substantiate the deltaic

origin of the middle part of the Nellie Bly formation. Maroon shales of the Missouri series occur, without exception, in close association with massive sandstone beds. The presence of maroon shale and sandstone in the Wann, Barnsdall and Tallant formations possibly represents an influx of fine clastic material from the mobile belt in southern Oklahoma.

Sediments deposited during Virgilian time in the Black Dog area are predominantly near shore clastic with the exception of the Kanwaka shale. Beds below the Kanwaka consist of maroon shales and sandstones which were probably derived from the uplifted eroding Arbuckle Mountains. Thin, lenticular limestones and calcareous, fossiliferous sandstones of the lower Vamoosa formation were probably formed during brief and somewhat localized invasions of the sea from the north.

CHAPTER IV

STRUCTURAL GEOLOGY

Southeastern Osage County is situated near the eastern margin of a regional structure known as the Prairie Plains homocline. Rocks of this region, on the western flank of the Ozark Plateau, dip gently westward at from 20 to 100 feet per mile and strike in a general north-south direction. In the Black Dog area, the strike of the formations is approximately N. 20° E., and the dip is 40 to 50 feet per mile to the west. Locally, the regional dip is interrupted by minor folds and faults.

Surface expression of the folds assumes the form of small domes and westward plunging anticlines or noses. Low dips are characteristic of the folds of the area. They are generally symmetrical or but slightly elongated and are irregularly distributed. According to Powers (1931, p. 121), the reflected anticline, or "Prairie type fold", is the most common type of upwarp of the area. Surficially these folds are small and gentle, but they increase in magnitude and dip with increasing depth. These folds are caused by repeated uplift of small buried hills of Pre-cambrian age. Apparently, these small, somewhat isolated areas were periodically upwarped throughout long periods of time.

Brown (1923, p. 501) states that the folds of southeastern Osage

County are primarily caused by compressional forces acting more or less equally in all directions. He also suggests that other factors, such as shear movement and differential compaction over buried hills, while not sufficient to produce the folds, exerted considerable modifying influence.

Bald Hill dome in the northern part of T. 20 N., R. 12 E., the largest structure in the area, displays a closure exceeding 80 feet, with an area of closure of approximately two square miles. Some of the other significant structures are: Delaware anticline, Red Bluff anticline, Edgewood dome, Scarp anticline, Turkey Creek dome, Wimberley dome, Wildhorse anticline, North Wildhorse dome, Cedar Bluff dome and South Brown anticline. In addition, other important unnamed structures are present, especially in the western part of the area.

Several zones of en echelon faults trend north-south through northeastern Oklahoma. Fath (1920, p. 78) describes these en echelon trends as follows:

> The faults...are of the normal type and are noteworthy not only because of their approximate parallelism but also because of their grouping into belts or series which also have a parallel trend.... Most of the individual faults trend about N. 20° - 45° W. and lie en echelon to one another in such a manner that the linear belts or series into which they are grouped trend from north to N. 25° E., or roughly at an angle of 45° with the trend of the faults.

The faults are, without exception, normal, and the vertical displacement and areal extent is small.

Numerous theories have been presented which attempt to explain the origin of the en echelon faults. Fath (1920, pp. 75-84) considered the faults a result of horizontal movement along lines of weakness in

competent, deep-seated rocks. Consequent drag on the overlying weak sediments theoretically opened short fractures at an angle of 45 degrees to the direction of movement. Foley (1926, pp. 293-303) considered rotational stress in a horizontal plane between the Ozark uplift and the granite (Nemaha) ridge of Kansas as a probable origin. Sherrill (1929, pp. 31-37) attributed the trends to torsion, augmented by slight uplift. Melton (1930, pp. 57-72) stated that the origin is closely related with the movements accompanying the Ouachita orogeny and correlated the strike of the faults with the trend of joints which radiate from the Ouachita Mountains. Additional theories have been advanced by Powers (1931), Kramer (1934) and others.

With few exceptions, all faults within the Black Dog area occur in three subparallel en echelon belts across the area in a direction of N. 20° E. The general strike of the faults within the belts is N. 26° W. They are all normal, and those down thrown to the southwest approximate those downthrown to the northeast. Vertical displacements are insignificant, and no evidence of horizontal movement was observed.

The majority of the faults appear as linears on airplane photographs. In most cases relative movement was observed directly from examination of the photographs, or it was implied by the outcrop pattern; however, in a few cases where recognizable datum beds were displaced, measurement of the throw was possible in the field. The fault in secs. 33 and 34, T. 22 N., R. 11 E. displays a throw of approximately 45 feet. A similar movement was measured along the fault in sec. 3, T. 21 N., R. 11 E. In the NE$\frac{1}{4}$ sec. 31, T. 21 N., R. 11 E., the first massive sandstone encountered above the Avant limestone displays a

Fault on 18-20-11 is greatest -

throw of 57 feet, the maximum movement recorded in the area. Several additional displacements of less than 35 feet were measured. Faults along which relative movement could not be determined, as well as outstanding linears, are indicated with a broken line on the accompanying map (Plate I).

CHAPTER V

ECONOMIC GEOLOGY

Osage County is one of the most active oil development areas in the United States today. During 1955, 877 commercial oil wells, 2 gas wells and 179 dry holes were drilled in the county. Production is averaging 60,500 barrels a day ("Revival in the Osage", 1956, pp. 44-47).

Petroleum is, by far, the most significant economic product of the Black Dog area. Since the first commercial production was obtained in 1905, development has been continuous until oil and gas is now produced from 14 different beds, ranging from the siliceous lime of Ordovician age to the lower Vamoosa sands of Pennsylvanian age. The Bartlesville sand is the most prolific producer. In December, 1955, a total of 1,403 wells produced 5,609 barrels of oil daily. The average daily production was 4.1 barrels per well (Vance Rowe Report, Dec., 1955).

The Wildhorse field in the northern part of T. 21 N., R. 10 E. and the southern part of T. 22 N., R. 10 E. is the most productive field. An average daily production of 2,900 barrels is obtained from 386 wells. Other large fields include Flat Rock field in T. 20 N., R. 12 E. and Osage City field in the east central part of T. 21 N., R. 8 E.

The majority of the limestones of the area are too thin and

impure to be used in the production of lime or for building stone. During the construction of Oklahoma State Highway 20, road ballast was obtained from the Avant limestone in sec. 24, T. 22 N., R. 11 E. and the Wildhorse dolomite in sec. 19, T. 22 N., R. 10 E. Both quarries are currently abandoned.

Clay from the lower part of the Wann formation, which was probably used in the foundries in Sand Springs, has been quarried in sec. 21, T. 20 N., R. 10 E. The pit is no longer active.

Sandstone for building purposes is obtained from the Nellie Bly formation in sec. 31, T. 20 N., R. 11 E. This sandstone is readily workable because it may be split along bedding planes into thin slabs ranging from one to 3 inches in thickness. After being sawed into uniform widths, the stone is used in a fashion similar to that of brick.

BIBLIOGRAPHY

Adams, G. I., Girty, G. H., and White, David, 1903, "Stratigraphy and paleontology of the Upper Carboniferous rocks of the Kansas section", U. S. Geol. Survey, Bull. 211.

Beckwith, H. T., 1928, "Geology of Osage County, Oklahoma", Okla. Geol. Survey, Bull. 40-T.

Brown, R. W., 1928, "Origin of the folds of Osage County, Oklahoma", Amer. Assoc. Petroleum Geologists, Bull. Vol. 12, pp. 501-513.

Dunbar, C. O., and Condra, G. E., 1932, "Brachiopoda of the Pennsylvanian system in Nebraska", Nebr. Geol. Survey, Bull. 5, series 2.

Fath, A. E., 1920, "The origin of the faults, anticlines, and buried 'Granite Ridge' of the northern part of the Mid-Continent oil and gas field", U. S. Geol. Survey, Prof. Paper 128-C, pp. 75-84.

Foley, L. L , 1926, "The origin of the faults in Creek and Osage Counties, Oklahoma", Amer. Assoc. Petroleum Geologists, Bull. Vol. 10, pp. 293-303.

Gardner, W. E., 1956, "Geology of the Barnsdall area, Osage County, Oklahoma", Unpublished Master of Science Thesis (in preparation), University of Oklahoma.

Girty, G. H., 1915, "Fauna of the Wewoka formation of Oklahoma", U. S. Geol. Survey, Bull. 544.

Gould, Chas. N., 1911, "Preliminary report on the structural materials of Oklahoma", Okla. Geol. Survey, Bull. 5.

_____, 1925, "Index to the stratigraphy of Oklahoma", Okla. Geol. Survey, Bull. 35.

Greene, F. C., 1918, "A contribution to the geology of eastern Osage County", Southwestern Assoc. Petroleum Geologists, Bull., Vol. 1, pp. 118-123.

Greig, P. B. Jr., 1954, "Geology of the Hallett area, Pawnee County, Oklahoma", Unpublished Master of Science Thesis, University of Oklahoma.

Haworth, Erasmus, 1898, "Special report on coal", University Geol. Survey of Kan., Vol. 3.

Hutchison, L. L , 1907, "The stratigraphy of Oklahoma north of the parallel of thirty-five degrees and thirty minutes", Unpublished Bachelor of Arts Thesis, University of Oklahoma.

Keyes, C. R., 1893, "Geological formations of Iowa", Iowa Geol. Survey, Vol. 1, pp. 13-161.

Kramer, William, 1934, "En echelon faults in Oklahoma", Amer. Assoc. Petroleum Geologists, Bull. Vol. 18, pp. 243-250.

Mather, K. F., 1915, "The fauna of the Morrow group of Arkansas and Oklahoma", Denison University, Scientific Laboratories, Bull. Vol. 17, pp. 59-284.

Melton, F. A., 1930, "Age of the Ouachita orogeny and its tectonic effects", Amer. Assoc. Petroleum Geologists, Bull. Vol. 14, pp. 57-72.

Mohler, C. E., 1942, "A field study of the Iola formation of Osage and Tulsa Counties, Oklahoma", Unpublished Master of Science Thesis, University of Oklahoma.

Miser, H. D., 1954, "Geologic Map of Oklahoma", Okla. Geol. Survey and U. S. Geol. Survey.

Moore, R. C., 1932, "A reclassification of the Pennsylvanian system in the northern Mid-Continent region", Kan. Geol. Society Guidebook, 6th Annual Field Conference, pp. 79-97.

_____, 1936, "Stratigraphic classification of the Pennsylvanian rocks of Kansas", Kan. Geol. Survey, Bull. 22.

_____, 1949, "Divisions of the Pennsylvanian system in Kansas", Kan. Geol. Survey, Bull. 83.

_____, and others, 1937, "Definition and classification of the Missouri subseries of the Pennsylvanian series in northeastern Oklahoma", Kan. Geol. Society Guidebook, 11th Annual Field Conference, pp. 39-43.

_____, and others, 1951, "The Kansas rock column", Kan. Geol. Survey, Bull. 89.

Morgan, G. D., 1924, "Geology of the Stonewall Quadrangle, Oklahoma", (Okla.) Bureau of Geology, Bull. 2.

Murray, A. N., and others, 1941, "Pennsylvanian stratigraphy of Tulsa County", Tulsa. Geol. Society Field Trip.

Oakes, M. C., 1940, "Geology and mineral resources of Washington County, Oklahoma", Okla. Geol. Survey, Bull. 62.

_____, 1951, "The proposed Barnsdall and Tallant formations in Oklahoma", Tulsa Geol. Society Digest, Vol. 19, pp. 119-122.

_____, 1952, "Geology and mineral resources of Tulsa County, Oklahoma", Okla. Geol. Survey, Bull. 69.

Ohern, D. W., 1910, "The stratigraphy of the older Pennsylvanian rocks of northeastern Oklahoma", State Univ. of Okla., Research Bull. 4.

Powers, Sidney, 1931, "Structural geology of northeastern Oklahoma", Journal of Geology, Vol. 39, pp. 117-132.

"Revival in the Osage", 1956, World Oil, Vol. 143, pp. 44-47.

Ries, E. R., 1954, "Geology and mineral resources of Okfuskee County, Oklahoma", Okla. Geol. Survey, Bull. 71.

Russell, O. R., 1955, "Geology of the Hominy area, Osage County, Oklahoma", Unpublished Master of Science Thesis, University of Oklahoma.

Sayre, A. N., 1930, "The fauna of the Drum limestone of Kansas and western Missouri", Kan. Geol. Survey, Bull. 17.

Schrader, F. C., and Haworth, Erasmus, 1905, "Oil and gas of the Independence Quadrangle, Kansas", U. S. Geol. Survey, Bull. 260.

Shannon, J. S., 1954, "The geology of the Pawhuska area, Osage County, Oklahoma", Unpublished Master of Science Thesis, University of Oklahoma.

Shimer, H W., and Shrock, R. R., 1944, Index Fossils of North America, John Wiley and Sons, Inc., New York.

Sherrill, R. E., 1929, "Origin of the en echelon faults in north-central Oklahoma", Amer. Assoc. Petroleum Geologists, Bull. Vol. 13, pp. 31-37.

Snider, L. C., 1917, "Geography of Oklahoma", Okla. Geol. Survey, Bull. 27.

Tanner, W. F., 1956, "Geology of Seminole County, Oklahoma", Okla. Geol. Survey, Bull. 74.

_____, 1956, "Geology of northeastern Osage County, Oklahoma", Okla. Geol. Survey, Circular 40.

Vance Rowe Reports, Dec. 1955, "Osage district".

White, David, and others, 1922, "Structure and oil and gas resources of the Osage Reservation, Oklahoma", U. S. Geol. Survey, Bull. 686.

Wilmarth, Grace M., 1938, "Lexicon of geologic names of the United States", U. S. Geol. Survey, Bull. 896.

APPENDIX

MEASURED STRATIGRAPHIC SECTIONS

IN

THE BLACK DOG AND ADJACENT AREAS

Township 19 North

1. Sec. 5, T. 19 N., R. 11 E.; measured from a position near road level in SE¼ northeastward to top of hill.

Nellie Bly formation	feet
Upper sandstone zone	
Sandstone, buff to brown, medium-grained, highly ferruginous, with many iron stain spots, weathers irregular and dark, caps hill.	6.0
Shale, covered, probably contains considerable sandstone	28.0
Sandstone, buff to dark yellow, friable, medium-grained, massive, laminated and cross-laminated, especially near base, middle part banded with iron streaks, marks base of upper sandstone zone.	36.0
Covered, probably shale with some sandstone.	72.0
Sandstone, gray to buff, fine-to medium-grained, interbedded with less resistant siltstone and shale, beds with little lateral continunity, dip variable.	12.0
Covered, probably same as unit below	99.0
Sandstone, buff to cream, fine-grained, massive to irregularly-bedded, interbedded with less resistant siltstone and shale, beds have little lateral continunity, dip variable, structure does not conform with overlying persistent sandstone zone	18.0

2. Sec. 6, T. 19 N., R. 12 E.; measured from near center E½ NE¼ NE¼ westward to a position near top of hill.

Nellie Bly formation	
Shale, gray, weathers yellow, with thin beds of sandstone, not measured	
Hogshooter formation	
Winterset limestone member	

	feet
Limestone, dark yellow to rust, argillaceous, fossiliferous, with crinoidal debris, corals, brachiopods, and dark phosphatic nocules. . . .	1.5
Lost City limestone member	
Limestone, gray, massive, dense, fossiliferous . . .	15.0
Coffeyville formation	
Clay, gray, similar to underclay, weathers dark. . .	0.5
Coal, several thin beds with dark shale partings . .	0.3
Covered, probably shale, with thin sandstone beds. .	45.0
Upper sandstone zone	
Sandstone, buff, fine-to medium-grained, with thin, interbedded gray shale.	7.0
Shale, gray, fissile	7.5
Sandstone, buff, fine-grained, massive-to cross-bedded, micaceous, top uniform, bottom irregular, minor channeling	6.0
Shale, gray, thin to fissile	7.0
Sandstone, buff to dark tan, fine-to medium-grained, massive-to cross-bedded, with iron stain spots, small nodular fragments of clay, and thin shale partings	5.0
Shale, gray, thin to fissile, with small nodular bodies of siltstone and sandstone	12.0
Siltstone, tan to rust, thin-to cross-bedded, micaceous, base covered, not measured	

Township 20 North

3. Sec. 4, T. 20 N., R. 9 E.; measured near the center S½ NE¼.

Vamoosa formation	
Kiheki sandstone member	
Sandstone, buff, massive, not measured	
Covered, probably shale.	26.5
Cheshawalla sandstone member	
Sandstone, buff, massive, cross-bedded and contorted	15.0
Tallant formation	
Covered, probably shale.	18.0
Sandstone, buff to orange, massive, somewhat contorted, weathers orange.	20.0
Shale, base covered, not measured	

4. Sec. 5, T. 20 N., R. 10 E. and sec. 31, T. 21 N., R. 10 E.; measured from 1/8 mile south NW cor. sec. 5 northwestward to the SE¼ SE¼ sec. 31.

	feet
Barnsdall formation	
Okesa sandstone member	
Sandstone, buff, fine-grained, thin-bedded, interbedded with thin siltstone and shale, grading upward into shale.	20.0
Sandstone, light yellow, fine-to medium-grained, massive	5.0
Sandstone, yellow, thin-to medium-bedded, interbedded with thin siltstone.	9.5
Sandstone, buff to yellow, thin-bedded, ripple-marked.	4.5
Sandstone, light yellow to orange, medium-grained, massive, banded	14.5
Sandstone, yellow to orange, fine-grained, thick-bedded.	3.0
Siltstone and shale, interbedded, thin-bedded, badly broken.	5.5
Wann formation	
Clem Creek sandstone member	
Sandstone, light buff to pink, medium-grained, thick-bedded, banded, brown iron stains common, weathers red, base covered by eolian deposits, not measured.	

5. Secs. 11 and 14, T. 20 N., R. 10 E.; measured from NE¼ SE¼ sec. 14 northward along lease road to SE¼ SE¼ sec. 11.

Wann formation	
Clem Creek sandstone member	
Sandstone, buff, fine-to medium-grained, ferruginous, weathers light yellow to brown, with some maroon shale, top eroded.	17.0
Shale, maroon, blocky, with thin sandstone and siltstone beds.	15.0
Sandstone, cream to buff, fine-to medium-grained, upper part silty, weathers orange.	6.0
Shale, maroon, blocky.	4.0
Sandstone, yellow to brown, weathers orange, loosely cemented.	8.0
Shale, gray to maroon, badly covered	5.5
"Washington Irving"? sandstone	
Sandstone, light buff to dark brown, fine-to coarse-grained, generally massive, weathers orange to dark, contains gray, blocky shale . .	46.0
Shale, dark gray, weathers red, with thin sandstone beds.	21.0
Sandstone, yellow, upper and lower parts silty, middle one foot packed with molds of Triticites.	3.0
Shale, dark bluish-gray, weathers gray to red, contains thin sandstone beds.	33.0

	feet
Shale and sandstone, alternating beds, shale, dark gray, blocky, sandstone, brown, medium-bedded, ripple-marked.	7.5
Shale, dark gray, blocky to knobby, weathers light gray to yellow, with small iron stone concretions and thin sandstone beds.	40.0
Iola formation	
Avant limestone member	
Limestone, gray to blue, fine to medium crystalline, wavy and medium-bedded, weathers to rusty color, interbedded with fine-grain, buff sandstone, base covered by debris in stream bed.	7.0

6. Sec. 14, T. 20 N., R. 10 E.; measured from stream northward in SW¼ SW¼ NW¼.

Wann formation	
Clem Creek sandstone member	
Sandstone and shale, badly covered, top eroded . . .	15.0
Sandstone, yellow, massive-to cross-bedded, weathers orange, forms pronounced bench	14.0
Shale, maroon, weathers yellow to maroon	24.0
Sandstone, yellow-brown, not resistant, ferruginous, forms slight bench	8.0
Shale, maroon, weathers dark, poorly exposed	20.0
"Washington Irving"? sandstone	
Sandstone, buff to yellow, fine-to coarse-grained, massive-to cross-bedded, contorted, siltstones present near base, hard to friable, weathers red, yellow to rust, forms high bench	38.5
Shale, upper part olive, sandy, weathers light yellow, with ironstone concretions, lower part covered.	38.0

7. Sec. 29, T. 20 N., R. 10 E.; measured from road level northward in SE¼ NE¼ NE¼.

Wann formation	
"Washington Irving"? sandstone	
Sandstone, buff to brown, fine-to medium-grained, extremely massive, not measured	
Shale, blue to olive, with thin sandy, limy beds, some of which are packed with molds of Triticites.	94.0
Iola formation	
Avant limestone member	
Limestone, dark bluish-gray, dense with small calcite crystals, thin-bedded, with shale partings,	

	feet
weathers into thin, wavy fragments, fossiliferous	3.0
Limestone, light pink to bluish-gray, fine to medium crystalline, medium-bedded, weathers dark brown	5.0

8. Sec. 9 and Sec. 16, T. 20 N., R. 11 E.; measured from gully in SE¼ NW¼ NE¼ sec. 16 northwestward to top of hill.

Wann formation	
Shale, forms gentle slope, not measured	
Sandstone, tan, medium-grained, forms slight bench	0.5
Shale, covered	42.0
Sandstone, buff, fine-to medium-grained, medium-bedded, forms first bench above Avant limestone	4.0
Shale, badly covered by sandstone debris	25.0
Iola formation	
Avant limestone member	
Limestone, gray, medium-crystalline, wavy-to medium-bedded, fossiliferous, weathers red to gray, badly covered by sandstone debris	6.0
Shale, covered, forms gentle slope	35.0
Limestone (?), covered bench bearing persimmon trees, probably lower Avant limestone of type locality	2.0
Muncie Creek shale member	
Shale, dark, poorly exposed	26.0
Paola limestone member	
Limestone (?), bench covered with persimmon tree	2.0
Chanute formation	
Shale, covered, probably includes upper part of Dewey formation	60.0
Dewey formation	
Limestone, dark brown, arenaceous, fossiliferous, weathers yellow	2.0

9. Sec. 20, T. 20 N., R. 11 E.; measured from a position immediately south of Shell Creek southward along road to top of hill.

Nellie Bly formation	
Upper sandstone zone	
Sandstone and shale, alternate bedded, sandstone, buff to brown, badly covered, shale, poorly exposed, forms slopes	42.0
Shale, dark gray, weathers light gray, contains limy streak near base	13.5
Sandstone, cream to buff, fine-grained, fairly massive, micaceous, silty, ripple-marked, weathers yellow	7.0

		feet
	Shale, gray to olive, weathers yellow, with thin siltstones	9.0
	Sandstone, buff to brown, fine-to medium-grained, massive, cross-bedded, ranges from resistant to friable, base of upper sandstone zone is within this interval	61.0

10. Sec. 29, T. 20 N., R. 11 E.; measured westward along road in the NE¼

Nellie Bly formation
Upper sandstone zone

	Sandstone, dark, highly ferruginous, badly eroded, not measured	
	Shale and sandstone, interbedded, shale, gray arenaceous, sandstone, yellow, friable.	40.0
	Sandstone, yellow, friable, thick-to cross-bedded, banded with yellow iron stain in place, highly ferruginous at top, weathers to yellow, rounded fragments	37.0

11. Sec. 35, T. 20 N., R. 11 E.; measured from stream in SE¼ NE¼ NW¼ eastward up hill to a position near north-south road.

Nellie Bly formation
Upper sandstone zone

	Sandstone, yellow to cream, medium-grained, massive, soft, lower bench of the upper sandstone zone .	25.0
	Shale, covered	10.0
	Sandstone, buff to tan, massive-to highly cross-bedded, some bedding irregular, sequence dip to northeast at 3 to 5 degrees, with thin beds of gray shale	88.0

12. Sec. 9, T. 20 N., R. 12 E.; measured from center W½ NE¼ NW¼ southwestward to top of hill.

Nellie Bly formation
Lower sandstone zone

	Shale, dark gray to olive, blocky, weathers to light gray, top eroded, not measured	
	Sandstone, buff, fine-to medium-grained, top pitted by erosion	2.5
	Shale, olive to dark gray, blocky, weathers to light gray.	2.0
	Sandstone, interbedded with shale.	1.5
	Shale, dark gray, clayey, lower part blocky, upper part thin to fissile	36.0

Hogshooter formation
Winterset limestone member

	feet
Limestone, gray, packed with crinoidal debris, brachiopods, bryozoans, corals, weathers yellow to rust, soft, badly covered	2.5
Coffeyville formation	
Shale, badly covered, upper part is lignitic clay, resembling an underclay, lower part covered . .	30.0
Upper sandstone zone	
Sandstone, buff to yellow, fine-grained, thin-to medium-bedded, cross-bedded, weathers light yellow, with shale partings and ripple-marks common.	44.0
Sandstone, with interbedded shale, micaceous, thin bedded, base covered, not measured	

13. Sec. 14, T. 20 N., R. 12 E.; measured from Flat Rock Creek southward along paved road to top of hill near center of section.

Coffeyville formation	
Sandstone, buff, thin-to medium-to cross-bedded, lenticular, top eroded.	4.0
Siltstone and shale, thin-to wavy-bedded	6.0
Sandstone, yellow, thin-to wavy-bedded	3.5
Shale, gray, fissile, with considerable thin, wavy-bedded siltstone.	20.5
Shale, gray, thin to fissile, with very thin siltstone beds.	45.0
Shale, poorly exposed.	25.0
Shale, gray, fissile to blocky	12.0
Shale, black, fissile, with rounded phosphatic nodules	7.0
Checkerboard limestone	
Limestone, gray, dense, hard, a single thick bed, fossiliferous, weathers light gray.	2.5

14. Secs. 15 and 22, T. 20 N., R. 12 E.; measured from center S½ sec. 15 southeastward to a position near center N½ NE¼ sec. 22.

Coffeyville formation	
Upper sandstone zone	
Sandstone, siltstone and shale, alternate bedded, top eroded.	20.0
Shale, gray, blocky in lower part, fissile to blocky in upper part, silty near top	112.0
Sandstone, yellow, thin-to medium-bedded, ferruginous, probably top of lower sandstone zone of Coffeyville formation, not measured.	

15. Sec. 17, T. 20 N., R. 12 E.; measured from center NE¼ SE¼ westward along stream.

	feet
Nellie Bly formation	
Covered, probably shale, with thin sandstone beds, not measured.	
Hogshooter formation	
Winterset limestone member	
Limestone, dark brown, sandy, fossiliferous, composed largely of crinoidal debris, with corals, brachiopods common, weathers dark, fossil fragments weather white.	1.5
Lost City limestone member	
Limestone, gray to blue, massive, siliceous, dense, fossiliferous, weathers gray to orange-yellow	4.5
Coffeyville formation	
Covered, probably same as unit below	13.0
Shale, gray, thin to blocky.	5.0
Underclay, gray-blue, with several thin streaks of coal and plant fragments.	0.7
Coal	0.2
Underclay (?) gray-blue, with many plant fragments .	0.2
Shale, gray, thin to blocky.	11.5
Shale, gray to buff, sandy, weathers yellow, with iron stains	15.0

16. Sec. 22, T. 20 N., R. 12 E.; measured from county line in SE¼ NE¼ SE¼ westward to top of hill and then southeastward to a position near county line.

Coffeyville formation	
Upper sandstone zone	
Sandstone, buff to tan, medium-grained, massive, cross-bedded, ripple-marked	7.0
Sandstone, tan, medium-grained, massive, resistant, forms bench	2.5
Sandstone, tan, fine-to medium-grained, thick to massive, becoming more massive upward, with shale partings.	22.0
Sandstone, buff to tan, fine-to medium-grained, thin-bedded, ripple-marked, with shale partings.	7.0
Sandstone, buff to yellow, medium-grained, massive, resistant, weathers to orange color, (lower most bench former).	1.2
Shale, gray, lignitic, with interbedded thin sandstones and siltstones	12.0
Shale, gray to dark blue, lower part thin-bedded, middle part blocky, upper part nodular to blocky with thin sandstone beds.	66.0

Township 21 North

17. Sec. 10, T. 21 N., R. 8 E.; from 1/8 mile north of center of south section line northward to top of hill.

	feet
Vamoosa formation	
Lower bed of Elgin sandstone member	
Sandstone, buff to gray, contorted, cross-bedded, weathers to rough, irregular surface, caps hill, top eroded.	10.0
Kanwaka shale member	
Shale, dark olive, with thin sandstone beds. . . .	77.0
Wynona sandstone member	
Shale, maroon, base covered.	24.0

18. Sec. 2, T. 21 N., R. 9 E.; measured from stream near center N½ westward to a position near west section line.

Vamoosa formation	
Wynona sandstone member	
Sandstone, buff, thick-to massive-bedded, poorly exposed, not measured	
Shale, maroon to gray, blocky, with thin, cream to light gray siltstone and sandstone beds . . .	33.0
Cochahee sandstone member	
Sandstone, buff, medium-grained, medium-bedded, upper part has been fractured into rectangular slabs which litter underlying shale slope	5.0
Shale, badly covered by sandstone debris	31.0
Kiheki sandstone member	
Sandstone, yellow, fine-to medium-grained, massive, somewhat contorted.	35.0

19. Sec. 4 and Sec. 5, T. 21 N., R. 9 E.; measured from pipe line in stream in NW¼ sec. 4, westward to top of outlying hill in NE¼ sec. 5.

Vamoosa formation	
Lower bed of Elgin sandstone member	
Sandstone, yellow to orange, medium-grained, contorted, cross-bedded, weathers into large, irregular fragments with rough, pitted surfaces, caps hill, badly eroded. . . .	6.0
Kanwaka shale member	
Shale, weathers to dark soil	50.0
Sandstone, dull yellow, iron stained, medium-bedded, with numerous molds of small pelecypods resembling Nuculana sp.	3.0
Shale, gray, with thin silty zones	4.5
Limestone, gray, arenaceous, with molds of small pelecypods common, weathers rust.	1.0

	feet
Wynona sandstone member	
Shale, gray, with calcareous nodules	7.0
Shale, maroon	7.0
Siltstone, green, medium-bedded	1.0
Sandstone, cream to yellow, calcareous	0.5
Siltstone, light gray	1.0
Shale, maroon, calcareous in upper part, leached green in places	17.0

20. Sec. 6, T. 21 N., R. 9 E.; measured from stream in SE¼ NE¼ NW¼ northwestward to a position near NW corner of section.

Vamoosa formation	
Upper bed of Elgin sandstone member	
Sandstone, orange, fine-to medium-grained, massive, contorted, weathers into irregular blocks, top eroded, not measured	
Kanwaka shale member	
Shale, dark, poorly exposed	110.0
Lower bed of Elgin sandstone member	
Sandstone, buff to yellow, fine-to medium-grained, thick-bedded, highly contorted, weathers into large, irregular shaped blocks with deeply pitted surfaces	4.0
Shale, dark, slope covered with sandstone debris, poorly exposed	49.0
Sandstone, buff, medium-grained, thin-to medium-bedded, upper surface bears many molds of pelecypods	2.0
Wynona sandstone member	
Shale, maroon, poorly exposed, base covered, not measured	

21. Sec. 19 and sec. 30, T. 21 N., R. 9 E.; measured from NE¼ NW¼ NE¼ sec. 30 northwestward up hill along road.

Vamoosa formation	
Kanwaka shale member	
Shale, dark, interbedded with thin siltstone and sandstone, not measured	
Shale, gray to olive, blocky	4.5
Sandstone, cream, fine-grained, calcareous, hard, with yellow iron stain, upper surface bears molds of pelecypods	1.0
Wynona sandstone member	
Shale, olive, with red tinge, weathers yellow to gray, contains ironstone concretions in upper part	4.0
Sandstone, yellow to dark brown, calcareous, upper part ferruginous, weathers rust	1.0
Shale, gray to olive	6.0

	feet
Sandstone, yellow, ripple-marked, lower part medium-bedded, upper part thin-bedded, with thin siltstone zones.	5.0
Shale, olive, weathers gray.	5.5
Shale, gray, with interbedded calcareous sandstone and siltstone	12.0
Shale, maroon, clayey.	5.5
Sandstone, buff to gray, hard to break, calcareous, ferruginous	2.0
Shale, dark maroon, with thin beds of cream colored siltstone	20.0
Upper sandstone bed	
Sandstone, buff to orange, fine-to coarse-grained, massive, cross-bedded, upper part is silty and ripple-marked	9.0
Shale, maroon, with ironstone concretions.	10.0
Sandstone, buff, silty	2.0
Shale, maroon, with thin silty streaks	16.0
Lower sandstone bed	
Sandstone, buff, fine-to medium-grained, massive, contorted, cross-bedded, weathers yellow, base covered.	20.0

22. Sec. 20, T. 21 N., R. 9 E.; measured from Mill Creek near center SW$\frac{1}{4}$ eastward along road to crest of hill 1/4 mile north SE corner of section.

Vamoosa formation	
Kanwaka shale	
Shale, dark, with thin siltstone and sandstone beds, poorly exposed.	27.0
Wynona sandstone member	
Sandstone, buff, thin-bedded, interbedded with gray shale and thin siltstone.	16.0
Shale, dark olive, with calcareous nodules	13.0
Shale, maroon.	15.0
Siltstone, cream, fine-grained, hard	1.5
Shale, maroon.	21.0
Upper sandstone bed	
Sandstone, buff to light orange, massive, cross-bedded, with clay pebble conglomerate in lower part, weathers dark red	15.5
Shale, maroon, with silty zone in upper part	21.0
Lower sandstone bed	
Sandstone, buff, massive, near base and top, middle part contains shale and siltstone. This bed marks the base of the Wynona sandstone member.	27.0
Shale, maroon, poorly exposed.	5.0
Sandstone, buff, thin-to medium-bedded, ripple-	

	feet
marked, weathers red, interbedded with maroon to olive shale	10.0
Shale, gray to olive, blocky	2.0
Siltstone, cream, one bed.	0.5
Shale, gray to olive, blocky	31.5
Limestone, gray to brown, arenaceous, weathers rust, deposits of white calcite in small solution cavities	1.0
Shale, dark, arenaceous, with iron stains.	4.0
Sandstone, yellow, weathers rust	1.2
Siltstone, buff, thin-bedded	1.3
Shale, olive green, blocky, weathers light green	1.5
Shale, maroon.	4.0
Sandstone, cream to buff, grades upward from thin-to medium-bedded, silty.	6.0
Shale, maroon to purple, blocky.	5.0
Sandstone, cream to buff, fine-grained, cross-bedded, with thin silty zones	3.0
Kiheki sandstone member	
Covered, probably sandstone.	13.0
Sandstone, buff, fine-grained, medium-bedded, exposed in stream bed	4.0
Sandstone, buff, fine-to medium-grained, massive, bottom not exposed.	6.0

23. Sec. 32, T. 21 N., R. 9 E.; measured from a position near road level northward in the SE¼ NW¼.

Vamoosa formation	
Wynona sandstone member	
Lower sandstone bed	
Sandstone, buff, massive, forms bench, top eroded.	10.0
Shale, maroon.	11.0
Sandstone, yellow, medium-grained, massive, exceptionally ferruginous, especially at base	6.0
Covered, probably shale.	66.0
Kiheki sandstone member	
Sandstone, buff to yellow, massive, cross-bedded, weathers with pitted surface.	28.0

24. Sec. 5, T. 21 N., R. 10 E. and secs. 32 and 33, T. 22 N., R. 10 E.; measured from sandstone in Wildhorse Creek in NE¼ NE¼ NE¼ sec. 5 up hill along winding road to SW¼ SW¼ SW¼ sec. 33.

Barnsdall formation	
Okesa sandstone member	
Shale, maroon to gray, with thin beds of hard, brittle, olive claystone, three massive sandstone beds 2 to 3 feet thick occur near	

	feet
top of unit	36.0
Sandstone, buff, fine-to medium-grained, one massive bed, resistant, with dark iron stain spots, forms bench.	12.0
Sandstone, buff, fine-to medium-grained, massive, cross-bedded, laminated, with interbedded gray and maroon shale, "concretionary" masses of sandstone occur in the shale.	18.0
Shale, clayey to arenaceous, with thin, laminated, silty sandstone beds, yellow iron stains common.	3.0
Sandstone, cream to buff, fine-to medium-grained, massive, laminated, weathers red, especially near top, with light gray shale in thin, nonresistant, irregular beds.	16.5
Wann formation	
Covered by alluvium, probably maroon shale, with thin sandstone beds.	28.0
Clem Creek sandstone member	
Sandstone, buff to tan, medium-grained, medium-to massive, weathers grayish-yellow, base not exposed	10.0

25. Sec. 18, T. 21 N., R. 10 E.; measured center N½ southwestward along pipe line to western line of section.

Vamoosa formation	
Kiheki sandstone member	
Sandstone, yellow, badly eroded.	10.0
Shale, gray to maroon, poorly exposed.	28.5
Cheshawalla sandstone member	
Sandstone, buff, fine-to medium-grained, massive, resistant, forms bench.	10.0
Tallant formation	
Shale, maroon, poorly exposed, probably includes some thin sandstone beds	21.0
Sandstone, yellow, forms slight bench.	12.0
Shale, maroon, poorly exposed.	11.0
Bigheart sandstone member	
Sandstone, buff, thick-bedded.	5.5
Covered, probably shaly sandstone.	6.5
Sandstone, buff to red, medium-to coarse-grained, massive, clay ball conglomerates near base. . .	15.5
Barnsdall formation	
Unnamed shale member	
Shale, bluish-gray, fissile.	12.0
Wildhorse dolomite lentil	
Dolomite, dark blue, wavy-bedded in beds 2 to 3 inches thick, contains Triticites sp..	1.0
Shale, bluish-gray, fissile, with several thin,	

feet

calcareous zones less than 6 inches thick, not measured.

26. Sec. 27 and Sec. 34, T. 21 N., R. 10 E.; from alluvium in SW¼ sec. 34 northwestward along road to SE¼ sec. 27.

Barnsdall formation
Okesa ? sandstone member
Sandstone, buff, medium-to massive-bedded, top eroded. 8.0
Wann formation
Sandstone, siltstone and shale, interbedded, poorly exposed 15.0
Sandstone, buff, thin-to massive-bedded, grades downward to maroon shale and thin siltstone . . 17.0
Sandstone, buff, thin-to medium-bedded, silty, weathers orange 3.0
Shale, olive to yellow, weathers cream 1.5
Shale, maroon, clayey, contains few lenses of thin, grayish-green, silty, shale 22.0
Clem Creek sandstone member
Sandstone, buff to tan, thick-bedded, weathers orange. 6.5
Shale maroon, weathers dark yellow 5.0
Sandstone, orange to yellow, weathers red. 4.0
Shale, maroon to gray, arenaceous, weathers yellow, not well exposed. 6.0
Sandstone, buff to orange, medium-grained, massive, somewhat cross-bedded, ferruginous, weathers orange to red, contains considerable maroon shale in upper part 46.0
Shale, lower part gray to maroon, clayey, weathers yellow, grades upward to soft, crumbly, yellow to red, sandy shale 13.5
"Washington Irving" ? sandstone
Sandstone, buff, fine-to medium-grained, massive, ferruginous 23.0
Shale, gray, blocky, with thin limy zones and sandstone beds. 47.0
Sandstone, brown, a single hard bed. 1.0
Shale, gray, fissile to blocky, with thin sandy streaks, base covered by alluvium 6.0

27. Sec. 1, T. 21 N., R. 11 E.; from center N½ NE¼ northwestward to crest of hill.

Wann formation
Sandstone, tan, massive, caps hill, top eroded, not measured.
Shale, poorly exposed, probably contains thin

	feet
sandstone beds.	54.0
Sandstone, yellow, calcareous, resistant	0.5
Shale, gray, poorly exposed.	25.0
Sandstone, buff, massive, cross-bedded, resistant, weathers dull yellow, with thin shale partings.	7.0
Sandstone, interbedded with shale, essentially covered	10.0
Iola formation	
Avant limestone member	
Limestone, dark gray, finely crystalline, massive- to wavy-bedded, fossiliferous, weathers light gray to yellow, and weathers into wavy slabs 1" to 6" thick, secondary deposits of white, laminated calcite along joints.	13.0
Muncie Creek shale member	
Shale, dark, with thin zone of oval ironstone concretions in lower part.	53.0
Paola limestone member	
Limestone (exposure doubtful) bench with persimmon growth.	2.0
Chanute formation	
Shale, exposure poor	17.0
Cottage Grove sandstone member	
Sandstone, buff to gray, calcareous, fine-to medium-grained, laminated, bedding wavy, weathers dull brown, forms bench with persimmon growth. . . .	4.0
Shale, dark gray, clayey, blocky, poorly exposed . .	19.0
Dewey formation	
Limestone, dark gray to brown, arenaceous, fossiliferous, weathers yellow.	3.0
Shale, dark, poorly exposed, base marked by bench with persimmon growth possibly indicating lower limestone	22.0

28. Sec. 14, T. 21 N., R. 11 E.; from center E½ NE¼ SE¼ westward to crest of hill.

Wann formation	
Sandstone, tan, fine-to medium-grained, massive, resistant, caps hill, weathers to dark brown. .	3.0
Shale, lower part, gray, clayey, weathers olive, upper part covered by sandstone debris, limestone float observed 10 feet above base	75.0
Sandstone, tan, fine-grained, thin-to massive-bedded, with ripple marks and fucoids	8.5
Iola formation	
Avant limestone member	
Limestone, bluish-gray, fossiliferous, littered by sandstone rubble	6.5

	feet
Muncie Creek shale member, Paola limestone member and Chanute formation (shale above Cottage Grove sandstone member)	
Covered, steep slope, with persimmon growth on slight bench near base.	71.0
Cottage Grove sandstone member?	
Covered, probably sandstone, indicated by well developed bench	6.0?
Covered, probably shale, indicated by steep slope. .	32.0
Dewey formation	
Limestone, yellow to brown, medium-bedded, fossiliferous, weathers dirty yellow.	3.0
Shale, poorly exposed, dark gray, calcareous	30.0
Limestone, (colloquial "Cowbarn" limestone) gray to rust, medium-crystalline, fossiliferous, weathers white to brown.	3.0

29. Sec. 15, T. 21 N., R. 11 E.; measured from NE¼ NE¼ SE¼ northwestward up hill.

Wann formation	
Covered, probably shale, with thin sandstone beds, not measured	
Sandstone, tan, fine-to medium-grained, massive, weathers to deep rust color, forms tree-covered bench	2.0
Covered, probably shale, with thin sandstone beds. .	43.0
Limestone, bluish-gray, marly, fossiliferous, lower 2 feet thin-bedded and nonresistant, upper foot more massive, resistant.	3.0
Shale, gray, clayey, weathers dark	14.0
Shale, gray, clayey, weathers light gray, chalky, with interbedded thin sandstone beds.	5.0
Sandstone, light cream to tan, fine-grained, massive, cross-bedded, with mold of pelecypods common on bedding surfaces	4.0
Shale, arenaceous, not well exposed.	2.5
Sandstone, buff to tan, fine-grained, cross-bedded, fossiliferous, with molds of crinoid stems, brachiopods, pelecypods, and gastropods common.	2.5
Shale, not well exposed.	4.0
Iola formation	
Avant limestone member	
Limestone, gray, massive, not measured, only topmost foot exposed.	

30. Sec. 28, T. 21 N., R. 11 E.; from stream near center of section northwestward up hill.

		feet
	Iola formation	
	Avant limestone member	
	Limestone, light gray, finely crystalline, lower part massive, upper part wavy-bedded, not as fossiliferous as to the north, weathers bright rust.	6.0
	Muncie Creek shale member	
	Shale, not exposed	38.0
	Paola limestone member	
	Limestone (?), covered, presence indicated by bench bearing persimmon trees	2.0?
	Chanute formation	
	Shale, calcareous, light olive, clayey, blocky, considerable sandstone debris near top of interval indicates sandstone bed (possible Cottage Grove sandstone equivalent)	33.0
	Dewey formation	
	Limestone, pinkish brown, arenaceous, fossiliferous, weathers bright yellow.	1.0
	Shale, dark, exposure poor	3.5
	Sandstone, tan to dark brown, calcareous, thick-bedded.	3.0
	Shale, dark, exposure poor	6.0
	Limestone, pink to brown, medium crystalline, fossiliferous, with many Triticites sp. becomes more arenaceous and darker upward . . .	3.0
31.	Sec. 31, T. 21 N., R. 11 E.; from stream in SE¼ SE¼ NE¼ northwestward along road to top of hill.	
	Wann formation	
	Sandstone, buff near base grading to red at top, fine-to coarse-grained, massive, clay pebble conglomerate in upper part	15.5
	Shale, gray, blocky, with thin siltstones, upper 3 feet of unit weathers to a mottled gray and red	10.5
	Sandstone, buff to brown, calcareous, with many molds of Triticites sp.	0.4
	Shale, gray, blocky.	1.5
	Sandstone, yellow to rust, calcareous, fossiliferous, with molds of pelecypods and brachiopods	1.0
	Shale, gray, fissile in lower part, becoming blocky towards top, contains few thin calcareous sandstone and siltstone beds in lower part, with ratio of sand to shale increasing upward, iron-stone concretions common near middle of unit	158.0

	feet
Sandstone, buff to cream, fine-grained, massive, displays pronounced rectangular joint pattern	3.0
Iola formation	
Avant limestone member	
Limestone, gray, finely crystalline, thick-to wavy-bedded, top exposed in stream 100 feet south of road, not measured	

32. Sec. 33, and sec. 34, T. 21 N., R. 11 E.; measured from bridge over Delaware Creek westward 150 yards and then southward to top of small hill.

Nellie Bly formation	
Upper sandstone zone	
Sandstone, buff, fine-grained, badly eroded, not measured	
Shale, essentially covered by sandstone debris . . .	26.0
Sandstone, poorly exposed, forms bench in shale slope	4.0
Shale, covered, gentle slope	11.0
Sandstone, light buff to gray, massive, weathers dark brown.	1.5
Shale, with thin sandstone beds, exposure poor . . .	7.0
Sandstone, light buff, fine-to medium-grained, thin-to medium-bedded, (probably base of upper sandstone zone)	3.0
Siltstone, interbedded with thin sandstone and shale bed. Sequence is gray to buff, thin-bedded, wavy-bedded, with ripple marks, becomes more shaley upward.	32.0
Sandstone, gray to buff, fine-to medium-grained, thin-to cross-bedded, lenticular, channels common, with ripple marks and trails common, interbedded with gray, lignitic shale	35.0

33. Sec. 30, T. 21 N., R. 12 E.; measured near center S½ NW¼.

Nellie Bly formation	
Lower sandstone zone	
Sandstone, buff, fine-to medium-grained, thick-bedded, speckled with iron spots, forms slight bench.	3.0
Shale, gray, clayey, with thin silty zones	28.0
Hogshooter formation	
Winterset limestone member	
Limestone, brown arenaceous, wavy-bedded, thin-bedded, weathers into bright yellow, platy fragments, fossiliferous.	2.0
Coffeyville formation	

		feet
	Sandstone, dark rust color, thin-to medium-bedded micaceous, highly ferruginous, nonresistant, weathers dark	5.5
	Shale, gray, clayey, weathers yellow to olive	15.5

34. Sec. 30, T. 21 N., R. 12 E.; measured from a position near NW corner SE¼ northward to top of hill.

	Nellie Bly formation	
	Lower sandstone zone	
	Sandstone, top eroded	2.0
	Shale, dark gray, clayey	18.0
	Sandstone, yellow, iron spots common, a single resistant bed	1.0
	Shale, poorly exposed	13.5
	Hogshooter formation	
	Winterset limestone member	
	Limestone, gray to rust, fossiliferous, with rounded phosphatic nodules, weathers yellow	2.0
	Coffeyville formation	
	Shale, gray, blocky near base, grades upward to clay, silty in lower part	39.0
	Upper sandstone zone	
	Siltstone, buff, thin-to wavy-bedded, micaceous, with thin shale partings	6.5
	Sandstone, brown, thin-to wavy-bedded, silty, micaceous, grades upward to siltstone	3.0
	Siltstone, buff, thin-to wavy-bedded, micaceous, with thin shale partings	13.0
	Sandstone, buff, medium-bedded, silty, micaceous, ripple-marked	2.0
	Shale, gray, blocky, breaks into small rectangular fragments parallel to pronounced jointing, iron stains on joint planes	13.0

35. Sec. 36, T. 21 N., R. 12 E.; measured southward along paved road up NW side of Turley Mountain, Tulsa County.

	Nellie Bly formation	
	Lower sandstone zone	
	Sandstone, yellow, fine-to medium-grained, massive, with thin silty shale partings, weathers brown	15.0
	Shale, poorly exposed, weathers gray to yellow	4.0
	Sandstone, yellow, fine-to medium-grained, two massive beds separated by shale parting, weathers brown	4.0
	Shale, poorly exposed, weathers gray to yellow	17.5
	Limestone, dark blue to rust, brecciated appearance, weathers yellow	1.0
	Shale, poorly exposed, weathers gray to yellow	22.0

	feet
Hogshooter formation	
Winterset limestone member	
Limestone, gray to blue, massive, packed with crinoidal debris, weathers to rust colored granular mass, covered by debris from massive sandstone beds above.	3.0
Coffeyville formation	
Shale, gray, blocky, not well exposed.	16.0
Sandstone and siltstone, interbedded, buff, thin and irregularly bedded.	12.5
Upper sandstone zone	
Sandstone, buff, fine-to medium-grained, massive, cross-bedded, resistant, weathers yellow, with thin shale partings	22.0
Shale, gray to olive, blocky, with thin sandstone beds, base not exposed.	100+

Township 22 North

36. Sec. 13, T. 22 N., R. 9 E.; measured from west end of bridge crossing Boar Creek westward along Oklahoma State Highway 20.

Vamoosa formation	
Kiheki sandstone member	
Sandstone, buff, fine-to coarse-grained, thin-to massive-bedded, some cross-bedding, ripple-marked, weathers to light rust color, contains clay pebble conglomerate near base, top eroded.	10.0
Shale, maroon to greenish-gray, blocky to fissile, contains 3 to 4 thin, lenticular silty beds . .	23.0
Siltstone, cream to buff, thin-bedded.	2.5
Shale, maroon to gray, blocky, lateral color variation	7.0
Cheshawalla sandstone member	
Sandstone, buff, fine-to medium-grained, massive, especially near top, weathers light yellow to purple, iron stains common near middle, some thin shale partings present	35.0
Tallant formation	
Shale, poorly exposed.	2.0
Sandstone, buff, medium-to cross-bedded, weathers dull yellow	5.0
Sandstone, buff, thin-bedded	3.0
Covered, probably shale.	23.0
Sandstone, light yellow, thick-to cross-bedded, interbedded with maroon shale and thin siltstone	12.0
Shale, green to maroon, clayey, with hard, platy streaks	3.0
Bigheart sandstone member	

	feet
Sandstone, light cream to orange, massive, cross-bedded, clay pebble conglomerate present near base, weathers orange to light purple, base not exposed	12.0

37. Sec. 14, T. 22 N., R. 9 E.; measured along Oklahoma State Highway 20 in the SE¼.

Vamoosa formation

Cochahee sandstone member

Sandstone, buff, fine-to medium-grained, weathers rust, spotted with brown iron stains, not observed in situ, sandstone debris and bench indicates its presence, not measured	
Covered, probably shale	8.0
Shale, olive, blocky to fissile, weathers to fissile fragments	3.0
Shale, bluish-gray, blocky, weathers to light gray, powdery mass	2.0
Sandstone, dark yellow to rust, calcareous, thin-bedded, dense	0.5
Shale, bluish-gray, blocky to thin, weathers light gray, powdery	2.0
Shale, olive, blocky to fissile, weathers fissile	2.4
Shale, bluish-gray, blocky to thin, weathers light gray, powdery	3.0
Limestone, dark gray, high iron content, badly weathered, fossiliferous, with poorly preserved fusulinids, Bryozoa, and crinoid stems, weathers gray to rust	1.0
Shale, greenish-gray, blocky, fissile	8.5
Shale, poorly exposed, weathers gray to yellow, with considerable thin silty sandstone	8.0
Sandstone, light gray, medium-bedded, cross-bedded, spotted with brown iron stain, silty streaks common especially near center of unit	6.6
Shale, maroon, fissile	3.0
Siltstone, buff to light gray, extremely silty	1.0
Shale, maroon, blocky	3.0
Shale, olive, arenaceous	1.0
Sandstone, buff, cross-bedded, silty, weathers light gray	5.7
Shale, maroon, thin to blocky, grades upward into thin siltstone	3.0
Shale, olive, fissile to blocky	1.0

Kiheki sandstone member

Sandstone, buff, fine-to coarse-grained, generally massive, somewhat cross-bedded, ripple-marked, with thin silty zones	25.0

feet

38. Secs. 19 and 20, T. 22 N., R. 9 E.; measured from 1/4 mile south NW cor. sec. 20 southwestward to top of hill in the NE¼ sec. 19.

Vamoosa formation
  Upper bed of Elgin sandstone member
    Sandstone, buff to orange, fine-to medium-grained, massive, highly contorted, weathers into large rough blocks, top eroded, not measured
  Kanwaka shale member
    Shale, dark, poorly exposed. 28.0
    Sandstone, forms slight bench, thickness included in overlying and underlying shale.
    Shale, dark, poorly exposed. 88.0
  Lower bed of Elgin sandstone member
    Sandstone, buff to orange, fine-to medium-grained, thick-bedded, contorted, weathers into large, irregular blocks. 6.0
    Shale, dark gray 55.0
  Wynona sandstone member
    Shale, covered, debris indicates maroon shale with thin silty zones 38.0
    Sandstone, thin-bedded, with interbedded shale and siltstone, base covered, not measured

39. Sec. 20, T. 22 N., R. 9 E.; measured from stream in SE¼ SE¼ northward.

Vamoosa formation
  Wynona sandstone member
    Upper sandstone bed
      Sandstone, covered, not measured
      Shale, maroon, with thin siltstone and sandstone beds, not well exposed. 15.0
      Sandstone, light gray, fine-grained, a single bed, forms slight bench. 2.0
      Siltstone, cream, thin-bedded, cross-bedded. 3.0
      Covered, probably shale. 3.0
    Lower sandstone bed
      Sandstone, buff to yellow, cross-bedded. 5.0
      Sandstone, buff, massive, base not exposed 6.0

40. Sec. 22, T. 22 N., R. 9 E.; measured from stream 1/8 mile north of center of section northward to a position near ranch house.

Vamoosa formation
  Cochahee sandstone member
    Sandstone, buff, fine-to medium-grained, lower part highly contorted, upper part evenly bedded,

	feet
fractured into long, rectangular blocks	5.0
Shale, light gray, blocky.	22.0
Shale, dark, clayey.	15.0
Kiheki sandstone member	
Sandstone, yellow, essentially fine-grained, cross-bedded and contorted, especially near base, silty, base covered	25.0

41. Sec. 36, T. 22 N., R. 9 E.; measured near the center SE$\frac{1}{4}$ sec. 36.

Vamoosa formation	
Cochahee sandstone member	
Sandstone, buff, fine-grained, thick-bedded, banded, ripple-marked, weathers to light orange, top eroded	6.0
Covered, probably shale.	32.0
Kiheki sandstone member	
Sandstone, buff to orange, massive, cross-bedded . .	23.0
Covered, probably shale.	15.0
Sandstone, buff, massive, contorted.	19.0
Shale, gray to maroon, with siltstone and thin sandstone in upper few feet	29.0
Cheshawalla sandstone member	
Sandstone, yellow, massive, not measured	

42. Sec. 18, T. 22 N., R. 10 E.; measured westward on Oklahoma State Highway 20 from 0.4 miles east of southwest cor. sec. 18.

Tallant formation	
Sandstone, light yellow, fine-to coarse-grained, thin-to massive-bedded, weathers orange to red, upper part coarse, with thin, interbedded siltstone and shale	18.0
Shale, olive to maroon	6.0
Sandstone, buff, fine-grained, weathers orange, lower part laminated, grades upward into massive bed	2.4
Shale, olive to yellow, thin-bedded, arenaceous. . .	3.0
Bigheart sandstone member	
Sandstone, yellow, fine-to medium-grained, massive, weathers orange	15.5
Sandstone, yellow, fine-to medium-grained, laminated, with many dark iron stain spots, weathers orange	4.5
Shale, olive, blocky	1.0
Shale, maroon.	3.5
Sandstone, cream to buff, medium-bedded, weathers to bright rust color.	4.0
Shale, maroon, blocky to fissile, overlying sandstone has channeled into shale in places.	7.0

feet

Sandstone, cream to buff, thin-to cross-bedded, with ripple marks 3.5

Barnsdall formation
Unnamed shale member
Shale, gray to maroon, fissile 2.0
Wildhorse dolomite lentil
Dolomite, light pinkish-gray to dark bluish-gray, crystalline, thin-to massive-bedded, weathers into dark platy fragments 0.2 to 0.5 feet thick 18.0
Shale, gray, not measured

43. Sec. 21, T. 22 N., R. 10 E.; from alluvium along stream in NE¼ westward to top of outlying hill.

Tallant formation
Bigheart sandstone member
Sandstone, badly eroded, not measured
Barnsdall formation
Unnamed shale member
Wildhorse dolomite lentil
Dolomite, bluish-gray, medium crystalline, thin-to massive, wavy-bedded, weathers dark 16.5
Shale, dark gray, fissile, with thin, fossiliferous, calcareous zone near middle yielding corals, crinoid stems, bryozoa, brachiopods, pelecypods, cephalopods, and gastropods 80.0
Okesa sandstone member
Sandstone, buff, medium-bedded in lower part, thin-bedded in upper part, interbedded with gray and maroon shale, percentage of shale increases upward. 26.0
Sandstone, buff, a single massive bed, weathers dark, base covered. 15.0

44. Secs. 23 and 24, T. 22 N., R. 10 E.; measured from stream near center NW¼ sec. 24 westward along Oklahoma State Highway 20 to a position near center sec. 23.

Barnsdall formation
Okesa sandstone member
Sandstone, light gray to yellow, medium-bedded, cross-bedded, with interbedded olive and maroon shale, exact base of member difficult to locate, not measured
Wann formation
Shale, maroon, gray to olive, with several thin silty and sandy zones generally less than a foot thick 22.0
Sandstone, yellow, a single bed, lower surface

	feet
reveals fucoids and trails, upper surface ripple-marked, with thin, off-white silty film on ripple marks.	0.4
Shale, covered, weathers light yellow.	2.0
Sandstone, yellow a single bed	0.7
Shale, dark gray, weathers light yellow, with several thin, silty sandstone beds.	16.0
Sandstone, dark brown, thin-to medium-bedded, with many rust colored iron spots, shale partings common near middle.	2.0
Shale, olive, arenaceous, weathers yellow.	2.5
Sandstone, creamy buff, fine-to medium-grained, one bed, weathers yellow.	0.3
Shale, dark gray, iron stained, with thin silty zones	4.0
Clem Creek sandstone member	
Sandstone, buff, fine-to medium-grained, massive, lower part weathers rust, upper part weathers light purple, resistant, forms prominent bench	29.0
Shale, gray to maroon, with thin sandstone beds, lower part covered.	6.0
Sandstone, buff, massive	9.0
Shale, gray to dark gray	12.0
Sandstone, buff, medium-to thick-bedded.	5.0
Covered, probably shale.	2.0
Sandstone, olive to yellow	2.5
Shale, gray-blue, lignitic, with iron stains	5.0
Limestone, yellow, extremely sandy, weathers into thin, rough fragments	0.5
Shale, lower part olive-green, grading upward to light gray, fissile, lignitic, iron stained, fossil plant fragments common in the lignite. .	5.0
Sandstone, yellow to gray, thin-bedded, calcareous, friable	2.0
Sandstone, buff, thin-to massive-bedded, with rust spots	13.0
Sandstone, buff, massive, with iron enriched zones .	5.0
Sandstone, yellow, a single, massive bed, base covered.	10.0

45. Sec. 30, T. 22 N., R. 10 E.; measured from stream in NE¼ NW¼ southwest to top of hill.

Vamoosa formation	
Kiheki sandstone member	
Sandstone, light buff to yellow, fine-to medium-grained, massive, cross-bedded, weathers orange, contains thin siltstone and shale beds.	23.0

	feet
Shale, gray to maroon, fissile to blocky	17.0
Sandstone, yellow to orange, fine-to coarse-grained, massive-to cross-bedded, lower surface irregular, clay pebble conglomerate in coarse sand matrix near base	10.0
Shale, maroon to greenish-gray, sandy in places, lower part covered.	40.0
Cheshawalla sandstone member	
Sandstone, buff, fine-grained, covered, may be considerably thicker than indicated	10.0
Tallant formation	
Covered, probably shale.	13.0
Sandstone, orange to yellow, massive, weathers bright rust	12.0
Covered, probably shale.	11.0
Bigheart sandstone member	
Sandstone, buff, medium-to massive-bedded, considerable iron stain present, weathers rusty yellow.	25.0
Barnsdall formation	
Unnamed shale member	
Covered, probably shale.	10.0
Wildhorse dolomite lentil	
Dolomite, pinkish-gray to dark gray, finely crystalline, weathers into characteristic dark, wavy slabs, not measured	

46. Sec. 22 and sec. 27, T. 22 N., R. 11 E.; measured from 100 yards north Oklahoma State Highway 20 in SE$\frac{1}{4}$ sec. 27 northward to SE$\frac{1}{4}$ sec. 22.

Wann formation	
Clem Creek sandstone member	
Sandstone, gray to buff, medium-grained, massive, with rust colored iron stained spots, weathers into rectangular blocks, top eroded	19.0
Sandstone, badly eroded, nonresistant.	5.5
Sandstone, light buff, massive-bedded, poorly cemented.	6.0
Covered, probably nonresistant sandstone	9.5
Sandstone, buff, thick-bedded.	4.0
Sandstone and siltstone, interbedded, thin-bedded. .	3.0
Sandstone, bright yellow, fine-to medium-bedded, thin-to medium-bedded, cross-bedded, high iron content, with thin silty zones.	14.0
Shale, gray, clayey.	4.0
Covered, probably shale.	13.0
Sandstone, buff to dark brown, fine-to medium-grained, medium-to massive-bedded, interbedded	

	feet
with thin, gray shale	27.5
Sandstone, similar to unit above, packed with molds of Triticites sp.	0.5
Shale, dark gray, blocky, with thin stringers of sandstone	44.0
Sandstone, buff, medium-grained, medium-bedded, upper surface irregular	1.5
Sandstone and shale, interbedded, thin-bedded. . . .	5.0
Shale, bluish-gray, blocky, with thin, calcareous, sandy zones	11.0
Sandstone, buff to gray, medium-grained, medium-bedded, ripple-marked, lenticular, thins to knife edge within 50 feet northward and southward.	1.5
Shale, gray, blocky.	9.5
Sandstone, dirty gray, ripple-marked	0.5
Shale, gray, blocky, with thin sandstone beds. . . .	7.5
Sandstone and shale, interbedded	6.0
Shale, olive to dark gray, blocky.	2.2
Sandstone, light rust.	1.0
Shale, dark gray, blocky, with small ironstone concretions	21.0
Sandstone, buff, with greenish tinge, fine-to medium-grained, iron stained, ripple-marked, fucoids and trails common	0.5
Shale, dark gray, clayey, poorly exposed	17.5
Sandstone, dirty buff, fine-to medium-grained, iron stained	0.5
Shale, dark gray, clayey, poorly exposed	31.0
Iola formation	
Avant limestone member	
Limestone, gray, finely crystalline, wavy-bedded, weathers light gray, not measured	

47. Sec. 24, T. 22 N., R. 11 E.; measured in road cut on Oklahoma State Highway 20 in NE¼ NW¼ SE¼ immediately west of Quapaw Creek.

Iola formation	
Avant limestone member	
Limestone, gray to pink, finely crystalline, massive, fossiliferous, weathers in white wavy layers 0.2 feet thick.	15.0
Muncie Creek shale member	
Shale, dark gray to black, blocky to fissile, with small phosphatic nodules and thin zones of oval ironstone concretions in lower part. Concretions are dark brown, and commonly have calcite filled shrinkage cracks	60.0

feet

Paola limestone member
Sandstone, dark gray, extremely calcareous, weathers dark brown 1.5
Chanute formation
Cottage Grove sandstone member
Sandstone, gray to yellow, fine-grained, thin bedded, silty, micaceous, lignitic, not resistant . . . 14.0
Thayer coal member
Coal 0.4

48. Sec. 29, T. 22 N., R. 11 E.; measured southward near ~~west~~ east section line from Oklahoma State Highway 20 to crest of hill.

Wann formation
Clem Creek sandstone member
Sandstone, orange to yellow, fine-to medium-grained, massive, cross-bedded, resistant, weathers red, forms bench, top eroded 8.0
Covered, probably shale. 27.0
Sandstone, yellow, calcareous, iron stained spots, nonresistant, forms slope 8.0
3 Sandstone, buff, iron stained spots, with several wavy, thin calcareous zones which weather readily, thus resulting in wavy appearance. . . 3.0
2 Sandstone, cream to buff, massive-bedded, rust spots common, grades upward into unit 3, resistant, forms bench 6.0
1 Shale, lower part dark gray, with thin siltstone beds, upper part covered, probably same lithology as below 160.0

49. Sec. 31, T. 22 N., R. 12 E.; measured on east end of outlying hill in the south-central part of the section.

Wann formation
Shale and sandstone, badly eroded, not measured
Iola formation
Avant limestone member
Limestone, light pink to brown, fine to medium crystalline, massive, fossiliferous, weathers to light gray, platy fragments. 9.0
Muncie Creek shale member
Shale, dark, with oval ironstone concretions 63.0
Paola limestone
Covered, probably sandy limestone, presence indicated by persimmon growth on slight bench . 2.0?
Chanute formation
Covered, probably shale. 6.0
Cottage Grove sandstone member

	feet
Sandstone, dark brown, fine-grained, lower part massive, resistant, forms bench, upper part laminated, weathers uneven	4.0
Shale, dark, clayey, not well exposed.	22.0
Dewey formation	
Limestone, yellow, marly, fossiliferous.	2.5
Shale, calcareous, dark gray	50.0
Nellie Bly formation	
Covered, slight bench indicates sandstone, not measured	

This volume is the property of the University, but the literary rights of the author are a separate property and must be respected. Passages must not be copied or closely paraphrased without the previous written consent of the author. If the reader obtains any assistance from this volume, he must give proper credit in his own work.

A library which borrows this thesis for use by its patrons is expected to secure the signature of each user.

This thesis by JOESPH BUFORD CARL has been used by the following persons, whose signatures attest their acceptance of the above restrictions.

NAME AND ADDRESS	DATE
[redacted]	