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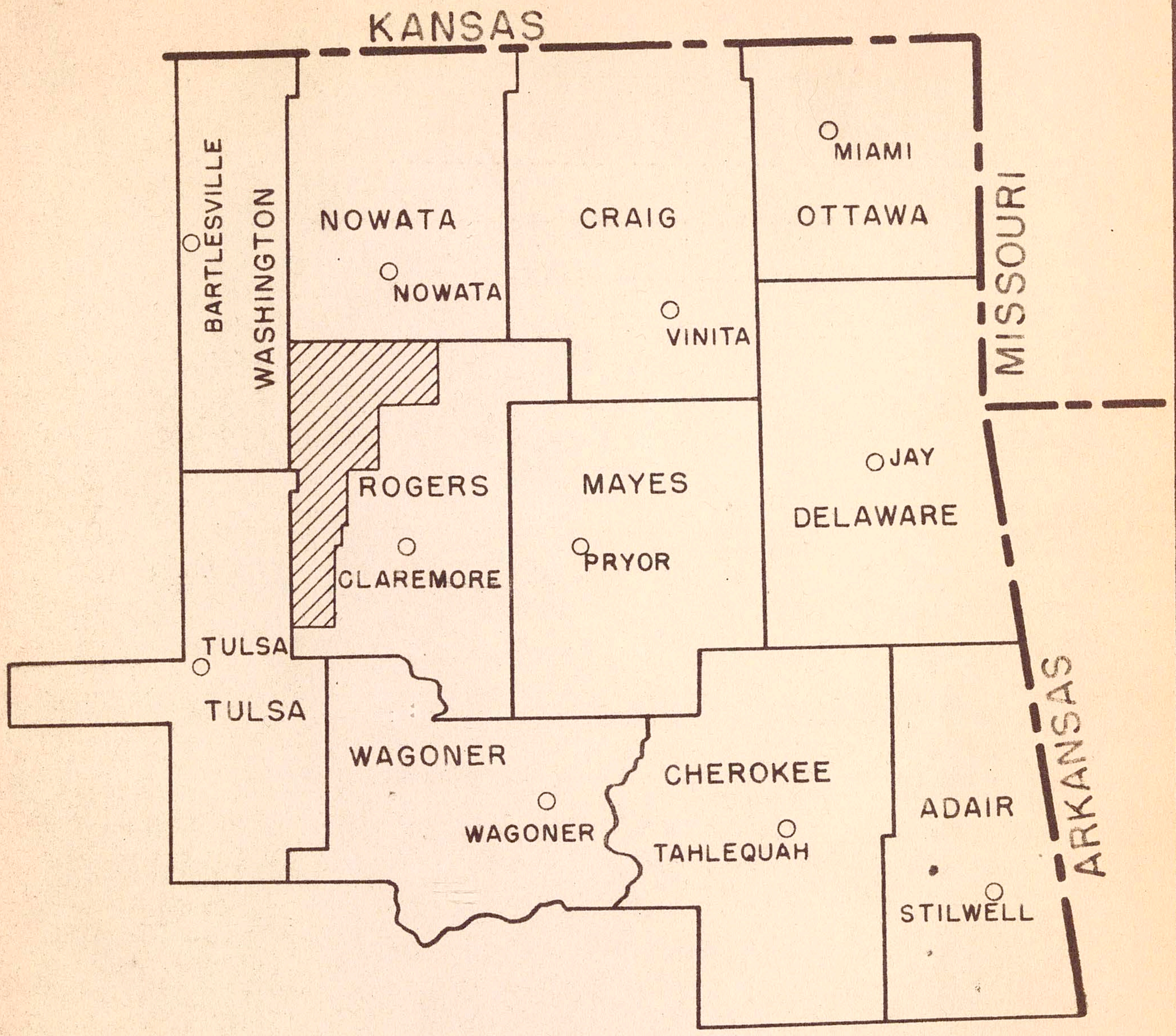

LOCATION MAP
OF
NORTHWESTERN ROGERS CO.

FIGURE I

THE GEOLOGY OF THE MARMATON GROUP OF NORTHWESTERN ROGERS COUNTY, OKLAHOMA

CHAPTER I

INTRODUCTION

Purpose and Scope of Report

The purpose of this report is to study in detail the character, thickness, and areal distribution of the formations in the Marmaton group as they occur in northwestern Rogers County. Within the area are exposures important in tracing the southern edge of the Higginsville limestone member of the Fort Scott formation, the pinch out of the Bandera shale as a mappable unit along with the possible merging of the Altamont and Pawnee limestones, the possible merging of the Anna shale into the lower part of the Oologah limestone, and in furthering the investigation of the Missouri-Des Moines contact.

Location of Area

The area covered in this thesis is in the northwestern part of Rogers County, Oklahoma (See Fig. 1). It is bounded on the north by Nowata County, and on the west by Washington and Tulsa Counties. The southern boundary is the center of T. 20 N., and the eastern boundary is essentially the Verdigris River. The area lies within Townships 20, 21, 22, 23, and 24 North, Ranges 14 and 15 East, and includes T. 24 N., R. 16 E, part of which lies east of the Verdigris River. It includes 220 square miles within these townships.

U. S. Highway 169 and Oklahoma State Highways 88 and 20 serve the area, as does the Missouri Pacific Railroad. Towns in the area include Talala in the north and Oologah in the north central parts.

Previous Investigations

The first detailed study of this area was made in 1905 and 1906 by L. L. Hutchison. His study compiled data from previous investigations and advanced the knowledge of the rocks. His results were not published but may be found in his dissertation in the University of Oklahoma Library.

The work by Ohern (1910) covering the stratigraphy of the Lower Pennsylvanian rocks of northeastern Oklahoma included the area covered by this thesis.

Ohern and Smith mapped Rogers County and adjacent areas and their maps were used in compiling the Geologic Map of Oklahoma (Miser, 1926).

Woodruff and Cooper (1928) gave a brief summary of the geology of Rogers County and included a geologic map of

Rogers County by Ohern and Smith. This map shows the general outcrop pattern of most of the formations in this study. However the outcrop of the Fort Scott limestone shown on their map more nearly defines the outcrop of the Fort Scott and Breezy Hill limestones; two units they did not differentiate because the Breezy Hill was thought to be the lower Fort Scott. Strata between the Dawson coal, above, and the Oologah formation, below, was mapped as one unit, the Nowata shale. All strata above the Dawson coal was mapped as the Coffeyville formation. The Checkerboard limestone was mapped as a member of the Coffeyville formation.

Davis (1939) mapped the base of the Checkerboard limestone as it occurs in the northwestern corner of Rogers County and the results were published by Oakes in his work on Washington County. Oakes (1952) mapped a three mile strip along the southwestern edge of Rogers County and included it in his report on Tulsa County.

Faucette (1954) and Cade (1952) mapped the Marmaton group from the northern edge of this area to the Kansas-Oklahoma line and have contributed greatly to the understanding of equivalent strata in this area. Their theses are on file at the University of Oklahoma Library.

Lohman (1952) made a detailed study of the Cabaniss group in the adjoining area to the northeast. Similar studies were made by Gruman (1954) in the adjoining area to the east and by Tillman (1952) to the southeast.

Present Investigation

Two trips were made to the area in the fall of 1953 to gain a general idea of the problems involved. All pertinent literature in the Geology Library was read and a base map drawn before the field work began.

A base map of the area at a scale of 3.10 inches per mile was constructed from aerial photographs at the same average scale. The aerial photographs were used stereoscopically in the field and in the office to trace the outcrops of the various mappable units. This was accomplished by placing acetate overlays on the photographs and tracing the outcrops onto this transparent overlay. These outcrops were then transferred to an ozalid copy of the base map and later traced onto the original base map.

Stratigraphic sections were measured with the use of a steel tape and hand level disregarding the regional dip which was calculated to be about 30 feet per mile to the westnorthwest. Good exposures of all units were found in or near the area and studied in detail.

Drillers logs were used to supply data for part of the area in T. 24 N., R. 16 E. where alluvium covers a considerable portion of the area east of the Verdigris River.

Topography and Drainage

The details of the surface features in this area are presented on the U. S. Geological Survey topographic maps of the Claremore quadrangle (1916, reprinted 1938) and Nowata quadrangle (1914, reprinted 1949). The general topography is formed by erosion of alternating resistant and less resistant strata to form gentle dip slopes and steep east facing escarpments.

The highest point in the area is about 860 feet above sea level in sec. 4, T. 21 N., R. 15 E. at the top of the cuesta formed by the Oologah formation. The lowest point is slightly less than 550 feet above sea level where the Verdigris River flows out of the southeastern corner of the area. The average elevation west of the outcrop of the Oologah formation is between 650 and 700 feet.

The Nowata shale, which overlies the Oologah formation, forms the face of a smaller escarpment which is capped by sandstones at the base of the Seminole formation.

The major stream of the area is the Verdigris River, which flows in a southwesterly direction parallel to the strike of the beds. The important streams draining the area east of the river in T. 24 N., R. 16 E. are Lightning and Spencer Creeks. The important streams in the area west of the Verdigris River include the Caney River, Talala, Four Mile, Rabb, and Bird Creeks. Tributaries to most of the above creeks and rivers are subsequent streams.

CHAPTER II

STRATIGRAPHY

Pennsylvanian strata in northern Oklahoma are divided into five series. In descending order they are: the Virgil, Missouri, Des Moines, Atoka, and Morrow series. The rocks studied in this investigation belong to the lower part of the Missouri and the upper part of the Des Moines series. They are of upper middle Pennsylvanian age.

The Missouri series in Oklahoma is divided into two groups, which are in descending order: the Ochelata and Skiatook. The lower Skiatook group, containing units included in this study, crops out in the western part of the area.

The Des Moines series includes in descending order: the Marmaton, Cabaniss, and Krebs groups. This study is principally concerned with the Marmaton, but includes a brief discussion of mapped units in the upper Cabaniss group.

Skiatook Group

The Skiatook group includes beds from the base of the Seminole formation up to the base of the Chanute formation. The lower three formations of the Skiatook group crop out in northwestern Rogers County. They are, in descending order: the Coffeyville formation, Checkerboard limestone, and Seminole formation. The upper two formations were mapped in Rogers County by Oakes in his work on Washington and parts of adjacent counties (1940), therefore this study, in so far as it is related to the Missouri series, is confined to the Seminole formation, of which the upper and lower contacts and the Dawson coal were mapped. The mapping of the upper contact of the Seminole, which is the base of the Checkerboard limestone, was taken from work by Oakes (1940, plate 1) and modified from observations by the writer.

Seminole Formation

The Seminole formation is overlain conformably by the Checkerboard limestone and has a regional unconformity at its base. The Seminole lies unconformably on formations of different age in northern Oklahoma, but in this area it rests on the eroded surface of the Nowata shale where formations younger than the Nowata shale have been removed by pre-Seminole erosion. Two formations of upper Desmoinesian age, the Holdenville shale and Lenapah limestone were eroded from this area before the deposition of the Seminole.

The Seminole formation is comprised of shales, sandstones, limestones and coal, in order of relative abundance.

In Rogers County the Seminole can be subdivided into four zones; a thin upper shaly zone lying directly below the

Checkerboard limestone; an upper sandy zone; a middle shaly zone; and a lower sandy zone resting on the eroded surface of the Nowata shale. The middle shaly zone contains the Dawson coal, which has been mined extensively in this area in the past.

First Reference: Taff, 1901.

Nomenclator: Taff, 1901.

Type Locality: NW corner of Coalgate quadrangle.

History of Usage: Taff named the Seminole formation presumably from the Seminole Nation. The Seminole was defined by Taff, and later the upper contact was designated by Morgan (1924, pp. 109-110) as the base of the DeNay limestone. The Seminole formation was shown on the old Geologic Map of Oklahoma (Miser, 1926) only as far north as the southern limit of Tulsa County. Ohern (1910) and others considered the Seminole in the area north of the Arkansas River, as being the Nowata formation. Later that portion of the Seminole above the base of the Dawson coal was placed in the Coffeyville formation, and the lower part remained in the Nowata formation and appeared as such on the old Geologic Map of Oklahoma (Miser, 1926).

Extension of the Seminole formation to include beds in northeastern Oklahoma was made by Dott (Moore, Newell, Dott, and Borden, 1937, P. 41) and the formation was defined as extending from the basal Missourian disconformity below to the base of the Checkerboard limestone above. The Checkerboard limestone is the equivalent of the DeNay limestone at the type locality of the Seminole formation.

Distribution and Thickness: The basal beds of the Seminole crop out across the western part of Rogers County from the central part of T. 21 N., R. 14 E. northward into Nowata County. The upper part of the Seminole crops out in this area only in the extreme northwestern corner of the county from the central part of T. 23 N., R. 14 E. to the NW cor. of T. 24 N., R. 15 E.

Beds below the Checkerboard limestone and its equivalent the DeNay limestone, and above the Missouri-Des Moines unconformity crop out in a northeasterly direction from Pontotoc County, across northeastern Oklahoma and into southeastern Kansas where the Checkerboard limestone becomes unidentifiable. Beds in Kansas representing the northward extension of the upper units of the Seminole are designated the Hepler sandstone.

From the latitude of Oologah southward into Tulsa County the Seminole is thicker due to the addition of beds at its base. North of Oologah the basal sand zone is overlapped by the middle shale zone and in Nowata County the Dawson coal lies within a few feet of the Lenapah limestone. In the northern part of Rogers County approximately 40 feet of the lower Seminole is lost by overlap in a distance of 10 miles.

The formation thins from about 200 feet in T. 23 N., to approximately 100 feet in T. 24 N. by overlap of the basal sandstones, which fill the irregularities on the surface of the Missouri-Des Moines unconformity and by a slight thinning of the upper units.

Lithology: The upper part of the Seminole consists of a light gray shale approximately 15 feet thick, deposited in an advancing sea prior to the deposition of the overlying Checkerboard limestone. This thin zone of shale is underlain by a thick deposit of massive and thinly bedded sandstones with a gray arenaceous shale. This upper sandy zone is approximately 60 feet thick and forms a high escarpment across the northwestern corner of the area.

The middle shaly zone is not exposed in a good outcrop in Rogers County. The lithology of this zone has been described from various strip pits in the vicinity of Collinsville, Tulsa County, and the following section is a summary from a paper on the Seminole by Jones (1941, p. 2):

	Feet
Sandstone, buff, ripple marked..................	6.0
Shale, dark blue-gray, calcareous..............	12.0
Shale, gray, platy, micaceous....................	8.0
Limestone, blue-gray, sandy, dense............	1.0
"Box slate", black, containing limy concretions..	5.0
Shale, gray, calcareous..........................	0.5
Coal, Dawson..	3.0

The Seminole beds in contact with the Nowata shale are composed of silty shale in T. 24 N., R. 15 E. and shaly and silty sandstone elsewhere. On the north line of sec. 18, T. 22 N., R. 15 E. about 6 feet above the base of the Seminole is a zone unlike any other observed in the Seminole in this area. It contains several thin stringers of coal interbedded with fine-grained, cross-bedded sandstone. This sandstone contains clay galls and land plant remains.

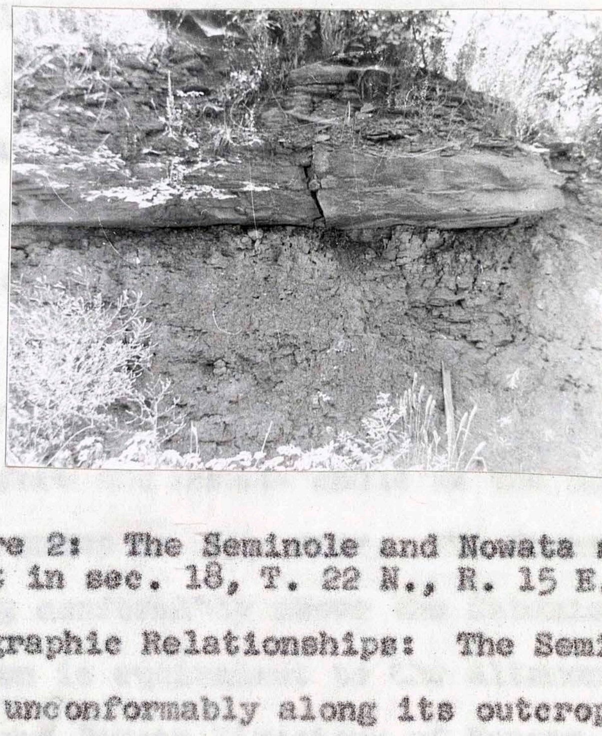

Figure 2: The Seminole and Nowata shale contact in sec. 18, T. 22 N., R. 15 E.

Stratigraphic Relationships: The Seminole overlies all older beds unconformably along its outcrop and it is conformably overlain by the Checkerboard limestone.

Correlations: The Seminole of this area is equivalent to the Seminole of the type locality. The lower part of the Seminole is overlapped in this area and the upper Seminole extends across Nowata County into Kansas. This upper Seminole is mapped in Kansas as the Hepler sandstone (Oakes, 1952, p. 54).

Marmaton Group

Strata from the base of the Fort Scott limestone to the disconformity which marks the upper limit of the Des Moines series are designated as the Marmaton group. The Marmaton contains several thick limestones and for this reason it is set apart from the underlying Cabaniss group. Most of the formations in the Marmaton are identifiable from the Arkansas River Valley of Oklahoma to Iowa and Illinois (Jewett, 1945, p. 29).

The Marmaton group contains, in descending order; the Holdenville shale, Lenapah limestone, Nowata shale, Oologah formation, Labette shale, and Fort Scott limestone. The Holdenville shale, Lenapah limestone, and part of the Nowata shale have been removed from this area by pre-Seminole erosion. Therefore the Nowata shale is the upper-most unit of the Marmaton group in this area. The Marmaton is considered as lying conformably above the Cabaniss group. The Oologah formation is equivalent to the Altamont limestone, Bandera shale, and Pawnee limestone of Kansas, where they are considered separate formations.

The Marmaton group was deposited under conditions referred to as cyclic sedimentation, which record repeated transgressions and regressions of the sea. Various types of rocks accumulated in marine and non-marine environments and the rocks deposited during one cycle are called a cyclothem. The ideal cyclic sequence consists of nine units, which in ascending order are: sandstone, sandy shale, fresh-water limestone, underclay, coal, black shale, calcareous shale, limestone, and shale (Weller, 1931, p. 163). The upper four members are typically marine and the others non-marine with the deposition of the limestone representing the culmination of the sea advance.

Greater subsidence and fewer interuptions of marine conditions in this area resulted in a general southward thickening of the Marmaton group and the included limestones, a reduction in the number of distinguishable cyclothems and the phases in each cyclothem.

Nowata Shale

The Nowata shale (Ohern, 1910, p. 23) overlies the Oologah formation, and was named from the town of Nowata, Nowata County, Oklahoma.

In Rogers County the Nowata shale consists predominantly of shale and silty shale with minor amounts of limy flagstones occurring in the northern part of the area.

First Reference: Ohern, 1910.

Nomenclator: Ohern, 1910.

Type Section:

> A complete and well-exposed section of the Nowata shale is in the SW ¼ of sec. 10, T. 27 N., R. 16 E., where a section from the Bandera shale to the Lenapah limestone was measured. This section of the Nowata is hereby designated the type section (Faucette, 1954, pp. 23-24).

History of Usage: The term Nowata shale is now used in the sense in which it was originally intended. Ohern (1910) and others for many years failed to recognize that the Lenapah was removed in the southern part of Nowata County, Rogers County, and northern Tulsa County by pre-Seminole erosion and the Lenapah limestone was erroneously correlated with the overlying Checkerboard limestone, thereby including the entire Seminole formation in the Nowata shale south of southern Nowata County. Ohern and Smith in the Geologic Map of Rogers County (Woodruff and Cooper, 1928, Plate 1), mapped the base of the Dawson coal as the southern equivalent of the Lenapah limestone, thereby including the lower half of the Seminole in the Nowata shale. The lower limit of the Seminole was correctly defined in this area in 1937 (Moore, Newell, Dott, and Borden, 1937, p. 41), thereby limiting the conception of the Nowata shale to the present one.

Distribution and Thickness: The Nowata shale is identifiable along the outcrop in northwestern Rogers County. Its range in thickness is from near 100 feet in T. 24 N. to 25 or 30 feet in sec. 15, T. 21 N., R. 14 E. South of T. 24 N. the greater part of the Nowata shale has been removed by pre-Seminole erosion.

Lithology: The Nowata is composed almost entirely of shale, containing only a minor amount of silty shale and a band of limy flagstones which occur north of the latitude of Oologah. Black shale and a silty limestone containing a molluscan fauna occur locally at the base of the Nowata shale in the central part of T. 23 N., R. 15 E.

There are several beds of limy flagstones separated by gray, calcareous shale containing a molluscan fauna. They occur near the base of the Nowata immediately west of the town of Oologah and stratigraphically higher north of the town. These flagstones grade into shale in the northern part of T. 24 N., R. 15 E. They do not occur in outcrop in Rogers County south of Oologah, but similar beds of flagstones have been described south of Bird Creek in Tulsa County and have been traced by Oakes (1952, p. 35) into the upper part of the Wewoka formation.

The Nowata shale crops out in a long narrow band and forms a topographic low between the more resistant Seminole and Oologah formations, and several small streams flow along its lower contact.

The lower sandstones of the Seminole are overlapped by the overlying shaly zone in the central part of T. 23 N., R. 15 E. and from this point to Nowata County the basal beds of the Seminole are only slightly more resistant to erosion than is the Nowata shale. In that area the Nowata shale forms an outcrop up to 2 miles in width and has a low rolling topography. The low hills are formed by limy flagstones.

Stratigraphic Relationships: The Nowata shale lies conformably above the Oologah formation, and except where removed by pre-Seminole erosion, conformably below the Lenapah limestone. From the northern part of T. 20 N., R. 14 E. northward to the southern part of Nowata County, the formations lying between the Nowata shale and the top of the Des Moines series have been removed by pre-Missourian erosion, and the Nowata shale is overlain unconformably by the basal Missouri Seminole formation.

Correlations: The Nowata shale is correlated with the upper part of the Wewoka formation south of the Arkansas River (Oakes, 1952, pp. 35-36). The name Walter Johnson sandstone (Jewett, 1941, p. 335) is applied to sandstones and siltstones occurring in the Nowata shale of Kansas and Missouri. It is correlated with the "Wayside sand" of the subsurface (Moore, Frye, Jewett, Lee, and O'Conner, 1951, p. 96).

Fossils Collected: In the west bank of Four Mile Creek in NW ¼ sec. 15, T. 23 N., R. 15 E. the following fossils were collected near the base of the Nowata shale:

<u>Paragassizocrinus</u> <u>tarri</u> (Strimple)
<u>Nuculopsis</u> <u>girtyi</u> Schenck
<u>Nuculana</u> <u>bellistriata</u> (Stevens)
<u>Amphiscapha</u> <u>catilloide</u> (Conrad)
<u>Euphemites</u> sp.
<u>Worthenia</u> <u>tabulata</u> (Conrad)
<u>Pseudorthoceras</u> <u>knoxense</u> (McChesney)
Nautiloids, 2 species
Proetid trilobite

Another collection was taken from the east bank of the South Fork of Talala Creek in the SW cor. sec. 15, T. 24 N., R. 15 E.:

<u>Lophophyllidium</u> sp.
<u>Amphiscapha catilloide</u> (Conrad)
<u>Bellerophon crassus</u> Meek and Worthen
<u>Strobeus primogenius</u> (Conrad)

Oologah Formation

The Oologah formation underlies the Nowata shale and is predominantly limestone. This formation has three members, in descending order they are: Altamont limestone, Bandera shale, and Pawnee limestone. North of T. 23 N., R. 15 E., the three units are mapped separately. South of this locality, where the Bandera shale is so thin that the three units cannot be traced, the Oologah is mapped as a single unit.

First Reference: Drake, 1897.

Nomenclator: Drake, 1897.

History of Usage: The term is now used in the sense in which it was originally intended. According to Hutchison (1907, pp. 60-66) Drake gave no detailed description of the formation nor did he map it, but in 1903 Adams mapped the formation from the Kansas line to the vicinity of Catoosa, Tulsa County and referred to it as the Oologah limestone. By 1910 the Oologah of Oklahoma was regarded as equivalent to the Altamont limestone, Bandera shale, and Pawnee limestones of Kansas (Ohern, 1910, p. 23).

On the old Geologic Map of Oklahoma (Miser, 1926) the three members were mapped as formations north of T. 23 N, T. 15 E., where the two limestones were thought to merge into one limestone, which was mapped as the Oologah limestone southward to the Arkansas River. This concept was generally held until Oakes (1952, p. 28) reverted to the original usage, and on the subsequent Geologic Map of Oklahoma (Miser, 1954) the three units, stratigraphically equivalent to the Oologah and formerly mapped as separate formations, now appear as one, the Oologah formation.

It is the belief of the writer that the Bandera shale is continuous in this area; that the usage of the member names of the Oologah formation should be extended southward as far as, and in places where, black shale is present in the upper part of the Oologah; that all black shale in the upper one-half of the Oologah in Rogers and Tulsa Counties be designated the Bandera shale member and the overlying and underlying limestones be designated the Altamont limestone member and the Pawnee limestone member respectively.

Distribution: As redefined by Oakes the Oologah formation crops out from the Arkansas River Valley northward to the Kansas-Oklahoma line, extending completely across the area of this investigation. Equivalents of the Oologah formation are identified in Kansas, Missouri, Iowa, and Illinois (Moore, 1949, p. 56).

Thickness: The Oologah formation occupies an interval ranging in thickness from about 55 feet to about 85 feet. The thickest portion is in the northern part of T. 22 N., R. 15 E., and it thins both to the north and south.

Lithology: The Oologah formation consists of dark gray to light-gray, massive and thinly-bedded, nodular limestones, which weather to a lighter color. Shale is an important component of the limestones and local lenses of fossiliferous, calcareous shale are common in the southern part of the area. Two beds of black, fissile shale, which are thicker in the northern part of the area, constitute from 5 to 20 percent of the formation. Gray nodules of chert are abundant in all exposures and on the upper weathered surface. In many localities the chert is removed prior to farming operations.

The Altamont member ranges from about 5 to 15 feet in thickness and is composed of massive to thinly-bedded, brown and blue-gray limestone. It contains dark-blue chert locally in the upper beds. The limestone constituting the Altamont member in this area is probably the upper limestone of the Altamont member in Nowata County, where it is composed of two limestones and an intervening black shale. In this study the shale and lower limestone have been considered as pinched out north of this area, between the upper limestone and underlying Bandera shale. It is possible that the black shale bed in the Altamont limestone in Nowata County is the equivalent of the shale referred to as Bandera in this area.

The Bandera shale member is a black platy to fissile shale containing numerous phosphatic concretions and at most places includes at the top a gray shale near 1 foot in thickness. The thickness of this member in T. 24 N., R 15 E. ranges from slightly more than 10 feet in the northern part, to near 5 feet in the southern part, where it becomes impossible to trace along the outcrop except at widely separated intervals. The Bandera shale is continuous across northeastern Oklahoma. In northern Nowata County this member reaches a thickness of 114 feet and is composed of minor amounts of black shale and limestone, and contains a thick widespread sandstone unit named the Bandera Quarry sandstone (Cade, 1953, p. 137). According to Jewett (1945, p. 35) a coal is present near the base of the Bandera shale in Kansas and Missouri, which is called the Mulberry coal, but it is not present in this area.

The Pawnee limestone is divided into four units, which are in descending order: Coal City limestone, Mine Creek shale, Myrick Station limestone, and Anna shale. The Anna shale is identifiable in the northern one-half of the area, but the other units, lacking distinct lithologic character, are not separated in this area.

The greater part of the Pawnee limestone is light blue-gray and weathers to a lighter gray. It is compact, finely crystalline, irregularly bedded, and appears to be nodular or brecciated on the weathered surface. It is abundantly fossiliferous, but the fossils are not well preserved except in shale lenses and along shaly partings.

The upper and lower beds of the Pawnee limestone can not be distinctly separated from the middle beds, but they are generally more evenly bedded and have a greater shale content.

Slight vertical changes in character of the Pawnee limestone are present and are best reflected by variations in the resistance to weathering. These changes appear to be cyclical in nature, but abrupt lateral changes prevent their use for correlations.

The Pawnee limestone in T. 24 N., R. 16 E. has at its base the Anna shale, which is a distinctive marker at the contact of the Labette shale and the Pawnee limestone. The upper part of the Anna shale is composed of about 10 inches of black, fissile shale overlain by about 2 inches of gray shale. Both shales contain many small, almost spherical, phosphatic concretions. In this township the Anna shale has at its base a brown, finely crystalline, silty limestone. It is about two feet thick and contains many well-preserved fossils. Composita is abundant and nearly perfect specimens can be broken out of this limestone. The color and character of this limestone is unlike any other limestone in the Pawnee

The black, fissile shale of the Anna is present in outcrop north of the Caney River. The underlying limestone is present in T. 24 N., R. 16 E., and is not present with the overlying black shale north of the Caney River in T.s 22 and 23 N., R. 15 E. South of Bird Creek in T. 20 N., R. 14 E.

Figure 3: A Biohermal buildup in the lower-middle Pawnee limestone in NW $\frac{1}{4}$ sec. 27, T. 22 N., R. 15 E.

Figure 4: A view showing the character of the lower part of the Pawnee limestone above a ledge formed by the Anna shale, and the limestone in the upper Labette shale in the SW cor. sec. 3, T. 22 N., R. 15 E.

Figure 5: Basal beds of the Pawnee limestone in sec. 9, T. 21 N., R. 15 E. The Anna shale is not present in this township.

Figure 6: The Anna shale in SW $\frac{1}{4}$ sec. 3, T. 22 N., R. 15 E.

the Pawnee limestone has a similar lithology at its base, but good exposures are lacking and definite correlations cannot be made.

Figure 7: Limestone immediately above the Anna shale in SW¼ sec. 19, T. 24 N., R. 16 E.

Along the outcrop between Bird Creek and the Caney River the shale and lower limestone of the Anna shale are not present, and the lithologic character of the basal Pawnee limestone, here, is similar to the limestones immediately overlying the Anna shale zone in the northern and southern portions of the area.

Stratigraphic Relationships: The Oologah formation conformably overlies the Labette shale, and conformably underlies the Nowata shale.

Correlations: The Oologah formation is the equivalent of three formations recognized in Kansas, Missouri, and Iowa. In descending order they are: Altamont limestone, Bandera shale, and Pawnee limestone. South of the Arkansas River equivalents of the Oologah formation lie in the middle part of the Wewoka formation (Oakes, 1952, p. 32).

Fossils Collected: The following fossils were collected from the Oologah formation near the base of the Pawnee limestone member in SW ¼ sec. 9, T. 21 N., R. 15 E:

Caninia torquia (Owen)
Lophophyllidium sp.
Chonetes granulifer Owen
Condrathyris perplexa (McChesney)
Dictyoclostus americanus Dunbar and Condra
"Marginifera" muricatina Dunbar and Condra
Mesolobus mesolobus (Norwood and Pratten)
Neospirifer dunbari King
Wellerella osagensis (Swallow)
Euphemites sp.
Trepospira sp.

From a shale lense in the upper-middle part of the formation in NC sec. 33, T. 21 N., R. 14 E. a collection was made of the following:

Composita subtilita (Hall)
Condrathyris perplexa (McChesney)
Dictyoclostus americanus Dunbar and Condra
Echinoconchus semipunctatus (Shepard)
Hustedia mormoni (Marcou)
Juresania symmetrica (McChesney)
Neospirifer cameratus (Morton)
Neospirifer dunbari King
Spirifer rockymontanus (Marcou)

Another collection from the lower part of the Pawnee limestone member in NW¼ sec. 10, T. 22 N., R. 15 E. yielded the following:

Prismopora sp.
Condrathyris perplexa (McChesney)

In SW cor. sec. 22, T. 22 N., R. 15 E. the lower Pawnee limestone member was found to contain:

Aviculopecten (*Fasciculiconcha*) *providencesis* (Cox)

From the lower part of the Pawnee limestone member in NE cor. sec. 6, T. 23 N., R. 16 E the following fossils were collected:

Cystauletes mammilosus King
Fenestrate bryozoan
Prismopora sp.
Chonetes granulifer Owen
Composita subtilita (Hall)
Condrathyris perplexa (McChesney)
Dictyoclostus americanus Dunbar and Condra
Linoproductus prattenianus (Norwood and Pratten)
"Marginifera" muricatina Dunbar and Condra
Meekella sp.
Spirifer rockymontanus Marcou
Allorisma sp.
Bellerophon sp.
Strobeus sp.
Trepospira sp.
Worthenia tabulata Conrad
Proetid trilobite

From a shale lense in the upper part of the formation in cen. sec. 33, T. 23 N., R. 15 E. the following collection was made:

Chonetes granulifer Owen
Composita subtilita (Hall)
Hustedia mormoni (Marcou)
Linoproductus prattenianus (Norwood and Pratten)
"Marginifera" muricatina Dunbar and Condra
Mesolobus mesolobus (Norwood and Pratten)
Neospirifer cameratus (Morton)
Wellerella osagensis (Swallow)
Fenestrate bryozoan

Another collection from the Pawnee limestone member in SW $\frac{1}{4}$ sec. 20, T. 23 N., R. 15 E. yielded the following:

Linoproductus prattenianus (Norwood and Pratten)

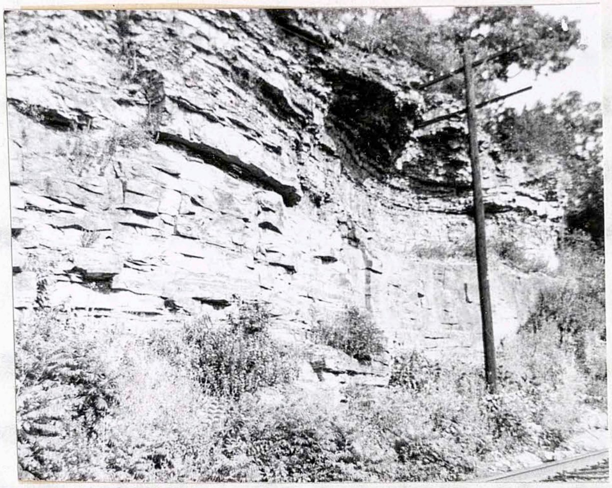

Figure 8: A view showing the relationship of the Pawnee limestone to the limestones in the upper Labette shale formation in SW ¼ sec. 3, T. 22 N., R. 15 E., where the Anna shale is present.

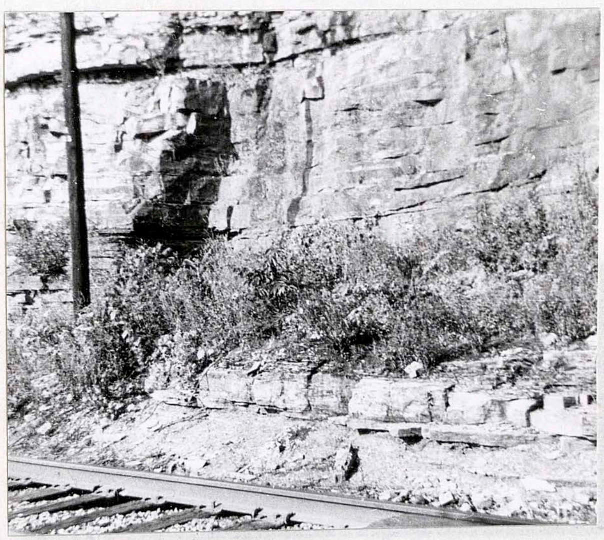

Figure 9: A view showing the lithologic character of the limestones in the upper Labette shale formation immediately below the Pawnee limestone in SW ¼ sec. 3, T. 22 N., R. 15 E.

Labette Shale

The Labette shale crops out across the area in a relatively narrow band, bounded on the west by an escarpment capped by the Oologah formation and on the east by the Verdigris River. Several outliers of Labette shale capped by the Oologah formation occur east of the river in the adjoining area.

The Labette shale includes all strata from the top of the Fort Scott limestone, below, to the base of the Oologah formation, above. It consists of, in order of relative abundance; clay shale, sandstone, shaly limestone, and silty shale. Good exposures of the formation are not uncommon although at most places slumpage of the Oologah has partially covered the outcrop.

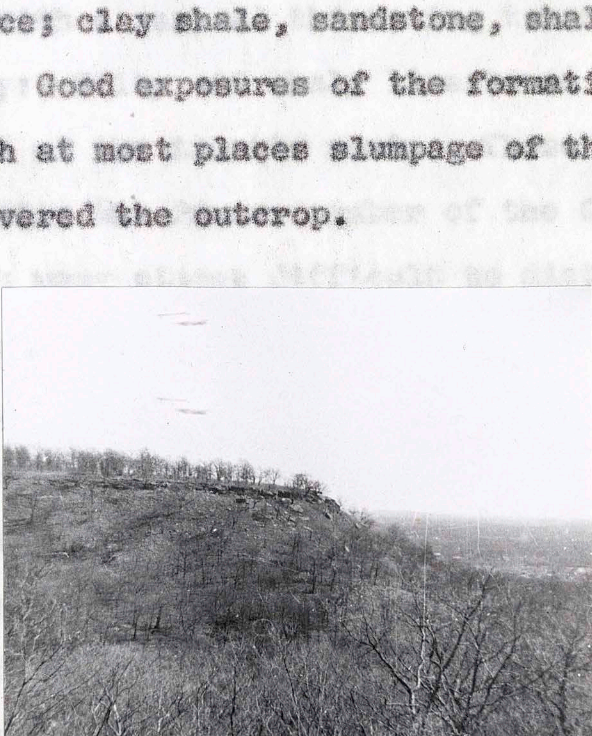

Figure 10: A view looking northeast from the SE ¼ sec. 9, T. 21 N., R. 15 E., at the east facing escarpment of the Labette shale capped by the Oologah formation.

First Reference: Swallow, 1866.

Nomenclator: Haworth, 1898.

Type Locality: Labette, Labette County, Kansas.

History of Usage: The term Labette shale has always been used as it was originally described.

Distribution and Thickness: The Labette shale is identifiable along its outcrop from northeastern Oklahoma through Kansas and Missouri and into Iowa (Moore, 1935, p. 61).

The Labette shale interval ranges in thickness from 80 to 240 feet, with a general thickening toward the south.

Lithology: Silty and shaly limestones are present in the upper part of the Labette shale. These limestones immediately underlie the Pawnee member of the Oologah formation and are at many places difficult to distinguish. They are, at places, 30 to 40 feet in thickness and are present in the outcrop south of T. 23 N., R. 15 E. They are lenticular masses and grade laterally into calcareous shales and siltstones. The locations of the best exposures of these limestones are set forth in measured section numbers 5, 6, and 7 in the Appendix.

The sandstones in the Labette shale are not continuous along the outcrop, but are of local development at all horizons in the formation. The thickest sand bodies are present in T. 24 N., R. 16 E., where the only massively bedded sandstones occur in the area, with the exception of a massive

Figure 11: A good exposure of the limestones in the Labette shale in the center of sec. 10, T. 22 N., R. 15 E.

Figure 12: A view showing the shaly character of the limestones in the Labette shale in SW ¼ sec. 10, T. 22 N., R. 15 E.

sandstone body in the lower part of the formation in T. 23 N., R. 15 E. All other sandstones in the outcrop are thin-bedded. Cross-bedding of the sandstones in this area is not common. Sandstone at many places in the northern part of the area and in a few localities in the central part of the area closely underlies the Pawnee limestone and is separated from it by 6 inches to 2 feet of gray shale.

The shale in the Labette formation is gray to tan, silty, and contains a few clay-ironstone concretions. Sandstones and silty shales are generally absent in the central part of the area and the formation is composed almost entirely of clay shale. A gradual facies change to thin-bedded sandstones and silty shales occurs to the south. Although lenses of sandstone are quite thick in the northern part of the area shale, again, is the predominant type of lithology in Nowata County.

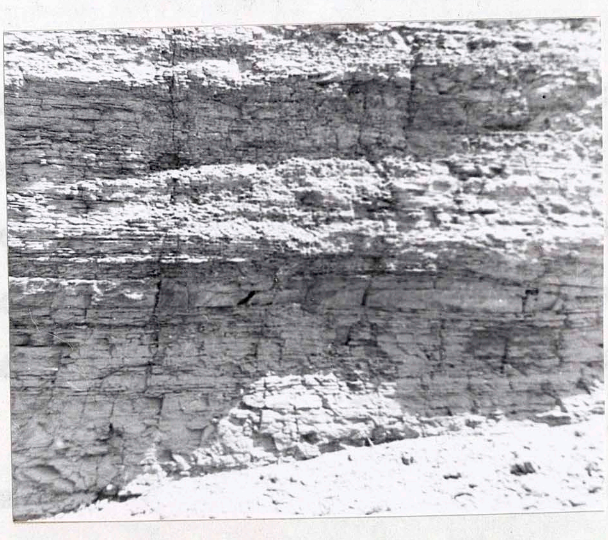

Figure 13: Silty and sandy shale in the middle portion of the Labette formation in SW ¼ sec. 25, T. 20 N., R. 14 E.

Stratigraphic Relationships: The Labette shale is conformable with the Oologah formation, above, and the Fort Scott formation, below.

Correlations: Sandstones in the Labette shale of the subsurface are referred to as the "Peru sand". Sandstones of the Labette shale, that crop out in Kansas, are collectively referred to as Warrensburg sandstone (Moore, Frye, Jewett, Lee, O'Connor, 1951, p. 97). Oakes (1952, p. 28) has correlated the Labette with the lower part of the Wewoka formation, the Wetumka shale, and the Calvin sandstone in the area south of the Arkansas River.

Fort Scott Limestone

The Fort Scott limestone formation is composed of three members, in descending order they are; Higginsville limestone, Little Osage shale, and Blackjack Creek limestone.

The upper limestone is not present in this area in outcrop, but calcareous gray shale of Higginsville age is exposed in the central and southern parts of the area. Its lithologic character in the northeastern part of the area is not known because the outcrop is obscured by the alluvium of the Verdigris River. Wells immediately west of the outcrop indicate the presence of the Higginsville as a limestone extending as far south as T. 23 N., R. 15 E.

First Reference: Swallow, 1866.

Nomenclator: Bennett, 1896

History of Usage: Swallow (1866, p. 25) first used the name to designate the upper limestone member of the Fort Scott coal series. Oakes (1952, p. 21) states that Broadhead in 1873-74 used the preoccupied name Oswego to designate beds which are in part known as the Fort Scott limestone.

The definition of the formation in current use was given by Bennett (1896, pp. 88-91), with the name of Oswego or Fort Scott limestone. Adams (1903, p. 29) dropped the term Oswego and used the name Fort Scott limestone, and this usage has been followed to the present time.

Previous to the correlation of the limestones in this area with the Fort Scott limestone of Kansas, Ohern (1910, pp. 14-16) designated strata from the base of the Verdigris limestone up to the base of the Labette shale, thereby including the Fort Scott limestone, as the "Claremore formation".

Distribution and Thickness: Driller logs of areas immediately west of the outcrop indicate that the Higginsville limestone is about 5 feet in thickness in Tps. 23 and 24 N., R. 15 E. At localities along the outcrop south of the Caney River calcareous shale of Higginsville age is the same approximate thickness. The Little Osage shale is about 7 feet thick throughout the area. The lower limestone ranges in thickness from over 25 feet in T. 24 N., R. 16 E. to about 13 feet in sec. 24, T. 20 N., R. 14 E.

Lithology: The outcrop in T. 24 N., R. 16 E. is so extensively covered with terrace material that good exposures of the Fort Scott limestone are absent. Some good exposures are present in Tps. 20 and 21 N., R. 15 E. The contacts everywhere are difficult to map because of their relation to the Labette shale and the Verdigris River. At places where the contact is not covered by alluvium it is partially obscured by soil derived from the overlying Labette shale.

The calcareous shale of Higginsville age is not well exposed, but on weathering yields an abundant assemblage of fossils. The calcareous shale grades upward into the gray-green shale of the Labette shale formation.

The Little Osage shale is black, fissile, and contains numerous phosphatic concretions, most of which are flattened parallel to the bedding. The nucleus of most of these concretions is organic.

Figure 14: The Blackjack Creek limestone in SW cor. sec. 13, T. 20 N., R. 14 E.

The Blackjack Creek limestone is at most places light gray, thin to massive, and irregularly bedded. Locally, individual beds are composed almost entirely of fusulinids or Chaetetes. The limestone is fine to coarsely crystalline and contains a few shaly partings.

Stratigraphic Relationships: The Fort Scott limestone conformably underlies the Labette shale and conformably overlies the Senora formation.

Figure 15: A view showing the lower Fort Scott limestone and its relation to the underlying Excello shale and Breezy Hill limestone of the Senora formation in SE ¼ sec. 13, T. 20 N., R. 14 E.

Correlations: The Fort Scott limestone in Oklahoma is continuous with the Fort Scott limestone of Kansas, Missouri, and Iowa. South of the Arkansas River the Fort Scott limestone grades into calcareous shale, which has been correlated with the lower part of the Calvin sandstone (Oakes, 1952, pp. 25-29)

According to Oakes (1952, p. 22) field mapping by Howe and Warren in 1951 established that the Higginsville limestone is not present in outcrop as far south as this area. Previous investigators had considered Blackjack Creek limestone as the Higginsville limestone. This resulted in erroneous correlations of all beds down to and including the Verdigris limestone.

Fossils Collected: Near the middle of the E. line of sec. 9, T. 21 N., R. 15 E. a collection of fossils from calcareous shale of Higginsville age yielded the following:

<u>Caninia</u> <u>torquia</u> (Owen)
<u>Cumminsia</u> <u>wardi</u> (Howell)
<u>Lophophyllidium</u> sp.
<u>Chonetes</u> <u>granulifer</u> Owen
<u>Condrathyris</u> <u>perplexa</u> (McChesney)
<u>Astartella</u> sp.
<u>Nuculopsis</u> <u>girtyi</u> Schneck
<u>Amphiscapha</u> <u>catilloide</u> (Conrad)
<u>Bellerophon</u> <u>crassus</u> Meek and Worthen
<u>Euphemites</u> sp.
<u>Glaphyrites</u> <u>angulatus</u> Miller and Furnish
<u>Meekospira</u> sp.
<u>Trepospira</u> sp.
<u>Worthenia</u> <u>tabulata</u> (Conrad)
<u>Mooreoceras</u> <u>normale</u> Miller, Dunbar, and Condra

A collection from phosphatic nodules in the Little Osage shale in the same locality consisted of the following:

<u>Orbiculoidea</u> <u>missouriensis</u> (Shumard)
<u>Petrodus</u>

The following fossil from the Blackjack Creek limestone was found in NW $\frac{1}{4}$ sec. 12, T. 24 N., R. 16 E:

<u>Chaetetes</u> <u>milleporaceus</u> Edwards and Haime

Another fossil from the Blackjack Creek limestone was collected in SW ¼ sec. 14, T. 24 N., R. 16 E:

Linoproductus prattenianus (Norwood and Pratten)

From the middle of the S. line of sec. 28, T. 24 N., R. 16 E. a collection from the Blackjack Creek limestone yielded the following:

Syringopora multattenuata McChesney
Dictyoclostus americanus Dunbar and Condra
Linoproductus prattenianus (Norwood and Pratten)

Cabaniss Group

The Cabaniss group as defined by Oakes (1953, p. 1525) comprises all strata above the Krebs group and below the Marmaton group. It includes in descending order: Senora formation, Stuart shale, and Thurman sandstone. The two lower formations of the Cabaniss group are overlapped by the Senora formation on the northern flank of the McAlester Basin, and in the latitude of this area the Senora lies unconformably on the eroded surface of the Boggy formation of the underlying Krebs group.

The outcrop of the Cabaniss group extends from the Arbuckle Mountains northeastward beyond the Kansas-Oklahoma line. The Cabaniss group unconformably overlies the Krebs group and is conformably overlain by the Marmaton group.

Senora Formation

The Senora formation unconformably overlies the Boggy formation of the Krebs group and conformably underlies the Fort Scott limestone of the Marmaton group. The Excello shale, Breezy Hill limestone, Lagonda, and Verdigris limestone members in the upper Senora were mapped in a relatively small area in the eastern part of T. 24 N., R. 16 E., immediately adjacent to areas in which they were mapped by Lohman (1952) and Gruman (1954). Lohman and Gruman include in their theses a thorough discussion of the members. A short description of each is given here to clarify the units as they are mapped in this study.

Figure 16: Excello shale lying between the Blackjack Creek limestone, above, and the Breezy Hill limestone, below, in SW cor. sec. 13, T. 20 N., R. 14 E.

Excello Shale: The black, fissile shale occupying the interval between the Blackjack Creek limestone member of the Fort Scott formation and Breezy Hill limestone of the Senora formation is the Excello shale member. It is uniform in thickness at about 4.5 feet, and contains many phosphatic nodules. Several of these nodules contain Glaphyrites and some have been replaced in part by pyrite. The largest concretion observed in this member contained a cephalopod about 5 inches in diameter covered by phosphatic material.

Breezy Hill Limestone: The Breezy Hill is a silty to shaly, finely crystalline, fossiliferous limestone with a thickness of about 7 feet throughout the area. It weathers to a light brown and is easily distinguished from the overlying Blackjack Creek limestone, which weathers to a lighter color.

Interval From the Breezy Hill Limestone to the Lagonda Sandstone: The Kinnison shale underlies the Breezy Hill limestone and is composed of 2 feet of gray to yellow shale. It is underlain by the Iron Post coal. This coal has been mined at a few localities by the farmers in this area. It is about 1 foot in thickness and has an underclay at its base.

The Lagonda member occupies the interval from the base of the Kinnison shale, above, to the Verdigris limestone below. Sandstone and shales of the Lagonda interval are termed Lagonda. The Lagonda sandstone will be discussed separately. The Lagonda shale, below the Iron Post coal, is gray, silty, and contains thin lenticular sandstones. The thickness of the shale is controlled by the thickness of the underlying lenticular Lagonda sandstone but it averages about 7 feet.

Figure 17: The Breezy Hill limestone lying below the Excello shale and above the Kinnison shale in SW cor. sec. 13, T. 20 N., R. 14 E.

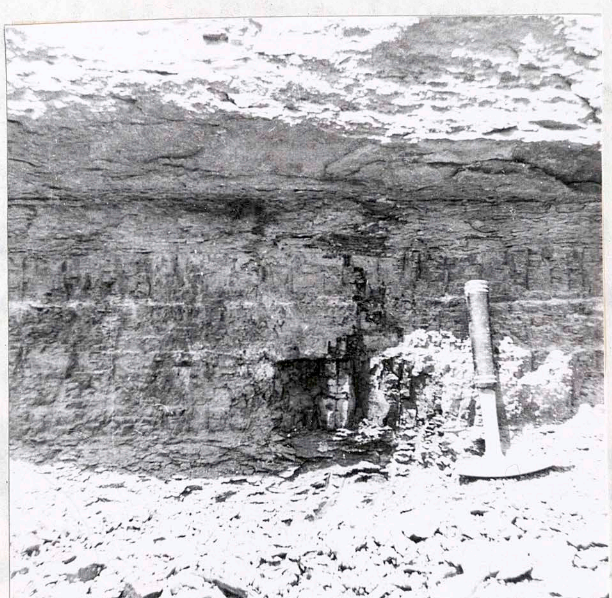

Figure 18: The Iron Post coal with a few inches of Kinnison shale lying above it in SW cor. sec. 13, T. 20 N., R. 14 E.

Lagonda Sandstone: The Lagonda sandstone is lenticular, limonitic, brown, micaceous, and fine-grained. The range in thickness is from 5 to 8 feet. This sandy zone occurs in the upper one-half of the Lagonda member in the area.

Interval From the Lagonda Sandstone to the Verdigris Limestone: This interval is about 20 feet, and it consists of light-gray, silty and micaceous shale with some lenticular sandstones near the top. This interval is the lower part of the Lagonda member.

Verdigris Limestone: The Verdigris limestone is 5 to 6 feet thick. It is a brown, silty to shaly, fossiliferous, and finely crystalline limestone, which weathers to a darker brown. The Verdigris limestone underlies the Lagonda member and is the lowest unit mapped in this study.

Fossils Collected: Fossil collected from the Excello shale in NC sec. 25, T. 24 N., R. 16 E. is:

Glaphyrites angulatus Miller and Furnish

Fossils collected from the Breezy Hill limestone in SE ¼ sec. 13, T. 24 N., R. 16 E. include:

Chonetes granulifer Owen
Condrathyris perplexa (McChesney)
"Marginifer" muricatina Dunbar and Condra

Another from the Breezy Hill limestone in NW ¼ sec. 18, T. 24 N., R. 17 E. is:

Dictyoclostus sp.

The following collection was made from the Breezy Hill limestone in NW ¼ sec. 36, T. 24 N., R. 16 E:

<u>Hustedia</u> <u>mormoni</u> (Marcou)
<u>Mesolobus</u> <u>mesolobus</u> (Norwood and Pratten)

CHAPTER III

REGIONAL GEOLOGY

Historical Geology

During Desmoinesian time this area was located on the southern edge of a moderately stable shelf, upon which thin alternating marine and non-marine deposits with wide areal distribution accumulated. Fluctuations of mean sea level caused repeated transgressions and regressions of the sea, resulting in successively repeated beds having similar lithological and paleontological characteristics. This type of sedimentation is called cyclic sedimentation and the marine and non-marine sequence of rocks deposited in one cycle is called a cyclothem. The thin stratigraphic units have wide distribution because the shelf area was essentially a flat surface and minor fluctuations of the strand line affected nearly all of the area of deposition.

South of the shelf area lay the McAlester Basin with its northern margin, during Marmaton time, along the line of the Arkansas River Valley. This basin of geosynclinal nature contains the thickest and most complete sequence of Pennsylvanian rocks in Oklahoma. Minor fluctuations in the sea level did not affect the sedimentation in the basin as markedly as on the shelf. As a result the sediments are not apparently cyclic in nature, therefore, fewer and thicker sedimentary units were deposited.

During lower Desmoinesian time the McAlester Basin subsided rapidly in response to great accumulations of sediments derived from a southern source. These sediments thin rapidly toward the shelf by overlap and convergence within units. The clastic nature of the sediments on the shelf was due in part to an over-supply of sediments to the basin that resulted in their deposition beyond the margin of the basin.

During upper Desmoinesian time the rate of supply of sediments diminished considerably and there was a corresponding decrease in the rate of subsidence of the basin. These sediments do not thin rapidly toward the shelf and the clastic sediments are confined mostly to the basin. During this time thick shale and limestone formations were deposited on the shelf area. These rocks constitute the Marmaton group, which is the more calcareous phase of the Des Moines series.

The depositional environment of the Marmaton group in this area was that of a moderately stable shelf intermediate between a more stable shelf to the north and a moderately subsiding basin to the south. The many cyclothems, which are well developed in Kansas, are fewer and less well developed in this area as a result of southward thickening and merging of the limestone phase of some of the cyclothems and southward thickening of the shale formations.

Desmoinesian time was brought to a close by a slight uplift of the shelf area, north of a northeast-southwest trending fault system in the Ozark area of Oklahoma, with the resultant withdrawal of the sea southward into the basin. This uplift was followed by erosion of Upper Marmaton beds throughout the shelf area. The Holdenville shale, Lenapah limestone and the upper part of the Nowata shale were eroded from this area.

Basal rocks of the Missourian series were deposited with the gradual encroachment of the sea onto the shelf with transgressive overlap northward over the eroded surface of the Marmaton rocks.

The deposition of the basal Missourian series was followed by a return to more stable conditions and the deposition of limestones and shales of the Skiatook group.

Structural Geology

The surface structure is a regional west-northwest dipping monocline, interrupted by structural terraces and a few small nosings on the monocline. The regional dip of 30 feet per mile is a result of uplift in the Ozark region to the east. The formations crop out in an arcuate pattern around the western flank of this Ozark uplift. The strike of the beds is generally north-northeast. The Verdigris River, except for minor adjustments to local structure, flows parallel to the strike of the beds throughout the length of this area.

Local variations in the structure are not pronounced, and reversal of dip was not noted at any locality. Subsurface domes and anticlines are generally reflected on the surface rocks by small nosings and structural terraces.

The Wisenhut anticline lies mostly in T. 22 N., R. 15 E. where it extends north and south through the center of the township. It is lower where it is crossed by the Caney River, but again rises to a prominent crest in the north central part of T. 21 N., R. 15 E. This anticline is expressed in the surface rocks as a structural terrace. The southern portion forms the highest topography in this area, and is the location of an inlier of Labette shale.

A sharp nosing on the monocline in the east central part of T. 24 N., R. 16 E. resulted in the development of an inlier of sediments from immediately below the Verdigris limestone up to the Lagonda sandstone.

A small nosing and an abundance of terrace material in sec. 15, T. 21 N., R. 14 E. has been interpreted by some to be an inlier of the Oologah formation.

A nosing is present in SW cor. T. 24 N., R. 15 E. The members of the Oologah formation have been mapped to this structure, but the interruption of the normal outcrop pattern has resulted in failure to trace these members beyond this point.

The faults in this area, which can be seen to displace the surface rocks, are small, and all are located in the eastern one-half of T. 24 N., R. 16 E. The youngest formation in this locality is the Fort Scott limestone, and it has been displaced by all of the faults.

The Wingenon School fault system is confined mostly to T. 24 N., R. 17 E. where it has been described by Lohman (1952, p. 55). The northeastern extension of this fault system enters this area in the NE ¼ sec. 13, T. 24 N., R. 16 E. At this locality the Lagonda sandstone is upthrown against the overlying Fort Scott limestone; constituting a throw of about 20 feet. It continues northwestward across section 12, but the throw diminishes rapidly in this section and it cannot be traced in the central and northern part except by alignment of drainage.

The Spencer Creek fault, discussed by Gruman (1954, pp. 64-65), is not present in this area, but several associated faults along Spencer Creek are present and are referred to here as the Spencer Creek fault system. It includes three small faults in the southeastern part of T. 24 N., R. 16 E. and the Spencer Creek fault of Gruman in T. 23 N., R. 16 E. The three faults in the area of this study are each about 1 mile in length and the strikes are northeast, northwest, and north. The northeastward striking fault is thought to branch from the northwest striking fault and to be intersected by the north striking fault. Although accurate measurements could not be made the throw of the faults are estimated to range from 10 to 25 feet. The fault planes appear to be nearly vertical, and the faults are assumed to be the normal type. Evidence for each of these faults includes; visible displacement, interruption of outcrop pattern, and alignment of streams. All except the northeast-southwest trending fault are strike faults.

Petroleum and Gas

Oil and gas development has been continuous in this area from the early nineteen hundreds to the present time. Several hundred wells have been drilled and many shallow oil and gas pools have been found. The area has produced a considerable quantity of oil over the years, but the production per well is very low.

The three principal producing horizons are the Bartlesville and Burgess sandstones and the "Mississippi lime" of drillers. The former producing mostly oil and the latter two mostly gas. The Bartlesville sandstone is the subsurface equivalent of the Bluejacket sandstone. The Burgess sandstone lies immediately above the "Mississippi lime" and is probably the basal sandstone of the Pennsylvanian system in the shelf area. The "Mississippi lime" includes all the limestones of the Mississippian system.

Oil and gas accumulations in the Bartlesville and Burgess sandstones are controlled more by permeability and

and porosity than by structure. For example the nosing described in T. 24 N., R. 16 E. does not have any noticeable effect on the accumulation of petroleum or gas in the Chelsea field.

The Wisenhut structure has produced oil and gas, but considering its size the amount has been very small. The southern end of this structure is now being actively developed and is yielding some of the best production in this area.

The Chelsea field is the oldest producing oil field in Oklahoma. The western edge of this field is in the eastern one-half of T. 24 N., R. 16 E., where production is principally from the Bartlesville sandstone at a general depth of 375 feet. Some dry gas is produced from the "Mississippi lime" at a depth of about 750 feet, but oil production from this horizon has been negligible. Most of the wells in this area are old and the production is very small. At the present time water flooding operations are being widely used to increase the recovery, and most drilling is in relation to this program.

Small pools producing oil and gas are located in every township in the area. These pools are of minor areal extent and have little production. All of the surface structures have been drilled and many have been dry.

The future development of shallow producing zones will probably be continued by independent operators. The Bartlesville sandstone is capable of production everywhere porosity and permeability is developed, without regard to structure, but the potential production of shallow wells is very low. The Arbuckle limestone and "Mississippi lime" should be further explored as they are good potential producing horizons.

Economic Deposits

Two beds of coal crop out in this area, and both have been mined at places along the outcrop. The Iron Post coal has been mined only for local use and the strip pits are of small areal extent. The coal, where it has been mined, averages about 1 foot in thickness. The Dawson coal has been commercially strip mined at several places along its outcrop. The greater part of the Dawson coal in Rogers County that was economically suitable for strip mining has been worked. The coal company that operated the mines moved its operations about five years ago and the pits are now abandoned and filled with water. It is not likely that the Dawson coal will be commercially mined in the future.

Limestone is a valuable resource and this area is fortunately endowed with an extensive deposit. The Oologah limestone in this area is not suitable for building stone, but could be useful in the making of lime, Portland cement, and rock wool. The percentage of calcium carbonate is about 95 percent at some places and selected sites of limestone may prove suitable for some chemical uses. The Oologah limestone at many places could be used for road metal and other construction projects in which crushed limestone is of value. Lack of transportation facilities is a hindrance to present exploitation of limestone in this area.

Gravel, used extensively on the country roads in this area, has, in part, been supplied from pits located in the eastern half of T. 24 N., R. 16 E. and in sec. 14, T. 21 N., R. 14 E.

Black shales from the Dawson coal strip pits and the Bandera shale are a source of phosphate for local agricultural use.

Sandstones from the outcrop of the Seminole formation have been used by local residents for ordinary building purposes.

CHAPTER IV

SUMMARY

A summary of the stratigraphic information derived from this study is as follows:

1. There is transgressive overlap at the base of the Missouri series in this area. The middle shale zone overlaps the lower sandy zone of the Seminole formation in the northern part of T. 23 N., R. 15 E., and from here northward to southern Nowata County, where the Seminole lies unconformably on the Lenapah limestone, the contact of the Seminole formation and the Nowata shale could not be accurately mapped.

2. The Lenapah limestone was not found in outcrop in this area. An outcrop of limestone in the SW ¼ sec. 33, T. 24 N., R. 15 E. previously identified as Lenapah is an outcrop of calcareous flagstones in the Nowata shale.

3. Black, fissile shale, probably equivalent to the Bandera shale, is present and has been identified in each township along the outcrop of the upper part of the Oologah formation. This shale is referred to as Bandera shale in this work. Previously the term Bandera shale has been applied only to outcrops north of T. 23 N., R. 15 E.

4. The Altamont and Pawnee limestones were previously thought to merge in the northern part of T. 23 N., R. 15 E., but this is not substantiated by field observations of the writer, although poor outcrops and a general southward thinning of the Altamont limestone and Bandera shale combine to prevent separate mapping of the Pawnee and Altamont limestones.

5. The Anna shale is pinched out between the overlying limestones of the Pawnee and the underlying Labette shale, and it is not present in outcrop between Bird Creek and the Caney River.

6. The Anna shale forms the base of the Pawnee limestone where it is present, but in the area where it is absent limestones equivalent to those immediately overlying it form the base of the Pawnee.

7. Further difficulties in identifying the base of the Pawnee limestone are encountered in T. 22 N., R. 15 E., where the Anna shale lies on a thick series of shaly limestones. It is believed that the thin limestone that at most places underlies the Anna shale is absent in this area. Here the writer has discounted the possibility of an abrupt lateral facies change in this thin limestone, and, because of the lack of distinct lithologic character of the thick limestone series, has assumed that all the limestones below the black shale are in the Labette shale formation.

8. The base of the Oologah formation is not a good

marker for subsurface studies due to the presence of thick, impure limestones in the upper Labette shale.

9. Evidence gained from driller's logs indicates that the Higginsville limestone is present in the northern part of the area, but due to its relationship with the Verdigris River the outcrop is obscured by alluvium and was not seen. Calcareous, gray shale of Higginsville age is present in outcrop in the central and southern part of the area.

BIBLIOGRAPHY

Adams, G. I., 1896, "A Geological Section from Galena to Wellington," Kansas University Geological Survey, Vol. 1, pp. 16-30.

Adams, G. I., 1903, "Stratigraphy and Paleontology of the Upper Carboniferous Rocks of Kansas," U. S. Geological Survey, Bulletin 211.

Bennett, J., 1896, The University Geological Survey of Kansas, Vol. I.

Cade, C. M. III, 1953, "Geology of the Marmaton Group of Northeastern Nowata and Northwestern Craig Counties, Oklahoma," Master of Science Thesis, University of Oklahoma.

Cade, C. M. III, 1953, "Geology of the Marmaton Group of Northeastern Nowata and Northwestern Craig Counties, Oklahoma," Tulsa Geological Society Digest, Vol. 21, pp. 130-148.

Davis, J. R., 1939, "A Field Study of the Checkerboard Limestone of Northeastern Oklahoma," Unpublished Master of Science Thesis, University of Oklahoma.

Drake, N. F., 1897, "A Geological Reconnaissance of the Coal Fields of Indian Territory," American Philosophical Society, Proceedings, Vol. 36, pp. 326-419.

Faucette, J. R., 1954, "The Geology of the Marmaton Group of Southern Nowata County, Oklahoma," Unpublished Master of Science Thesis, University of Oklahoma

Gruman, W. P., 1954, "Geology of the Foyil Area, Rogers and Mayes Counties, Oklahoma," Unpublished Master of Science Thesis, University of Oklahoma.

Haworth, E., 1898, "Stratigraphy of the Kansas Coal Measures," Kansas University Geological Survey, Vol. 3, pp. 13-105.

Hutchison, L. L., 1907, "Stratigraphy of Oklahoma North of the Parallel of Thirty-five Degrees and Thirty Minutes," Unpublished Bachelor of Arts Thesis, University of Oklahoma

Jewett, J. M., 1941, "Classification of the Marmaton Group, Pennsylvanian, in Kansas," State Geological Survey of Kansas, Bulletin 38.

Jewett, J. M., 1945, "Stratigraphy of the Marmaton Group, Pennsylvanian, in Kansas," State Geological Survey of Kansas, Bulletin 58.

Jones, D. J., 1941, "The Conodont Fauna of the Seminole Formation," University of Chicago Press.

Lohman, C., Jr., 1952, "Geology of the Whiteoak Area, Craig and Rogers Counties, Oklahoma," Unpublished Master of Science Thesis, University of Oklahoma.

Miser, Hugh D., 1926, "Geologic Map of Oklahoma," United States Geological Survey.

Miser, Hugh D., 1954, "Geologic Map of Oklahoma," Oklahoma Geological Survey and United States Geological Survey.

Moore, R. C., 1949, "Divisions of the Pennsylvanian System in Kansas," State Geological Survey of Kansas, Bulletin 83.

Moore, R. C., Frye, J. C., Jewett, J. M., Lee, W., and O'Connor, H. G., 1951, "The Kansas Rock Column," State Geological Survey of Kansas, Bulletin 89.

Moore, R. C., Newell, N. D., Dott, R. H., and Borden, J. L., 1937, "Definition and Classification of the Missouri Subseries of the Pennsylvanian Series in Northeast Oklahoma," Kansas Geological Society, Guide Book, Eleventh Annual Field Conference.

Morgan, George D., 1924, "Geology of the Stonewall Quadrangle, Oklahoma," Bureau of Geology Bulletin 2.

Oakes, M. C., 1940, "Geology and Mineral Resources of Washington County, Oklahoma," Oklahoma Geological Survey, Bulletin 62.

Oakes, M. C., 1952, "Geology and Mineral Resources of Tulsa County, Oklahoma," Oklahoma Geological Survey, Bulletin 69.

Oakes, M. C., 1953, "Krebs and Cabaniss Groups, of Pennsylvanian Age, in Oklahoma," American Association of Petroleum Geologists, Bulletin, Vol. 37, No. 6, pp. 1523-1526.

Ohern, D. W., 1910, "The Stratigraphy of the Older Pennsylvanian Rocks of Oklahoma," Oklahoma State University, Research Bulletin 4.

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

Taff, J. A., 1901, U. S. Geological Survey, Geologic Atlas, Coalgate Folio (No. 74).

Tillman, J. L., 1952, "Geology of the Tiawah Area, Rogers and Mayes Counties, Oklahoma," Unpublished Master of Science Thesis, University of Oklahoma.

Weller, J. M., 1931, "The Conception of Cyclic Sedimentation During the Pennsylvanian Period," Illinois State Geological Survey, Bulletin 60, part 5, pp. 163-177.

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

APPENDIX

MEASURED STRATIGRAPHIC SECTIONS

1. Sec. 1, T. 20 N., R. 14 E. Measured north along the west road bank, from the southeast corner of the section to the top of the hill.

		Feet
OOLOGAH FORMATION		
9	Limestone, white, massive, irregularly bedded, top eroded	15.0
8	Limestone, white, finely crystalline, contains shale partings, thinly bedded in upper part, contains chert along fractures, top covered	12.0
LABETTE SHALE		
7	Covered	6.0
6	Limestone, brown, finely crystalline, fossiliferous	1.0
5	Shale, gray, contains limonitic nodules	8.0
4	Siltstone, brown	4.0
3	Shale, covered, probably gray shale	9.0
2	Siltstone, brown, thin bedded to cross-bedded, limonitic, interbedded with shale, slightly calcareous in lower part	56.0
1	Shale, gray, lower part not measured	15.0

2. Sec. 23, T. 20 N., R. 14 E. Measured south from the creek to top of hill 0.3 miles south of the northwest corner of the section.

		Feet
OOLOGAH FORMATION		
15	Limestone, top eroded	
14	Limestone, white to light tan, fossiliferous, irregular bedded, coarsely crystalline	4.5
13	Limestone, brown, weathers darker, limonitic, coarsely crystalline	4.0
LABETTE SHALE		
12	Covered, probably gray shale	2.0

	Feet
11 Limestone, brown, white specked, coarsely crystalline....................................	0.9
10 Covered, probably shale..........................	2.0
9 Limestone, brown, finely crystalline.........	0.9
8 Shale, gray, calcareous...........................	4.0
7 Limestone, brown, coarse to finely crystalline with shaly partings, fossiliferous in lower part..................................	3.0
6 Shale, calcareous, fossiliferous..............	2.0
5 Limestone, brown, fossiliferous, lenticular..	0.3
4 Shale, gray, calcareous...........................	3.0
3 Limestone, brown, silty, fossiliferous, lenticular...	0.5
2 Shale, silty to sandy contains limestone nodules in lower part..........................	34.5
1 Shale, not measured	

3. Sec. 24, T. 20 N., R. 14 E. Measured from water level at bridge across Bird Creek westward to top of cuesta capped by Oologah limestone, in the northeastern corner of the section.

OOLOGAH FORMATION	
20 Limestone, not measured.	
LABETTE SHALE	
19 Shale and sandy shale, covered................	150.0
18 Sandstone, brown, thinly-bedded, fine to medium-grained, contains silty shale, about.	34.0
17 Shale, gray, contains limonitic nodules......	17.0
FORT SCOTT LIMESTONE	
16 Shale, light gray, calcareous, about..........	6.0
	207.0
Little Osage shale member	
15 Shale, black, fissile, contains phosphatic concretions, top eroded, about............	7.0
Blackjack Creek limestone member	
14 Limestone, brown, argillaceous, finely crystalline, sparsely fossiliferous, thinly bedded...	1.0
13 Limestone, bluish-gray, irregularly bedded, weathers to tan nodules......................	2.5
12 Limestone, gray, massive, fossiliferous, irregularly bedded, contains white fossiliferous chert, fossils well preserved.........	1.3
11 Limestone, gray, irregularly bedded, finely crystalline, contains limonite specks......	4.4
10 Limestone, gray, massive, weathers darker gray, irregularly bedded in upper part, coarsely crystalline...	4.0
	13.2

	Feet
SENORA FORMATION	
Excello shale member	
9 Shale, gray	0.6
8 Shale, black, fissile; contains phosphatic nodules, gradational with lower limestone	4.0
Breezy Hill limestone member	
7 Limestone, dark-blue, dense	1.0
6 Shale, gray, calcareous	0.6
5 Limestone, dark-brown, weathers to tan, finely crystalline matrix; contains coarsely crystalline calcite, fossiliferous	4.4
4 Limestone, gray, massive, weathers brown, finely crystalline, fossiliferous, shaly in lower part	3.0
	9.0
Kinnison shale member	
3 Shale with coal grading upward into limestone	0.3
Lagonda member	
2 Iron Post coal	1.0
1 Underclay, not measured	

4. Sec. 28, T. 20 N., R. 14 E. Measured at the Garnett Quarry near the center of the section.

	Feet
OOLOGAH FORMATION	
Altamont limestone member	
4 Limestone, gray, shaly, top eroded, about	5.0
Bandera shale member	
3 Shale, gray, fossiliferous; contains limestone nodules and phosphatic concretions	2.0
2 Shale, black, platy to fissile; contains phosphatic concretions	3.0
Pawnee limestone member	
1 Limestone, dove gray, not measured, more than	20.0
	30.0

5. Sec. 24, T. 21 N., R. 14 E. Measured north toward road from 0.2 miles south of the center of the north line of the section.

	Feet
OOLOGAH FORMATION	
3 Limestone, massive, not measured, estimated	60.0
LABETTE SHALE	
2 Limestone and interbedded siltstone, brown, thinly bedded, non-fossiliferous, medium to finely crystalline, about	40.0
1 Shale, gray, not measured	
	100.00

6. Sec. 16, T. 21 N., R. 15 E. Measured west

	Feet
from the center of the east line of the section to the top of the cuesta.	
OOLOGAH FORMATION	
7 Limestone, not measured	
6 Limestone, gray, massive, coarsely crystaline, limonitic........................	10.0
LABETTE SHALE	
5 Covered..	3.0
4 Limestone, bluish-gray, thinly bedded, silty, interbedded with calcareous siltstones and shale, partially covered, about.............	23.0
3 Covered..	132.0
FORT SCOTT LIMESTONE	
Little Osage shale member	
2 Shale, black, mostly covered, about..........	6.0
Blackjack Creek limestone member	
1 Limestone, not measured	

7. Sec. 3, T. 22 N., R. 15 E. Measured in bluff west of the railroad, in the southwest corner of the section.

OOLOGAH FORMATION	
9 Limestone, light gray, massive, forming the dip slope, top eroded, estimated thickness..	50.0
8 Limestone, white to tan, irregularly bedded in upper part, massive in lower, non-fossiliferous; contains fenestrate bryozoans and black chert......................	8.3
7 Shale, gray; contains many round phosphatic concretions..................................	0.2
6 Shale, black, fissile; contains flat phosphatic concretions......................	1.4
LABETTE SHALE	
5 Limestone, dark gray, crystalline, irregularly bedded in upper part........................	7.0
4 Limestone, brown, finely crystalline, limonitic; contains white specks...........	0.3
3 Limestone, brown, coarsely crystalline, same as below...................................	1.5
2 Limestone, brown, finely crystalline, massive to thinly bedded; contains silt and shaly streaks..	15.5
1 Covered, not measured	
	842

8. Sec. 16, T. 22 N., R. 15 E. Measured north along the center of the west line.

Feet

OOLOGAH FORMATION

6 Limestone, gray, irregular bedded, coarsely crystalline, fossiliferous; contains light brown chert in shaly zone near top, slightly siliceous, top eroded.............. 16.0

5 Covered.. 10.5

4 Limestone, dark gray, coarsely crystalline... 1.0

3 Limestone, weathers brown..................... 1.5

LABETTE SHALE

2 Shale and thin beds of dense, brown, limy flagstones, about.............................. 30.0

1 Covered, not measured

9. Sec. 32, T. 22 N., R. 15 E. Measured west along side of road in NW ¼ of section.

OOLOGAH FORMATION

13 Limestone, gray, finely crystalline, irregularly bedded in upper part, mostly covered, about.............................. 7.0

12 Covered....................................... 8.0

11 Limestone, dove-gray, thinly bedded, limonitic 5.0

10 Limestone, gray to brown, massive, porous and pitted on weathered surface................. 6.0

9 Covered.. 3.0

8 Limestone, gray, irregularly bedded; contains brown chert................................15.0

7 Limestone, gray, finely crystalline, coraline and crinoidal; contains black and brown chert and shaly partings................... 16.0

6 Limestone, brownish-gray, fossiliferous; contains opal, brown chert and plack shaly partings................................. 1.5

5 Limestone, dove gray, finely crystalline, nodular in upper part...................... 23.0

84.5

LABETTE SHALE

4 Shale, gray, calcareous...................... 4.0

3 Sandstone, fine-grained, limonitic........... 0.7

2 Siltstone and thin-bedded shaly sandstone, in part cross-bedded....................... 15.0

1 Covered, not measured

10. Sec. 28, T. 23 N., R. 15 E. Measured west from Four Mile Creek to the top of the hill 0.2 miles south of the northwest corner of the section.

SEMINOLE FORMATION

5 Sandstone, dark brown, massive, top eroded... 10.0

Feet

NOWATA SHALE

4 Shale, greenish-gray, about.................. 45.0

OOLOGAH FORMATION

3 Limestone, brown, fossiliferous, thinly bedded, not well exposed, about............ 4.0

2 Shale, black, fissile; contains phosphatic concretions.............................. 4.0

1 Limestone, white, irregularly bedded, finely crystalline, exposed........................ 12.0

11. Sec. 33, T. 23 N., R. 15 E. Measured in creek bank about 50 yards east of U. S. Highway 169, in SW $\frac{1}{4}$ of section.

OOLOGAH FORMATION

Altamont limestone member

4 Limestone, brown, fossiliferous, thinly bedded, top eroded............................ 5.0

Bandera shale member

3 Shale, gray; contains limestone nodules...... 1.5

2 Shale, black, fissile; contains phosphatic concretions.............................. 3.0

Pawnee limestone member

1 Limestone, gray, massive, not measured

12. Sec. 19, T. 24 N., R. 15 E. Measured in the creek 0.3 miles east, 0.2 miles north of the southwest corner of the section.

OOLOGAH FORMATION

7 Limestone, top eroded, exposed.............. 20.0

6 Limestone, white, finely crystalline, irregularly bedded, fossiliferous.......... 4.7

5 Shale, black, fissile; contains phosphatic concretions, about....................... 0.8

4 Limestone, bluish-gray, coarsely crystalline, weathers to light brown.................... 1.5

LABETTE SHALE

3 Covered, yellow soil, about.................. 2.0

2 Sandstone, brownish-yellow, fine-grained, limonitic, top and base covered, about..... 1.0

1 Shale, covered, not measured

13. Sec. 4, T. 24 N., R. 16 E. Measured from a draw in the SE $\frac{1}{4}$ of the section northward to the crest of the hill.

OOLOGAH FORMATION

	Feet
9 Covered, top eroded, contains; light gray, finely crystalline, hard limestone, about..	15.0
8 Limestone, tan, thinly bedded..................	7.0
7 Limestone, tan to gray, massive; contains chert nodules near top.......................	5.0
6 Limestone, gray................................	3.0
5 Covered, contains black, fissile shale........	1.0
4 Limestone, brown, fossiliferous, silty........	2.0
LABETTE SHALE	
3 Shale, gray, calcareous........................	0.6
2 Sandstone, brown, fine-grained, calcareous....	2.0
1 Shale, covered, not measured	

14. Sec. 17, T. 24 N., R. 16 E. This section, which is now mostly covered, is adapted from a section measured by Jewett (1945, p. 137) in the SE ¼ of the SE ¼.

OOLOGAH FORMATION	
11 Limestone, dove-gray, exposed.................	2.0
10 Shale, black; contains phosphatic concretions	2.0
9 Limestone, poorly exposed......................	0.3
8 Covered...	1.0
7 Limestone, dark gray, algal and crinoidal....	0.8
6 Limestone, dark dove-gray, weathers brown, granular, slightly cross-bedded...........	1.0-2.0
5 Shale, gray.....................................	0.7
4 Limestone, dove-gray, weathers brown, granular massive; contains large crinoid fragments..	1.3
3 Shale, sandy....................................	0.5
2 Limestone, sandy................................	0.3
LABETTE SHALE	
1 Shale and sandstone, exposed...................	40.0

15. Sec. 28, T. 24 N., R. 16 E. Measured in the bank of the Verdigris River north of the bridge near the center of the south line of the section.

FORT SCOTT LIMESTONE	
Blackjack Creek limestone member	
2 Limestone, bluish-brown, coarsely crystalline, irregularly bedded, shaly in lower part..................................	10.0
1 Limestone, bluish-white in upper part, white in lower part, fusulinid zone in upper part, finely crystallined, lower limestone forms the base of the river, base not exposed, measured..........................	15.0

	Feet
16. Sec. 31, T. 24 N., R. 16 E. Measured west from creek in SW ¼ of sec. 31 to top of hill in SE ¼ sec. 36, T. 24 N., R. 15 E.	
OOLOGAH FORMATION	
Altamont limestone member	
12 Covered; contains tan to blue-gray, finely crystalline, fossiliferous limestone exposed at places in the central and lower parts, about	10.0
Bandera shale member	
11 Shale, black, fissile to platy; contains phosphatic concretions; mostly covered, about	5.0
Pawnee limestone member	
10 Limestone, gray, fine to coarsely crystalline, massive, porous and pitted on weathered surface, thinly bedded in upper part	6.0
9 Covered	2.0
8 Limestone, light-gray, finely crystalline, algal, nodular and irregularly bedded, very resistant in lower part	17.0
7 Limestone, dove-gray, finely crystalline, shaly, lower beds algal and nodular; contains brown chert	11.0
6 Covered	0.6
5 Limestone, blue-gray, crystalline; contains many streaks of calcite parallel to bedding	1.5
4 Shale, mostly covered; contains black, fissile shale with phosphatic concretions	1.5
3 Limestone, brown, silty, fossiliferous	2.0
	56.6
LABETTE SHALE	
2 Covered	6.0
1 Sandstone, brown, massive, fine-grained, cross-bedded in part, exposed	35.0
17. Sec. 36, T. 24 N., R. 16 E. Measured up the hill on the south line of the southeast ¼ of the section.	
SENORA FORMATION	
Blackjack Creek limestone member	
11 Limestone, white, fossiliferous, top eroded	5.7
Excello shale member	
10 Shale, black, fissile; contains phosphatic concretions	4.0

Feet

Breezy Hill limestone member
9 Limestone, gray, weathers brown, fine to coarsely crystalline, slightly silty..... 5.6
Kinnison shale member
8 Shale, covered.................................... 2.0
Lagonda member
7 Iron Post coal.................................... 1.0
6 Underclay, about.................................. 0.3
5 Shale, interbedded with lenticular sand....... 7.3
4 Lagonda sandstone, lenticular, limonitic, micaceous, fine-grained....................... 4.0
3 Shale, buff, silty; contains thin bedded sandstone lenses, micaceous at top, base covered, about..........................19.5
Verdigris limestone member
2 Limestone, yellowish-brown, dense, finely crystalline, fossiliferous................... 6.0
Unnamed shale member
1 Shale, mostly covered, measured...............12.0

18. Sec. 31, T. 24 N., R. 17 E. Measured west along the road bank 0.1 miles south, and 0.3 miles east of the northwest corner of the section.

SENORA FORMATION
Lagonda member
5 Shale, light-gray, sandy and micaceous, not measured
Verdigris limestone member
4 Limestone, buff, weathers dark brown, fossiliferous.................................. 5.0
Unnamed shale member
3 Shale, black, fissile; contains phosphatic concretions...................................... 3.0
2 Limestone, light to dark brown, consists of loosely cemented brachiopod shells........... 0.3
1 Shale, gray, not measured

[redacted]