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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

GEOLOGY OF THE BARNSDALL AREA, OSAGE COUNTY, OKLAHOMA

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

MASTER OF SCIENCE

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BY

WILLIAM EDGAR GARDNER [redacted]

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GEOLOGY OF THE BARNSDALL AREA, OSAGE COUNTY, OKLAHOMA

A THESIS

APPROVED FOR THE SCHOOL OF GEOLOGY

BY

[redacted]

Geology

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GEOLOGY OF THE BARNSDALL AREA, OSAGE COUNTY, OKLAHOMA

CHAPTER I

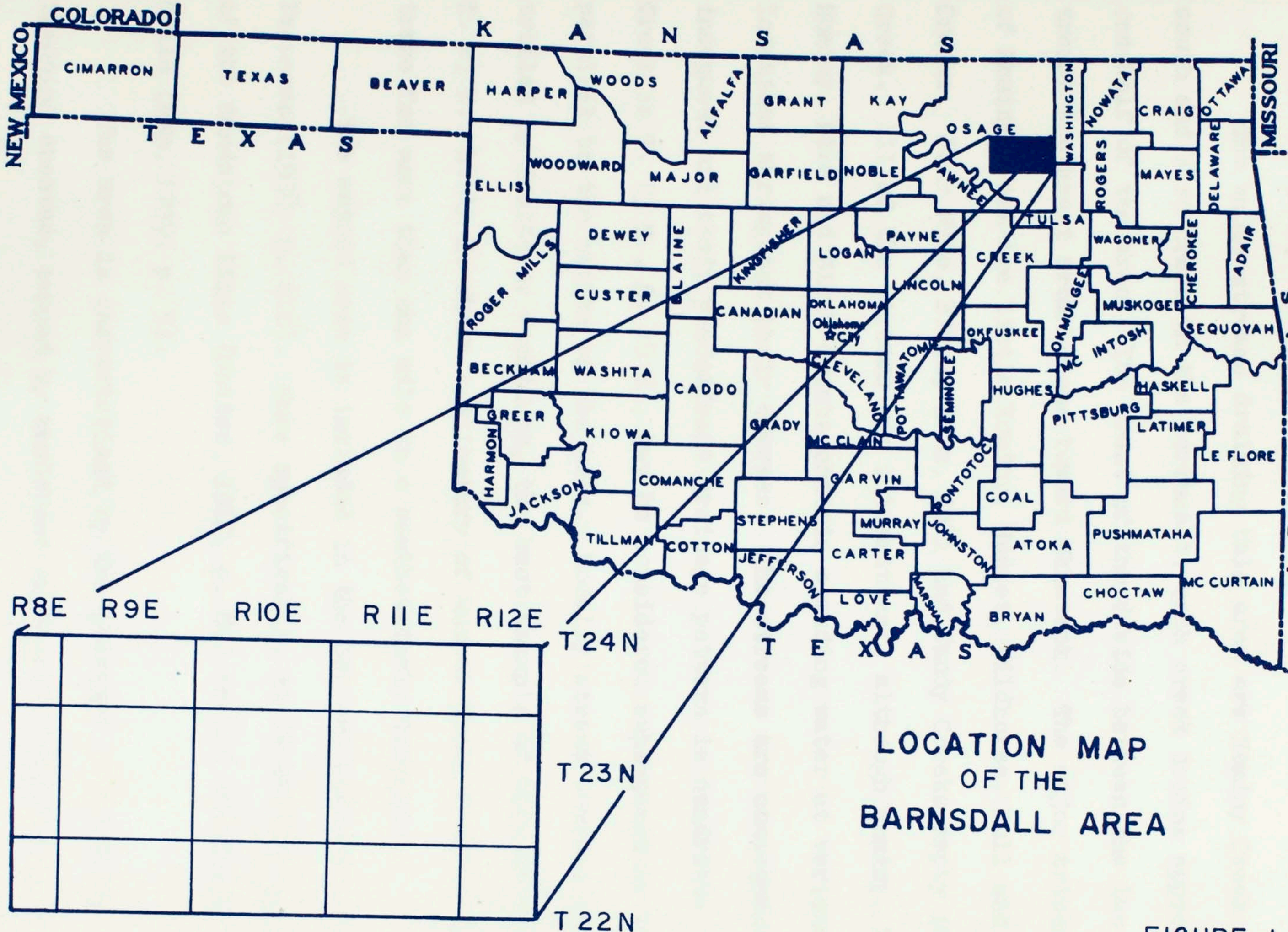
INTRODUCTION

The Barnsdall area is located in the southeastern part of Osage County. It includes the N$\frac{1}{2}$ of T. 22 N., all of T. 23 N., the S$\frac{1}{2}$ of T. 24 N., the eastern edge of R. 8 E., all of Rs. 9, 10, 11 and that portion of R. 12 E., located within Osage County. It comprises a total area of approximately 280 square miles (Fig. 1).

The Missouri, Kansas and Texas and Midland Valley Railroads serve this area. The former passes through the towns of Hominy and Wynona in the western part of the area. The latter serves Avant and Skiatook (just south of the southeastern limit of this report).

Three State Highways traverse the area. State Highway 99 runs from Hominy through Wynona toward Pawhuska, a short segment of State Highway 20 leads southeastward from Hominy toward Skiatook, and State Highway 11 connects Skiatook, Avant, Wolco and Barnsdall. Graded county roads, few of them section line roads, wind through the central two-thirds of the area.

There are four towns located within the Barnsdall area; Hominy, the largest, is located in sec. 1, T. 22 N., R. 8 E., Wynona in sec. 22,



LOCATION MAP
OF THE
BARNSDALL AREA

FIGURE 1

T. 24 N., R. 9 E., Wolco in sec. 24, T. 24 N., R. 11 E. and Avant in sec. 7, T. 23 N., R. 12 E.

The major streams draining this area are Hominy Creek in the south and Bird Creek in the northeast; each creek drains approximately one-half of the area. The crest of the divide between the two creeks trends southeast from Wynona toward Skiatook. The major tributaries of Hominy Creek are Little Hominy, Sunset, Wildhorse, Bull and Quapaw Creeks. Four Mile, Birch, Clem, Bull and Candy Creeks empty into Bird Creek. All of the streams are intermittent, although Hominy, Little Hominy, Bird and Birch Creeks contain standing water at various locations throughout their courses. The streams are consequent and insequent and their predominant drainage pattern is dendritic. Bull Creek in T. 23 N., R. 10 E., may be considered subsequent as it flows parallel to the strike of the beds. Locally stream courses are controlled by faults or fractures, the best example of this is in sec. 33, T. 23 N., R. 11 E. where a tributary of Quapaw Creek follows a fault trace for more than one mile in a southeasterly direction.

The mapped area is included in the Central Lowland province of Fenneman (1938, p. 616). More specifically, it is located in a part of the Sandstone Hills (Snider, 1917, p. 80) called the Chautauqua Hills (Ham, 1939, p. 5).

The area is characterized by the presence of southwesterly trending cuestas, capped by sandstone or massive limestone, separated by lowlands cut in thick shales. Recognition of these contrasting topographic features is facilitated both in the field and on airplane photographs, by the different types of vegetation growing on the outcrops of sandstone and shale. Blackjack and post oak (appearing dark on the photos) grow in abundance on sandstone outcrops, and bluestem grass (appearing light on the photos) covers the outcrops of shale.

The highest elevations in the area, 1,050 feet in the west and 1,003 feet in the east, coincide with that of the Pawhuska Rock Plain described by Ham (1939, pp. 28-34). The lowest elevation, 636 feet, is located along Bird Creek in sec. 10, T. 22 N., R. 12 E.

The purpose of this investigation is to map the key beds cropping out within the area from the upper part of the Nellie Bly formation to the base of the Elgin sandstone, to describe the lithology and stratigraphic relations of these units and where possible to collect and identify fossils. This investigation is one of several conducted by graduate students of the Department of Geology of the University of Oklahoma in conjunction with the Oklahoma Geological Survey in Osage and surrounding counties. It is hoped that the information contained in this report will aid in the understanding of the geology of northern Oklahoma.

The area was mapped by the stereoscopic study of airplane photographs furnished by the Oklahoma Geological Survey. Beds, faults, linears, drainage and culture were traced from the photos on to acetate overlays. After being field checked, this information was transferred to township plats, then to a base map at the same scale as that of the photos. As none of the townships is exactly standard size, their true dimensions were obtained from the Osage Indian Agency in Pawhuska, Oklahoma, and plotted to scale on the base map. Contacts were arbitrarily adjusted when necessary to compensate for abnormal distortion of some of the photos.

Stratigraphic thicknesses were measured with a hand level and six-foot steel tape. As the regional dip in the area is generally less than 40 feet per mile, it was seldom necessary to apply a correction factor to the measured sections. While in the field, contacts were checked, lithologic samples and fossils were collected and photographs were made. Insoluble residue tests were run on samples of several limestones cropping out within the area. The data obtained from these tests is incorporated into the descriptions of the various units.

The first detailed work on the geology of the rocks cropping out in parts of the Barnsdall area appears in U. S. Geol. Survey Bulletin 686. The mapping for that report was conducted in the years 1917-18 in an effort to stimulate the search for petroleum by furnishing information concerning the oil prospects in Osage County (White and others, 1922, p. X). Many key beds were mapped, but, unfortunately, few of these beds were traced for any great distance. Several of the units mapped in this thesis were named and described in the aforementioned publication.

H. T. Beckwith (1928) compiled the information presented in Bulletin 686 and combined it with data gleaned from other sources. This material appears in Oklahoma Geological Survey Bulletin 40-T.

Malcolm C. Oakes has done more than any individual to systematize the geology of southeastern Osage County. The information contained in two of his publications, Oklahoma Geological Survey Bulletins

62 and 69 was often used during the preparation of this report.

The most recent work in areas adjoining the Barnsdall area has been done by Joseph B. Carl (Carl, 1956) to the south and William F. Tanner to the north (Tanner, 1956).

Numerous sources other than those mentioned above have been used in the preparation of this report; they are listed in the Bibliography, page 75.

CHAPTER II

STRATIGRAPHY

GENERAL STATEMENT

A total thickness of 1,280 feet of Upper Pennsylvanian sediments crops out in the Barnsdall area. This sequence consists of alternating beds of shale, sandstone, siltstone and minor amounts of limestone and dolomite. A marked increase in the ratio of sandstone to shale is noticeable as beds are traced from north to south.

The Pennsylvanian rocks of this area are divided into two series, the Missouri and Virgil. These two series will be discussed separately.

MISSOURI SERIES

Keyes (1892, p. 85 and pp. 114-15) applied the term Missouri formation to the Upper Coal Measures of Iowa. Moore (1932, p. 114) raised the term to series status and defined it as those units occurring between the base of the Pedee group and the top of the Bourbon group.

The Missouri series is unconformably underlain by the Des Moines series and overlain unconformably by the Virgil series. The base of the Missouri in Oklahoma is drawn at the base of the Seminole formation. The base of the Vamoosa formation (the base of the Cheshewalla sandstone in the Barnsdall area) marks the top of the series.

In Oklahoma, the Missouri series has been divided into two groups; they are, in ascending order, the Skiatook group and the Ochelata group.

Skiatook Group

Moore and others (1937, pp. 39-43) established the term Skiatook group permanently in the literature. The group includes the strata between the base of the Missouri series and the base of the Chanute formation. Only the upper two formations of this group, the Nellie Bly and Dewey, crop out in the Barnsdall area. One hundred eight feet of Skiatook sediments have been measured. Gray calcareous shale, siltstone, sandstone and limestone are the lithologies present in this interval.

Nellie Bly Formation

Although D. W. Ohern named the Nellie Bly formation, Gould (1925, p. 74) was the first to publish the name. The formation was named for the exposures of shale and sandstone cropping out along Nellie Bly Creek in T. 24 N., R. 13 E. in southern Washington County. It has been traced south-southwestward from the vicinity of South Coffeyville, Oklahoma, to southeastern Seminole County. The Nellie Bly crops out in parts of nine sections in the southeastern corner of the Barnsdall area. A maximum thickness of 90 feet of gray-green to dark gray shale, siltstone, sandstone and lenses of limestone is exposed in the area.

Only one good exposure of this unit is located within the area. At this exposure, in the $SE\frac{1}{4}$ sec. 16, T. 22 N., R. 12 E., on the west side of the dirt road from Skiatook to Avant, the Nellie Bly consists of 86 feet of dark gray siltstone, calcareous shale and medium- to thin-bedded sandstone (Fig. 2). The sandstone is probably equal to the upper sandstone bed described by Carl (Personal communication, July, 1956), in his report on the Black Dog area. North of the locality in section 16 and along the same road, the Nellie Bly is exposed locally.

The Nellie Bly formation correlates with the lower part of the Kansas City group of Kansas and the upper half of the Francis formation of south-central Oklahoma (Oakes, 1940, pp. 50-51). It is underlain conformably by the Hogshooter limestone and overlain conformably by the Dewey formation. No fossils were found in the formation.

Dewey Formation

The Dewey was named by Ohern (1910, p. 30) for the limestone exposed in quarries of the Dewey Portland Cement Company, T. 27 N., R. 13 E., in Washington County, Oklahoma. He described the Dewey as follows:

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

It has been mapped from the vicinity of Wann, Oklahoma, T. 28 N., R. 14 E. southwestward to the North Canadian River in Okfuskee County. Its southern equivalent, the Belle City, has been traced into

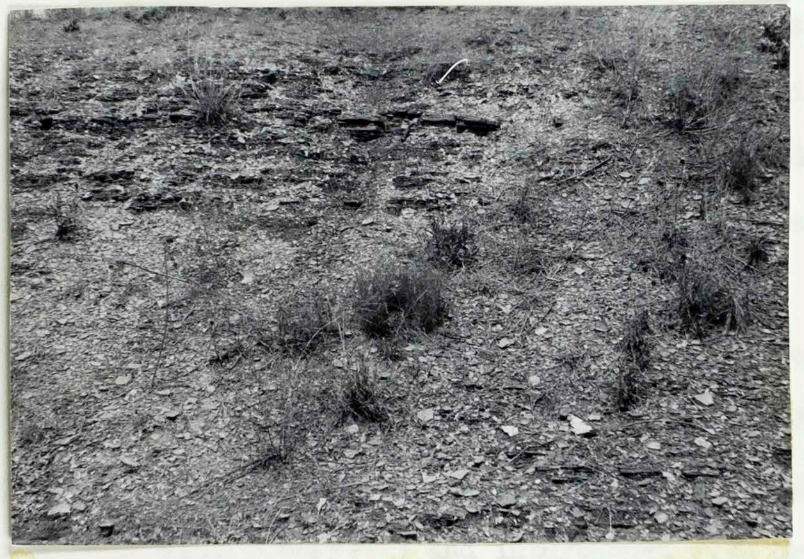


Figure 2. An exposure of the upper part of the Nellie Bly formation. SE$\frac{1}{4}$ sec. 16, T. 22 N., R. 12 E.

northern Pontotoc County.

In the Barnsdall area the Dewey forms a narrow band of outcrop extending from sec. 33, T. 23 N., R. 12 E., to the SW cor. sec. 17, T. 22 N., R. 12 E. Its thickness ranges from 20.5 feet in the NE$\frac{1}{4}$ sec. 33, T. 23 N., R. 12 E. to 14.6 feet in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 16, T. 22 N., R. 12 E. Lithologically, it consists of purple-gray to dark gray limestone and gray-green calcareous shale.

The Dewey consists of three distinct lithologic units in the Barnsdall area: a lower limestone, locally massive; a middle, calcareous shale containing interbedded limestone lenses and stringers; and a persistent upper massive limestone.

An excellent exposure of the Dewey formation is located along the road from Skiatook to Avant in the NE$\frac{1}{4}$ sec. 32, T. 23 N., R. 12 E. Here, the lower limestone is gray to purple, medium-crystalline, fossiliferous (none well preserved) and interbedded with greenish, calcareous shale; the middle shale is greenish-gray, calcareous and contains stringers and nodules of limestone; the upper limestone is gray to purple-gray, compact, iron-stained and extremely fossiliferous. Along the same road in the NE$\frac{1}{4}$ sec. 10, T. 22 N., R. 12 E., the lower limestone is covered with rubble. The middle shale is well exposed and is similar to that mentioned at the previous location. The upper limestone is 1.5 feet thick, bluish-gray and forms a slight bench around the knoll to the east of the road (Fig. 3).

An insoluble residue was made of a sample of the upper bed of the Dewey from an exposure in the NE$\frac{1}{4}$ sec. 16, T. 22 N., R. 12 E. Residue constitutes 9.3 per cent of the sample. A large part of the

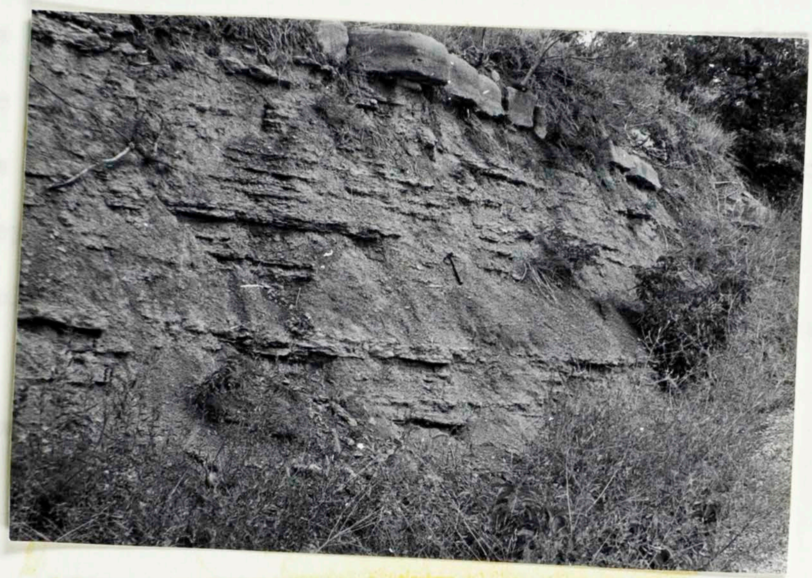


Figure 3. The best exposure of the Dewey formation in the area. Notice the limestone stringers in the shale. NW$\frac{1}{4}$ sec. 10, T. 22 N., R. 12 E.

sand-size particles consist of silicified skeletal remains of micro-organisms. No appreciable decrease in carbonate content was noted from north to south in the Barnsdall area; however, Carl (personal communication, July, 1956) noted an increase in sand content to the south in the Black Dog area.

The Dewey formation correlates with the Cement City member of the Drum limestone of Kansas (Oakes, 1940, p. 56).

The Nellie Bly formation underlies the Dewey conformably and the Chanute formation unconformably overlies it.

The following fossils were collected from various exposures of the Dewey formation:

Coelenterata
- Caninia torquia (Owen)
- Syringopora sp.

Brachiopoda
- Composita sp.
- Neospirifer sp.

Ochelata Group

The term Ochelata was first used by Ohern (Gould, 1925, p. 75) as a formation name. Moore and others (1937, pp. 39-43) redefined the term and raised it to group status. The lower boundary is set at the base of the Chanute formation and its upper limit is the base of the Virgil series. The Ochelata group consists of gray to maroon shales, thin to massive sandstones and thin to massive limestones. The thickness of this group within the Barnsdall area is approximately 810 feet.

Chanute Formation

Haworth and Kirk assigned the name Chanute to a shale and sandstone sequence exposed near Chanute, Kansas (Wilmarth, 1938, p. 399). In 1908, Haworth and Bennett restricted application of the term Chanute to include only the beds between the top of the Dewey limestone and the base of the Iola formation (Moore, 1936, pp. 109-111).

The Chanute and its equivalents crop out from the Kansas-Oklahoma line southwestward to southern Seminole County (Tanner, 1956, p. 86). Its thickness ranges from 59 feet in the NE$\frac{1}{4}$ sec. 33, T. 23 N., R. 12 E., to 40.5 feet in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 16, T. 22 N., R. 12 E. Gray-green, clayey shale, lensing sandstone (locally massive), siltstone and traces of coal compose the Chanute in the Barnsdall area.

Six members are recognized in northern Oklahoma; four of these are exposed within the area. These members are, in ascending order, a lower shale, the Thayer coal, the Cottage Grove sandstone and an upper carbonaceous shale. Only the lower shale member is really uniform in thickness and lithologic character. None of the members is mappable.

The lower shale member is well exposed in the NE$\frac{1}{4}$ sec. 33, T. 23 N., R. 12 E., and just west of the road in the NW$\frac{1}{4}$ sec. 10, T. 22 N., R. 12 E., at the top of the hill. At both locations the shale is green to dark gray, clayey and blocky. The unit grades vertically into sandstone and siltstone. A limestone and shale conglomerate occurs near the base of this shale in the NW$\frac{1}{4}$ sec. 10, T. 22 N., R. 12 E. The average thickness of the lower shale member is 20 feet.

The Thayer coal is exposed at only one location within the Barnsdall area; at the side of the farm road, near the base of the hill in the NE$\frac{1}{4}$ sec. 20, T. 23 N., R. 12 E. The term, carbonaceous shale, is more applicable to the Thayer at this exposure. It is smutty and is 0.4 feet thick (Fig. 4). South of the Barnsdall area in the first road-cut west of Skiatook, along State Highway 20, 0.4 feet of coal, probably Thayer, crops out at road level (Fig. 5).

The Cottage Grove sandstone member is inconsistent in thickness and character in the Barnsdall area, but is locally recognizable. Seven feet of yellow-buff, medium-grained, medium- to massive-bedded, iron-stained Cottage Grove sandstone is exposed in the NE$\frac{1}{4}$ sec. 20, T. 23 N., R. 12 E. Approximately 20 feet of sandstone thought to be Cottage Grove crops out along the stream in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 16, T. 22 N., R. 12 E. At this location the sandstone grades vertically from medium- to coarse-grained and from thin- to massive-bedded. Siltstone and shale are interbedded with the sandstone. At places the Cottage Grove is thin (one to two feet) and most of it is gray siltstone.

The carbonaceous shale member is poorly exposed along the old route of State Highway 11 in the NE$\frac{1}{4}$ sec. 17, T. 23 N., R. 12 E. No other outcrop of this member was found in the area.

The Chanute formation of northeastern Oklahoma is a direct correlative of the Chanute shales of southern Kansas. Its central Oklahoma equivalent is believed to be the Hilltop formation (Tanner, 1956, p. 86).

The Chanute lies unconformably upon the Dewey limestone and is overlain conformably by the Iola formation. The limestone and shale conglomerate observed in the NW$\frac{1}{4}$ sec. 10, T. 22 N., R. 12 E. may be

Figure 4. The only exposure of the Thayer coal in the Barnsdall area. NW$\frac{1}{4}$ sec. 21, T. 23 N., R. 12 E.

considered evidence, at least locally, for an unconformity at the base of the Chanute. Other than this conglomerate, no field evidence was found to substantiate the existence of a post-Dewey, pre-Chanute unconformity.

No fossils were found in this formation in the Barnsdall area.

Iola Formation

The Iola formation was named by Haworth and Kirk from the limestone exposures in the quarries near the town of Iola, Kansas (Wilmarth, 1938, p. 1017). Newell (Moore and others, 1932, p. 92) sub-divided the Iola of Kansas into three members. All of these members; the lower, Paola limestone; the middle, Muncie Creek shale and the upper, Avant limestone are present in the Barnsdall area.

This formation has been mapped from the northeast corner of Washington County southwestward to T. 15 N., R. 9 E., in Creek County. In the Barnsdall area, the Iola crops out from T. 24 N., just north of Avant, through R. 12 E. and leaves the area in sec. 13, T. 22 N., R. 11 E.

The maximum thickness of the unit in the Barnsdall area is 96 feet and the minimum thickness is 49.5 feet. Thin sandy limestone, dark gray to black shale and wavy- to massive-bedded limestone are the lithologies present in the Iola.

<u>Paola limestone member</u>. The Paola limestone member, though probably present throughout the extent of the Iola formation in the Barnsdall area, is exposed at few places. Two-tenths of a foot of the unit is exposed on the east side of the former route of State Highway

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Figure 5. An excellent exposure of the upper part of the Chanute formation (Thayer coal and Cottage Grove member) and all of the Iola formation. Along State Highway 20. NE$\frac{1}{4}$ sec. 24, T. 22 N., R. 11 E.

11 in the $NW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 17, T. 23 N., R. 12 E. Here, it is a gray, marly sandy limestone. It crops out along the road from Avant to Skiatook in the $NE\frac{1}{4}$ sec. 33, T. 23 N., R. 12 E. One to two feet of sandy, gray to yellow limestone is exposed at this location. No other outcrops were definitely identified as Paola within the Barnsdall area. Where the Paola is not represented by an outcropping limestone bed, a row of persimmon trees commonly indicates the present of the unit (Mohler, 1942, p. 8). South of the Barnsdall area in the first road-cut west of Skiatook on State Highway 20, 1.5 feet of dark gray, sandy to marly limestone, probably the Paola, crops out (Fig. 5).

<u>Muncie Creek shale member</u>. The Muncie Creek shale member, a lithologically consistant unit, is generally not well exposed. It consists of dark gray to black, fissile to blocky shale. Its thickness ranges from approximately 40 to 59 feet. Near the base, a zone of phosphatic nodules normally occurs.

The unit is exposed (poorly) in the $NW\frac{1}{4}$ $SE\frac{1}{4}$ sec. 10, T. 23 N., R. 12 E. Here, the shale is dark gray and weathers gray-green. Phosphatic nocules are present, but were not seen in place. The unit is fairly well exposed in the $SW\frac{1}{4}$ sec. 16, T. 22 N., R. 12 E. Fifty-nine feet of dark gray to black, fissile shale crops out at this location. Phosphatic nodules and ironstone concretions are abundant here. Many of them contain calcite fillings in fractures.

<u>Avant limestone member</u>. The Avant limestone, which equates to the Raytown limestone of Missouri and Kansas, was named by Ohern (1910, pp. 31-32). Its type locality is in the vicinity of Avant, Osage County, Oklahoma. This limestone is the most easily recognizable

unit in the Barnsdall area. It caps a steep escarpment all along its outcrop. A system of NW-SE and NE-SW joints is distinctly displayed on airplane photographs. It is a relatively clean limestone, containing less than 8.1 per cent insoluble residue in samples tested. The upper 5 to 10 feet of this unit are characteristically wavy-bedded (Fig. 6). This bedding is noticeable at least as far south as the Arkansas River. Tanner (1956, p. 16) attributes the formation of wavy-bedding to the scouring and winnowing action of currents in a lagoonal environment. Although the Avant is generally fossiliferous, few of the fossils are well preserved. At its maximum development, in the old Avant quarry NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 17, T. 23 N., R. 12 E., it is 53 feet thick (Fig. 7). With the exception of this one occurrence, the Avant is between 25 and 30 feet thick. Oakes (1952, p. 86) attributes the increased thickness of the Avant in the vicinity of the quarry to the incorporation of the lower limy zone of the Wann formation with the upper part of the Avant. The limestone is characteristically pinkish-gray to steel-gray, medium to coarsely crystalline and fossiliferous.

In the NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 10, T. 23 N., R. 12 E., the Avant consists of 30.5 feet of reddish-gray, medium to coarsely crystalline, massive- to wavy-bedded, fossiliferous limestone. At the Avant quarry, mentioned above, it is composed of 48 feet of massive, gray limestone overlain by 5 feet of wavy-bedded, gray, medium-crystalline limestone and yellow, calcareous, fossiliferous shale. Along the road, north of Javine School, sec. 18, T. 22 N., R. 12 E., the Avant is reddish- to purple-gray, dense to medium-crystalline and wavy-bedded. Crinoid columnals stand in relief on the weathered surfaces of the unit at this

Figure 6. Wavy-bedded Avant limestone, slope strewn with Avant rubble. Along farm road in NW$\frac{1}{4}$ sec. 21, T. 23 N., R. 12 E.

Figure 7. Thickest exposure of the Avant limestone, exposed at the Avant quarry. SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 17, T. 23 N., R. 12 E.

location.

To the south in the Black Dog area, the Avant splits into an upper and lower limestone separated by a sandstone bed (Carl, personal communication, July 1956).

The Iola formation of the Barnsdall area is a direct correlative of the Iola of Kansas. It lies conformably upon the Chanute formation and is, in turn, conformably overlain by the Wann formation.

The following fossils were collected at the Avant quarry in sec. 17, T. 23 N., R. 12 E.

Bryozoa
- Fenestrellina sp.
- Polypora sp.
- Unidentified encrusting forms

Coelenterata
- Lophophyllidium coniforme Jeffords
- Thamnopora carbonaria (Mather)

Brachiopoda
- Composita subtilita (Hall)
- Derbyia crassa (Meek and Hayden)
- "Dictyoclostus" sp.
- Linoproductus sp.
- Meekella striatocostata (Cox)
- Schuchertella pratteni (McChesney)

Pelecypoda
- Nuculopsis girtyi Schenck

Gastropoda
- Trepospira depressa (Cox)
- Worthenia tabulata (Conrad)

Crinoidea
- Columnals

Wann Formation

Ohern (1910, p. 28) proposed the term Wann formation:

> ...for a series of shales, sandstones and limestones which

> occupy the interval between the top of the Curl formation [Coffeyville] and that of the Stanton limestone....It is composed of three members, the Hogshooter limestone member, the Copan member [Nellie Bly and Dewey] and the Stanton limestone member [Birch Creek].

The name fell into disuse until Oakes (1940, p. 74) resurrected it and redefined its limits. The term now applies:

> ...to all strata 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 erosions.

The type locality for this formation is in the area just west of the town of Wann in northwest Nowata County, Oklahoma. It has been mapped from the Kansas-Oklahoma line southward to south-central Creek County, where it is truncated by the Barnsdall formation.

A band of outcrop 6 to 8 miles wide is occupied by the Wann in the Barnsdall area. No measured sections containing the complete thickness of this unit could be obtained within the area; therefore, it was necessary to resort to composite sections to determine full thicknesses. The Wann is about 250 feet thick in T. 24 N., and approximately 305 feet thick in T. 22 N.

The lithologic character of the Wann is quite varied. In T. 24 N., and the N$\frac{1}{2}$ T. 23 N., the Wann consists of dark gray to gray-green shales, gray to red limestone, limy sandstones and buff, thin- to medium-bedded sandstones. The percentage of limestone decreases rapidly to the south where extremely lenticular thin to massive sandstones and gray shales occupy the limestone intervals. An excellent exposure of some of the previously-mentioned sandstones is located along the road from Avant to Skiatook in the NW$\frac{1}{4}$ sec. 33, T. 23 N.,

R. 12 E. The sandstones range from thin- to massive-bedded and are generally medium-grained. Several of the beds are fossiliferous. Brachiopods and casts of Triticites sp. are the most abundant fossils.

Oakes (1940, pp. 75-80) zoned the Wann on the basis of lithology. The zones, in ascending order, are as follows: (1) dark clay shale, (2) dark shale and thin, platy limestone, (3) calcareous, fossiliferous shale and limestones, (4) sandstone and shale. This zonation does not apply south of the N$\frac{1}{2}$ T. 23 N., for the limestones die out and are replaced by sandstones, shales and siltstones.

The most persistent lithologies in the Wann of the Barnsdall area are a basal dark gray, blocky shale with locally thin to massive sandstones, and a similar shale at the top of the formation. The units within the Wann formation that will be discussed are the basal shale, the "Fusulina-bearing" limestone, the Red limestone, the Clem Creek sandstone member and the upper shale.

The basal shale of the Wann formation has been inspected at several locations. Characteristically, this unit consists of dark gray to gray-green, blocky shale. Near the upper limit of the shale, siltstone and medium-bedded sandstones are commonly interbedded with the shale. A complete thickness of this unit, 67 feet, is exposed along the road from Avant to Skiatook in the NW$\frac{1}{4}$ sec. 33, T. 23 N., R. 12 E. Just south of Avant, along the same road in the SW$\frac{1}{4}$ sec. 7, T. 23 N., R. 12 E., the full thickness of the basal shale is well exposed. The thickest exposure of the bed near the Barnsdall area is in sec. 27, T. 22 N., R. 11 E. At this location 138 feet of gray-green, blocky shale crops out. Fifteen to twenty feet of this interval consists of thin sandstones and siltstones.

Thin limestone, limy sandstone, siltstone and medium- to massive-bedded sandstone crop out above the basal shale in T. 24 N. Two of the limestones included within this interval were mapped by geologists of the United States Geological Survey in 1917-18.

Hopkins and Powers (White and others, 1922, p. 238) described the lower of these units, the "Fusulina-bearing" limestone, as follows:

> It is a gray to yellow, thin-bedded to platy limestone from 2 to 4 feet thick. Its upper surface is covered with large Fusulina [Triticites sp.] , which have much the shape and size of wheat grains, and its lower surface shows many Productus and fragments of crinoid stems.

Along the road leading north from Avant toward Wolco in the E½ sec. 6, T. 23 N., R. 12 E., 0.7 feet of purple-gray, medium-crystalline limestone covered with fusulinids, is exposed. This bed crops out on the side of the hill in the NW¼ SE¼ sec. 10, T. 23 N., R. 12 E. Only the upper surface, packed with fusulinids, is well exposed. The results of an insoluble residue test performed on a sample of this limestone taken from an exposure on Birch Creek dome in the NE¼ sec. 29, T. 24 N., R. 11 E., indicate that this limestone is rather sandy; 12.9 per cent of the sample consists of sand-sized particles, 11.1 per cent consists of clay-sized particles, and 76 per cent consists of carbonate.

A limestone found along the road in the NE¼ sec. 32, T. 23 N., R. 12 E. may possibly be the "Fusulina-bearing" limestone.

The Red limestone crops out in approximately the same area as the "Fusulina-bearing" limestone, but does not extend as far south. Hopkins and Powers (White and others, 1922, p. 238) made the following comments concerning the Red limestone:

> ...above the top of the Fusulina-bearing limestone, is the base of another limestone, which because of its large content of iron usually weathers red on exposed surfaces. It is at most places a massive red or reddish-brown sandy limestone...

The most continuous exposure of this bed is along the south side of the Midland Valley Railroad in secs. 10 and 11, T. 23 N., R. 11 E. The characteristic rusty red color is prominent here. It is sandy and locally fossiliferous along this exposure. North of Avant in the road cut in the NE$\frac{1}{4}$ sec. 6, T. 23 N., R. 12 E., the Red limestone occurs in two benches separated by gray shale. It is reddish-gray, medium-crystalline, fossiliferous and weathers red to rusty-gray.

Despite their local prominence, neither the "Fusulina-bearing" limestone, nor the Red limestone were mapped, because of their limited areal extent.

<u>Clem Creek sandstone member</u>. From zero to 20 feet above the Red limestone, a complex sequence of sandstone, shale and siltstone crops out. This sequence was named the Clem Creek sandstone by Emery (White and others, 1922, p. 3). He described the Clem Creek as:

> ...a series of massive, medium-grained sandstones and thin lenticular shales aggregating 60 to 65 feet in thickness and exposed along Clem Creek in the northwest part of T. 23 N., R. 11 E. This formation is limited below by the Red limestone...its upper limit is the top of a massive bed of sandstone 18 feet thick, which is marked by a line of woods at the base of a grass covered prairie, developed on the overlying shale.

This is the only sandstone unit in the Wann formation with any degree of lateral continuity. The tracing of this member was difficult because of its rapidly changing character. As the Red limestone which defines the lower limit of this unit does not extend farther south than sec. 11, T. 23 N., R. 11 E., the determination of the base of the Clem Creek is uncertain. For this reason, the base of the Clem Creek sandstone has been mapped with a dashed line (Plate I). Its thickness ranges from 15 to 20 feet in T. 24 N., Rs. 11 and 12 E., (Fig. 8) to 65 feet at the type locality to 29 feet along State Highway 20 in T. 22 N., R. 10 E. This unit cannot be recognized by lithologic character. The presence of the overlying gray shale is the only criterion for identifying the Clem Creek where the Red limestone is absent.

In the cut along the Midland Valley Railroad in sec. 11, T. 23 N., R. 11 E., the basal beds of the Clem Creek are exposed. Thirty feet of thin- to massive-bedded, buff to red, fine- to medium-grained, cross-bedded sandstone interbedded with lenses of gray shale and siltstones are exposed in this cut (Fig. 9). Contorted bedding in the thinner sandstone beds is common here. Just south of the previous location, along the road to Avant in the southern half of the same section, a complete thickness (65 feet) of the unit is exposed. The upper massive bed described by Emery is exposed along Clem Creek in the NE$\frac{1}{4}$ sec. 8, T. 23 N., R. 11 E.

The exposures of this member in the southern half of T. 23 N., R. 11 E. are poor. In this area, as many as three benches as as few as one bench seem to constitute the Clem Creek. A 19-foot sequence of maroon to gray shale and massive-bedded, medium-grained, iron-stained sandstone is exposed along the north-south road in the SE$\frac{1}{4}$ sec. 22, T. 22 N., R. 11 E. The full thickness of the unit in this general area

Figure 8. Sandstones of the Clem Creek member of the Wann formation exposed in road cut just north of Avant. NE$\frac{1}{4}$ sec. 6, T. 23 N., R. 12 E.

Figure 9. The lower part of the Clem Creek member near the type locality. Near the west line sec. 11, T. 23 N., R. 11 E.

is approximately 25 feet. Carl (personal communication, July, 1956) has measured 29 feet of buff, massive-bedded Clem Creek in the road cut along State Highway 20 in the NE$\frac{1}{4}$ sec. 23, T. 22 N., R. 10 E.

The occurrence of a thin limestone above the Clem Creek was mentioned by Hopkins and Powers (White and others, 1922, p. 239). This bed may be examined on the west side of the dirt road from Avant to Wolco in the SW$\frac{1}{4}$ sec. 30, T. 24 N., R. 12 E.

The upper shale of the Wann formation is easily recognized by the development of an extensive grass-covered prairie on its surface in Tps. 22, 23, and 24 N., R. 10 E. Lithologically, it is a gray to dark gray-green, locally maroon, shale. Its thickness ranges from 72 feet in sec. 25, T. 24 N., R. 11 E., to 50 feet in T. 22 N., R. 11 E. Sandstone, locally massive, and siltstone beds occur within the shale. To the south in Tps. 23 and 22 N., Rs. 10 and 11 E., the percentage of sandstone increases. The development of these sandstones renders the mapping of the base of the overlying Barnsdall formation (Okesa sandstone member) a difficult task.

The Wann formation, as redefined by Oakes (1940, p. 80) corresponds to that part of the South Kansas section above the Iola formation and below the uppermost member of the Stanton limestone, probably the South Bend limestone member.

The Wann rests conformably upon the Iola formation and is overlain conformably by the Torpedo sandstone, where present, or unconformably by the base of the Barnsdall formation where the Torpedo sandstone has been removed by pre-Birch Creek erosion (Oakes, 1940, p. 80).

The following fossils were collected from exposures of the Wann formation:

Protozoa
 Triticites sp.

Bryozoa
 Polypora magna Mather

Brachiopoda
 Derbyia crassa (Meek and Hayden)
 Linoproductus sp.
 Marginifera sp.

Pelecypoda
 Myalina glossodoidea Newell

Barnsdall Formation

Oakes (1951, pp. 119-120) applied the name Barnsdall to the sequence of limy sandstone, sandstone and shales occurring above the Wann formation or the Torpedo sandstone, where present, and below the base of the Bigheart sandstone member of the Tallant formation. This formation is typically exposed in the vicinity of Barnsdall (formerly Bigheart), sec. 18, T. 24 N., R. 11 E. The Barnsdall formation was originally described as follows:

> At the state line, the Barnsdall consists of Birch Creek limestone at the base and two unnamed shale members that are separated by inconspicuous unnamed sandy limestone less than 2 feet thick. Southward this unnamed sandy limestone grades into sandstone continuous with the Okesa sandstone member. Farther south the Okesa is much thicker, at the expense of the two shale members, and includes as its basal bed, limy sandstone that is equivalent to the Birch Creek limestone.

The formation extends from the Kansas-Oklahoma line southwestward into Seminole County (Tanner, 1956, p. 84). In the Barnsdall area, the formation trends in a southwesterly direction from the NE$\frac{1}{4}$

T. 24 N., R. 11 E., through T. 23 N., R. 10 E., to the N$\frac{1}{2}$ T. 22 N., R. 10 E.

Its thickness ranges from 111 feet in the NW$\frac{1}{4}$ sec. 30 and the SW$\frac{1}{4}$ sec. 19, T. 24 N., R. 11 E., to 137 feet in the SE$\frac{1}{4}$ sec. 27, T. 23 N., R. 10 E. South of the Barnsdall area in T. 22 N., R. 10 E., Carl (Personal communication, July, 1956) measured a thickness of approximately 170 feet.

The Barnsdall is composed of lenticular, massive- to thin-bedded, fine- to coarse-grained sandstones; laminar to thin-bedded, light gray siltstones; gray to maroon, blocky shales (locally fossiliferous); and minor amounts of dolomite and sandy limestone.

Birch Creek limestone member. This limestone was named by Bowen (White and others, 1922, pp. 17-18) for its excellent exposures along Birch Creek in T. 24 N., R. 10 E. The original description is as follows:

> It is a hard light-gray crystalline, somewhat dolomitic limestone and is sparingly fossiliferous. It contains a considerable percentage of iron, which gives it an unusually high specific gravity and produces a deep rusty-brown color on the weathered surface. Laterally it grades into limy sandstone.

The application of the term limestone to this unit is misleading. Generally the unit contains over 50 per cent sand. A sample from an exposure just south of Wolco in the NE$\frac{1}{4}$ sec. 25, T. 24 N., R. 11 E. contains 76 per cent insoluble residue, most of which is sand.

Greene (1918, p. 121) mentioned a limestone, the Bull Creek, exposed in T. 23 N., R. 11 E.; this unit is undoubtedly the same as the Birch Creek limestone.

In the $NW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 17, T. 24 N., R. 11 E., just east of the bridge over Bird Creek, the Birch Creek consists of 2.5 feet of rusty-red, slabby, limy sandstone. Numerous casts and molds of brachiopods occur in the unit at this point. At the intersection of the north-south road and the east-west road along the south line of the $SW\frac{1}{4}$ sec. 21, T. 24 N., R. 11 E., the Birch Creek is characteristically rusty to dark maroon, fossiliferous and high in sand content. Molds and casts again are common. The best exposure in the area is in the railroad cut in the $SW\frac{1}{4}$ sec. 20, T. 24 N., R. 11 E. Here, the Birch Creek is 5 feet thick, dark red on weathered surfaces and grades from sandy limestone at the base into limy sandstone at the top (Fig. 10). South of sec. 5, T. 23 N., R. 11 E., the Birch Creek limestone loses its identity and becomes a locally limy to dolomitic phase of the Okesa sandstone member. This carbonate phase is best developed in the $SW\frac{1}{4}$ $SW\frac{1}{4}$ $SE\frac{1}{4}$ sec. 34, T. 23 N., R. 10 E. where 6 feet of dolomite is exposed. It grades vertically from a rusty gray, arenaceous dolomite into a light gray medium to coarsely crystalline dolomite similar to the Wildhorse dolomite that crops out one-half mile west of this location.

Carl (personal communication, July, 1956) has observed a limy zone near the base of the Okesa member along State Highway 20 in T. 22 N., R. 10 E. The absence of the Birch Creek in the southern half of the area renders the base of the Barnsdall formation indefinite, as the sandstones developed in the upper shale of the Wann formation closely resemble those of the Okesa member of the Barnsdall formation.

Okesa sandstone member. This member was named for the town of

Figure 10. Thickest occurrence of the Birch Creek limestone in the area. Exposed in cut along the Midland Valley Railroad. SW$\frac{1}{4}$ sec. 20, T. 24 N., R. 11 E.

Okesa in T. 26 N., R. 11 E. by Clark (White and others, 1922, p. 95). In the type locality, the Okesa is separated from the Birch Creek member by a thick unnamed shale. In the northern part of the Barnsdall area the intervening shale is less than 6 feet thick and in T. 23 N., it disappears entirely.

The lithologic character of the Okesa varies markedly from place to place. In general, it is a complex sequence of lensing, buff to rusty buff, thin- to massive-bedded sandstones, light gray siltstones and gray to maroon shales. Locally a limy to dolomitic phase equivalent to the Birch Creek limestone, occurs near the base of the Okesa. From the S$\frac{1}{2}$ T. 23 N., R. 11 E., southward, the sands and shales of the member form the base of the Barnsdall formation.

Exposures of the Okesa sandstone are numerous along State Highway 11, between the village of Wolco and the town of Barnsdall. The sandstones along this road are light to rusty buff, medium-grained and generally medium-bedded. Molds and casts of brachiopods are locally common in the lower beds of the Okesa in this area. Ten feet of buff to rusty, massive-bedded Okesa is exposed in the creek bed near the cen. sec. 14, T. 23 N., R. 10 E. More than 15 feet of the lower part of the Okesa caps the hill in the SW$\frac{1}{4}$ sec. 9, T. 23 N., R. 11 E. The sandstone exposed here is buff to orange-buff, medium- to coarse-grained, thin- to medium-bedded and is commonly contorted.

A sequence of alternating massive- to medium-bedded, medium- to coarse-grained sandstone and maroon to gray blocky shales, 49 feet thick, is exposed in the NW$\frac{1}{4}$ sec. 30 and the SW$\frac{1}{4}$ sec. 19, T. 24 N., R. 11 E. Along the county road leading to Barnsdall, on the E. line of sec. 6, T. 23 N., R. 11 E., 51 feet of Okesa is exposed. The sandstone ranges from buff to brownish, thin- to massive-bedded, fine- to medium-grained. Approximately 30 per cent of this outcrop consists of maroon shale and light gray siltstone. The NE-SW trending road passing through secs. 13, 24, and 23, T. 23 N., R. 10 E., cuts in and out of the Okesa member for a distance of 2½ miles. The sandstones, shales and siltstones of the member are well exposed in numerous places along this road. Several outliers of Okesa are situated in secs. 26 and 35, T. 23 N., R. 10 E. The lithology of the member, on these outliers is essentially the same as that described at previous locations.

Were it not for the consistent character of the overlying unnamed shale member and the shaly nature of the underlying Wann formation, the Okesa would be extremely difficult to distinguish.

Unnamed shale member.* Above the Okesa is the most persistent member of the Barnsdall formation. It is a dark gray, fissile to blocky shale. At places, thin limestones occur within this shale; one of these limestone beds is exposed in the road cut along State Highway 20 near the S. line sec. 16, T. 22 N., R. 10 E. Fossil collecting is excellent at this location.

The shale is 67 feet thick in the cen. sec. 14, T. 23 N., R. 10 E., 87 feet (including the Wildhorse dolomite lentil) at the SE cor., sec. 33, T. 23 N., R. 10 E. and thickens to a maximum of 100 feet in T. 22 N., R. 10 E.

In the SW¼ sec. 18, T. 24 N., R. 10 E., along the road leading west from Barnsdall more than 60 feet of the unnamed shale member are exposed. Here it is dark gray and weathers gray-green. No calcareous

* Same shale as top p. 34 (Okesa mis-correlated!)

zones are present in this exposure.

The unit is well exposed in the SW$\frac{1}{4}$ sec. 34, T. 23 N., R. 10 E. Here, it consists of gray-green to dark gray, blocky shale. Thin calcareous zones, locally fossiliferous are included within the shale at this location.

The best exposure of the unnamed shale, by far, is the previously-mentioned road cut along State Highway 20.

Wildhorse dolomite lentil. Included in the upper part of the unnamed shale member of the Barnsdall formation is the Wildhorse dolomite lentil. Its thickness ranges from 0.1 feet at the S. line of the SW$\frac{1}{4}$ sec. 22, T. 23 N., R. 10 E., to approximately 20 feet in the SW$\frac{1}{4}$ sec. 6, T. 22 N., R. 10 E. The unit extends from the first location mentioned above to sec. 18, T. 21 N., R. 10 E., where it grades into one of the calcareous zones of the unnamed shale member (Carl, personal communication, July, 1956). The Wildhorse dolomite is the most distinctive unit cropping out west of the Avant limestone. Where well exposed, it forms a steep escarpment. Wavy-bedding, like that of the Avant limestone, is characteristic of the Wildhorse. Where fully developed, the unit is nearly pure dolomite, containing less than 2 per cent insoluble residue.

At its northernmost exposure, in the SW$\frac{1}{4}$ sec. 22 and in the NW$\frac{1}{4}$ sec. 27, T. 23 N., R. 10 E., the Wildhorse is represented by a thin zone of cream-colored, limy nodules. These nodules are relatively impure, containing 25.4 per cent clay and silt size particles and 4 per cent sand size particles. From this location, southward, the Wildhorse rapidly increases in thickness.

Twelve feet of wavy-bedded, medium-crystalline, pinkish-gray Wildhorse caps the small outlier in the SE¼ sec. 27, T. 23 N., R. 10 E. Approximately 20 feet of Wildhorse is exposed in the bed of Hominy Creek in sec. 6, T. 22 N., R. 10 E. At this location the color of the weathered surface is rusty-red; generally it is brownish-gray. The bed caps most of the hills in the SW¼ T. 22 N., R. 10 E., (Fig. 11). In this locality, wavy bedding is prominent and the unit commonly breaks into large rectangular blocks, that litter the slopes of the hills.

The Birch Creek limestone probably is equal to the South Bend limestone of Kansas; the rest of the Barnsdall formation correlates with the lower part of the Weston shale of southern Kansas (Oakes, 1952, p. 92). The south-central Oklahoma equivalent of this formation is the Hilltop formation (Tanner, 1956, p. 84).

The Barnsdall rests conformably upon the Torpedo sandstone where present and unconformably on the Wann formation where the Torpedo has been removed by pre-Birch Creek erosion. It is conformably overlain by the Bigheart member of the Tallant formation.

The following fossils found in the Barnsdall formation have been identified:

Bryozoa
- Encrusting forms

Coelenterata
- Lophophyllidium coniforme Jeffords

Brachiopoda
- Derbyia crassa (Meek and Hayden)
- Orbiculoidea missouriensis (Shumard)

Pelecypoda
- Myalina glossodoidea Newell
- Nuculana bellistriata (Stevens)

Figure 11. Low hills capped by the Wildhorse dolomite. SW$\frac{1}{4}$ sec. 16, T. 22 N., R. 10 E.

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

Scaphopoda
Dentalium sp.

Cephalopoda
Pseudorthoceras knoxense (McChesney)

Tallant Formation

Oakes (1951, pp. 121-22) applied the name Tallant formation to those rocks above the Barnsdall formation and below the base of the Vamoosa formation (the Cheshewalla sandstone being its base). According to Oakes the Tallant:

> ...consists of sandstone and shale. In Osage County, the only area in which Tallant rocks have been much scrutinized, 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.

The beds of the Tallant and part of the overlying Vamoosa formation were formerly included in the Nelagoney formation of Ohern (Gould, 1925, p. 75).

The Tallant formation extends from the Kansas-Oklahoma border, in a strip only a few miles wide, southward into northwestern Okfuskee County, where it is truncated by the overlying Vamoosa formation. Within the Barnsdall area, the Tallant forms a band of outcrop 2 to 3 miles wide in Tps. 22, 23 and 24 N., Rs. 9 and 10 E. A definite thinning of the Tallant section occurs from north to south. In T. 24 N., R. 10 E., it is 230 feet thick and in T. 22 N., R. 10 E., it is between 80 and 100 feet thick (Fig. 12).

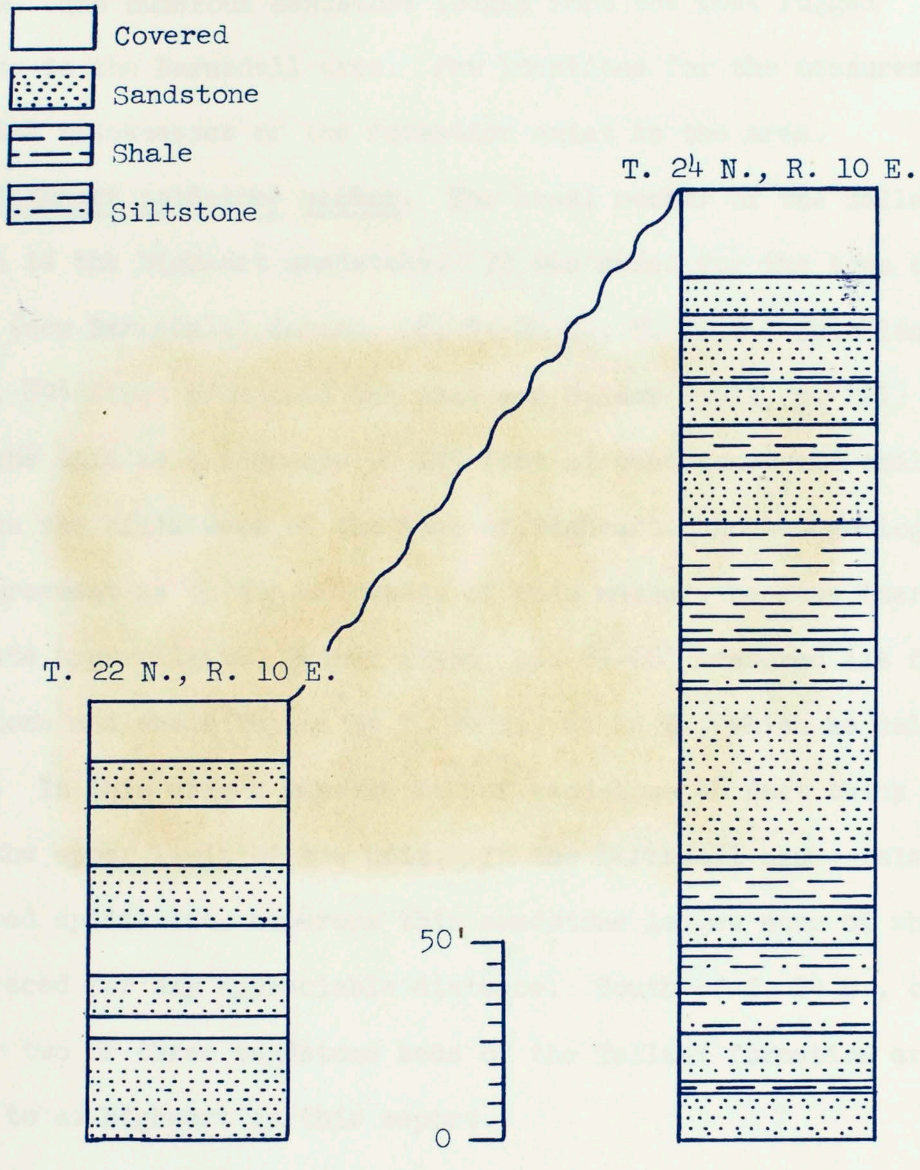

Figure 12. Columnar sections of the Tallant formation illustrating the N-S thinning of the unit beneath the Missouri-Virgil unconformity.

The Tallant formation consists of alternating massive- to thin-bedded sandstone and maroon to gray shales with minor amounts of siltstone. The numerous sandstone ledges form the most rugged topography in the Barnsdall area. Few locations for the measurement of accurate thicknesses of the formation exist in the area.

Bigheart sandstone member. The basal member of the Tallant formation is the Bigheart sandstone. It was named for the town of Bigheart (now Barnsdall) in sec. 18, T. 24 N., R. 11 E. Hutchison (1907, p. 89) first mentioned the name and Snider (1911, p. 221) defined the unit as a sequence of 175 feet of sandstones and shales exposed in the hills west of the town of Bigheart. No two geologists are in agreement as to the thickness of this member, because there is no definite upper limit. Tanner (1956, pp. 65-66) measured 114 feet of sandstone and shale in the N½ T. 24 N., R. 10 E., which he called Bigheart. In this area a massive bed of sandstone 48 feet thick is used as the upper limit of the unit. In the Barnsdall area, this massive bed splits into numerous thin sandstone ledges none of which can be traced for any appreciable distance. South of T. 24 N., only the lower two or three sandstone beds of the Tallant formation are referred to as Bigheart in this report.

One hundred and six feet of Bigheart is exposed near the cen. sec. 22, T. 24 N., R. 10 E. It is composed of thin to massive, fine- to medium-grained, buff to gray-buff sandstones with interbedded maroon, blocky shales and light gray siltstones. The upper massive sandstone is 45 feet thick at this location.

The Bigheart sandstone member consists of 50 feet of thin- to massive-bedded, contorted, buff to rusty buff, medium- to coarse-grained sandstone, interbedded with maroon blocky shale in secs. 14 and 11, T. 23 N., R. 10 E. South-southeast of this location in the $N\frac{1}{2}$ sec. 23, T. 23 N., R. 10 E., two prominent Bigheart-capped outliers are situated. Only remnants of the basal bed crop out here. From 15 to 20 feet of massive, medium-grained, buff to rusty buff Bigheart sandstone is exposed just north of the main road in the $NE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 25, T. 23 N., R. 10 E. A complete thickness of the unit crops out along the small stream in the $NE\frac{1}{4}$ sec. 32, T. 23 N., R. 10 E. Here, it is composed of a lower massive bed 30 feet thick and 18 feet of thin sandstone and maroon shale. An excellent exposure of this lower massive bed may be observed in the road cut in the $SW\frac{1}{4}$ $SW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 34, and the $SE\frac{1}{4}$ $SE\frac{1}{4}$ $SE\frac{1}{4}$ sec. 33, T. 23 N., R. 10 E. In this cut, 24 feet of massive- to medium-bedded, buff, medium- to coarse-grained, contorted and cross-bedded sandstone is exposed (Fig. 13).

Just north of Hominy Creek in the $SW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 6, T. 23 N., R. 10 E., the Bigheart member consists of a lower massive bed 23 feet thick and a sequence of sandstones and shales 15.5 feet thick.

South of the Barnsdall area in the region mapped by Carl (personal communication, July, 1956) the Bigheart ranges from 20 to 30 feet thick.

Revard sandstone member. Tanner (1956, Plate I) mapped the Revard sandstone member to the southern border of his area in the vicinity of Birch Creek (T. 24 N., R. 10 E.). This bed can be traced a short distance into the Barnsdall area with assurance. South of T. 24 N., R. 10 E., this member splits into thin sandstone lenses.

Figure 13. Basal bed of the Bigheart sandstone, notice contorted bedding at the pick handle. SE$\frac{1}{4}$ SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 33, T. 23 N., R. 10 E.

None of these sandstone lenses could be traced to the south successfully; therefore, the unit was not mapped. The Revard member is mentioned in only one measured section, where its existence is fairly well substantiated. At this location, cen. sec. 22, T. 24 N., R. 10 E., the Revard is 22 feet thick and consists of alternating light buff, medium-grained sandstone and maroon shale. That part of the Tallant formation occupied by the Revard sandstone in the north is probably missing in the south part of the Barnsdall area due to the thinning of the formation beneath the Missouri-Virgil unconformity.

The Tallant formation is a correlative of the upper part of the Weston shale of southern Kansas (Oakes, 1952, p. 95). It may possibly correlate with a part of the Hilltop formation of Seminole County (Tanner, 1956, p. 86).

The Barnsdall formation underlies the Tallant conformably and the Vamoosa formation overlies it unconformably. No visible evidence for an unconformity was noted in the field, but the pronounced thinning of the Tallant from north to south seems to confirm the existence of one.

VIRGIL SERIES

The Virgil series of the Pennsylvanian system was named for the rocks exposed in the vicinity of Virgil, Kansas, by Moore (1936, p. 96). In Kansas the base of the Virgil is drawn at the base of the Tonganoxie sandstone. The Oklahoma equivalent of the Tonganoxie is believed to be the base of the Vamoosa formation, the Cheshewalla sandstone being its basal member in northern Oklahoma (Oakes, 1952, p. 93).

The rocks of Virgil age in the Barnsdall area attain a maximum thickness of 445 feet. Most of this thickness consists of shale, though sandstone is common in the lower 75 feet of the series.

The Virgil series of Kansas and northern Oklahoma has been divided into three groups which, in ascending order, are the Douglas, Shawnee and Wabaunsee (Moore, and others, 1951, pp. 55-73). The terminology of the subdivisions of the Virgil series in northern Oklahoma is somewhat complicated. Group names that were established to divide the cyclical, carbonate rich, shallow marine deposits of Kansas, and formation names applied to the clastic, basinal deposits of central and south-central Oklahoma have been extended into northern Oklahoma. The beds here have some of the characteristics of each area; therefore, it is impossible to dispense with the use of either set of terms. For the purposes of this report, the group names, Douglas and Shawnee, will be considered together. As the formational name, Vamoosa, refers to the equivalents of these two groups, all the members of the Douglas and Shawnee groups will be considered as members of the Vamoosa formation.

Douglas and Shawnee Groups

The Douglas group was named by Haworth (1898, p. 93), for a sequence of shale, limestone and sandstone displayed in Douglas County, Kansas. Moore (1936, p. 93) redefined the limits of the Douglas group to include the rocks present in the interval between the Virgil-Missouri unconformity and the base of the Oread limestone. In the Barnsdall area, the rocks from the base of the Cheshewalla sandstone member to the base of the Oread limestone member or to the base of the Kanwaka shale where the Oread is missing, are considered Douglas equivalents.

Haworth also named the Shawnee group (1898, p. 93). As redefined by Moore (1932, pp. 93-94), it includes the beds from the base of the Oread limestone to the top of the Topeka limestone. The only beds of Shawnee age in the Barnsdall area are the Oread, Kanwaka and Elgin members of the Vamoosa formation.

Vamoosa Formation

Morgan (1921, pp. 125-28) named this formation after the town of Vamoosa, Seminole County, Oklahoma. It was described as follows: "It consists in large part of chert conglomerate, of massive, coarse, red and brown sandstone and red shales".

The Vamoosa extends southwestward from the Oklahoma-Kansas line to northern Pontotoc County. It covers the western one-third of the Barnsdall area. Here, it averages 445 feet thick and consists of sandstones, gray-green to maroon shales and minor amounts of thin limestone in the lower 160 feet of its outcrop. The remaining part of the formation contains a large percentage of shale, both maroon and gray, and a small percentage of sandstone. Some limy siltstone occurs in the $N\frac{1}{2}$ of the area.

<u>Cheshewalla sandstone member</u>. Moore, and others (1937, p. 38) correlated the Bigheart sandstone with the base of the Virgil series of Kansas. Oakes (1950, p. 67) revised the Missouri-Virgil boundary of northern Oklahoma, placing the base of the Virgil series at the base of the Cheshewalla sandstone. Oakes (1952, p. 93) made the following

comments concerning the Cheshewalla:

> The Tonganoxie equivalents in Oklahoma are the Cheshewalla sandstone of north Osage County, Oklahoma, the Cheshewalla of the type locality, in the vicinity of Tallant, Osage County and the conglomeratic sandstone beds in the lower part of the Vamoosa formation in the area north of the Arbuckle Mountains.

Although coarse sands and local clay-pebble conglomerates occur at or near the base of the Cheshewalla no evidence of an unconformable relationship between it and the underlying Tallant formation was found other than the north to south thinning of the Tallant.

Winchester, Heald and others (White and others, 1922, p. 61) gave the name Cheshewalla sandstone to the first heavy bed of massive sandstone below the Labadie limestone in T. 25 N., R. 10 E. The type locality for this member is along Cheshewalla Creek in sec. 9, T. 25 N., R. 10 E.

In the Barnsdall area it averages 20 feet in thickness and generally forms a good bench. It is normally buff, medium- to massive-bedded, cross-bedded and locally contains plant fragments.

The Cheshewalla is well exposed on the dirt road from Barnsdall to Wynona in sec. 10, T. 24 N., R. 10 E., just north of the Barnsdall area. At this location it is 17 feet thick, buff and massive- to cross-bedded. Farther south in the NE$\frac{1}{4}$ sec. 27, T. 24 N., R. 10 E., the bed is about 28 feet thick. This increase in thickness is due to the inclusion of a wedge of maroon shale within the sandstone.

Along the main road, near the N. line of the SW$\frac{1}{4}$ sec. 2, T. 23 N., R. 10 E., the unit is massive- to thin-bedded, medium- to coarse-grained, cross-bedded and contains a few plant fragments.

A thickness of 24 feet of medium- to coarse-grained Cheshewalla is exposed in the $E\frac{1}{2}$ sec. 32, T. 23 N., R. 10 E. The main east-west road in the same section crosses the Cheshewalla in the $SE\frac{1}{4}$.

A good exposure of the bed is in the creek bed near the NW cor. sec. 31, T. 23 N., R. 10 E. Here, 25 feet of buff to orange-buff, medium- to coarse-grained, cross-bedded, massive sandstone is exposed.

In sec. 14, T. 22 N., R. 9 E., along State Highway 20, the Cheshewalla is buff, massive-bedded, fine- to medium-grained, iron-stained and includes some thin shale partings.

A maroon to gray shale overlies the Cheshewalla throughout its outcrop in the Barnsdall area. In T. 22 N., some light gray siltstone is included within this shale. This shale interval ranges from 10 to 35 feet.

Kiheki sandstone member. This member was named by Tanner (1956, p. 45) for the railroad siding along the M. K. and T. tracks in sec. 33, T. 25 N., R. 10 E. In the type area it forms:

> ...a single, more or less continuous sandstone ledge, 5 to 25 feet thick 30 feet below the Labadie limestone and from 50 to 75 feet above the Cheshewalla sandstone.

The presence of a thick shale above, and the bench forming characteristics of the bed itself, render it the most prominent sandstone in the Barnsdall area.

The Kiheki extends from sec. 24, T. 27 N., R. 10 E. to the Arkansas River. The bed, under its present name, has not been traced south of the river.

The unit is composed of two sandstone ledges separated by maroon (locally gray) shale. The lower ledge is, by far, the more prominent of the two. The member ranges in thickness from 25 feet in T. 24 N.,

R. 10 E., to 35 feet in T. 22 N., R. 9 E. Farther south in sec. 36, T. 22 N., R. 9 E., it attains a maximum thickness of 57 feet (Carl, personal communication, July, 1956).

On the Ambrose ranch in the NW$\frac{1}{4}$ sec. 27, T. 24 N., R. 10 E., 32 feet of Kiheki was measured. Both the upper and lower beds are massive, buff to rusty buff and medium-grained. The shale interval between the beds is 16 feet.

An easily accessible exposure of the Kiheki is along the road through the SE$\frac{1}{4}$ sec. 3, T. 23 N., R. 10 E. The lithologic character of the unit is essentially the same as that of the previous location.

Approximately 30 feet of Kiheki sandstone and shale is exposed along the east-west road running through the S$\frac{1}{2}$ secs. 31 and 32, T. 23 N., R. 10 E. Some siltstone is associated with the massive- to medium-bedded sandstones in this area.

A complete thickness of the member is well exposed in the creek bed near the SE cor. sec. 25, T. 23 N., R. 9 E. The sandstone is orange-buff, medium-grained, thin- to massive-bedded and weathers into rounded boulders.

At the southern boundary of the Barnsdall area along State Highway 20, near the SE cor. sec. 14, T. 22 N., R. 9 E., 35 feet of thin- to massive-bedded, buff, coarse-grained, contorted, mud-cracked, Kiheki sandstone is exposed (Fig. 14).

A sequence of gray to gray-green shale with thin interbedded siltstones and local thin limestone occurs between the Kiheki member and the overlying Cochahee member. This interval is 55 feet in secs. 17 and 20, T. 24 N., R. 10 E. and 53 feet along State Highway 20 in sec. 14,

Figure 14. The Kiheki sandstone member in a cut along State Highway 20. SE$\frac{1}{4}$ sec. 14, T. 22 N., R. 9 E. Notice fault near the right side of the picture.

T. 22 N., R. 9 E. Because of the shaly nature of this sequence, good exposures are found at few places. In a recent road cut in sec. 14, T. 22 N., R. 9 E., the full thickness of this interval is well exposed. Olive to gray-blue shales comprise most of the interval. One thin limestone bed crops out 21 feet below the base of the Cochahee sandstone member at this location.

Cochahee sandstone member. Winchester, Heald and others (White and others, 1922, p. 60) named this sandstone for its good exposures along Cochahee creek, T. 25 N., R. 10 E. The bed has been mapped from the SE$\frac{1}{4}$ sec. 18, T. 25 N., R. 10 E. (Tanner, 1956, Plate I) to the cen. T. 21 N., R. 9 E. (Carl, personal communication, July, 1956). The Cochahee, though thin, was easily mapped because of the non-resistent nature of the underlying shale section. Its thickness ranges from 6 to 11 feet in the Barnsdall area. In T. 24 N., and the northern part of T. 23 N., the Cochahee is consistently coarse-grained, buff to rusty buff and poorly cemented. To the south in the southern half of T. 23 N., and in T. 22 N., it is buff to orange-buff, medium-grained, slabby and jointed.

Along the road from Barnsdall to Wynona near the north line of sec. 20, T. 24 N., R. 10 E., the Cochahee is 10 feet thick, buff and coarse-grained. Just north of the stream crossing the section line road separating secs. 7 and 8, T. 23 N., R. 10 E. the unit consists of 11 feet of rusty buff, thin- to massive-bedded, coarse-grained, porous, iron-stained sandstone.

In the SE$\frac{1}{4}$ sec. 25, T. 23 N., R. 9 E., 8 feet of pinkish-buff, medium-grained, iron-stained Cochahee crops out. South of State Highway 20, west of the north-south farm road, the Cochahee forms a low "rim rock" at road level. It is about 6 feet thick, orange-buff, medium-grained, tightly cemented and cross-bedded. Some contorted bedding is noticeable.

A comparison of the outcrop of the Cochahee sandstone as mapped in this report and that of the Four Mile sandstone of Bowen (White and others, 1922, p. 18 and Plate V) shows the two to be the same.

A complex sequence of maroon shales, rapidly lensing beds of sandstone and locally calcareous siltstone, separates the Cochahee member from the overlying Wynona sandstone member. This interval contains several bench forming sandstones in T. 24 N., R. 10 E., but these benches die rapidly as they are traced into T. 23 N., R. 9 E. This interval is 80 feet along the road from Barnsdall to Wynona in secs. 19 and 20, T. 24 N., R. 10 E.; it thins fairly uniformly to 35 feet in sec. 15, T. 22 N., R. 9 E. Some calcareous siltstones within this sequence are exposed in the road cut just west of Sunset Creek in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 13, T. 23 N., R. 9 E.

<u>Wynona sandstone member</u>. The Wynona sandstone was named by Heald, Bowen and others (White and others, 1922, pp. 195-196) for the exposures of sandstone in the southeastern part of the town of Wynona, sec. 22, T. 24 N., R. 9 E. It was originally described as follows:

> The Wynona sandstone, which lies from 2 to 15 feet below the Oread limestone, is a massive bed 15 to 25 feet thick ...in the south-central part of this township [T. 24 N., R. 9 E.] the sandstone loses its massive character and is a thin, flaggy bed which may locally grade into a massive sandstone.

In his report on northeast Osage County, Tanner (1956, p. 52) mapped two sandstone beds within the Wynona member. The upper bed is the Wynona of the type locality and the lower is equivalent to the upper persistent sandstone of the Four Mile sandstone of Bowen (White and others, 1922, p. 18). Both of these beds have been mapped in the Barnsdall area.

The sandstones of the Wynona member have been traced northward to the middle of T. 26 N., (Tanner, 1956, Plate I). They extend southward from Wynona through R. 9 E., in the Barnsdall area, to the Arkansas River. Greig (1954, Plate I) has mapped a unit called the Wynona sandstone as far south as sec. 33, T. 20 N., R. 8 E.

The member is approximately 65 feet thick in T. 24 N., R. 9 E. In T. 22 N., R. 9 E., its thickness is estimated to be between 80 and 90 feet. The combination of low relief, width of outcrop and the varying character of this unit in the south preclude the measurement of accurate thicknesses.

Lithologically, the Wynona member consists of lenticular, locally massive sandstones interbedded with deep maroon shales and light gray siltstones.

Lower sandstone bed of the Wynona member. The lower sandstone bed is generally more consistent in thickness and stratigraphic position than the upper sandstone bed. It is well exposed in cuts along the main road from Wynona to Barnsdall. The best of these exposures is located in the NE$\frac{1}{4}$ sec. 26, T. 24 N., R. 9 E. A thickness of 16.9 feet of buff to rusty buff, medium-grained, thin- to massive-bedded, cross-bedded ripple marked sandstone is present here.

Approximately 21 feet of this unit, with the characteristics mentioned above, crops out in the SE$\frac{1}{4}$ sec. 6, T. 23 N., R. 10 E. Farther south, near the W. line sec. 13, T. 23 N., R. 9 E., in the road cut west of Sunset Creek, the lower bed of the Wynona consists of 9.5 feet of medium- to massive-bedded sandstone and 5.5 feet of thin sandstone and siltstone, interbedded with minor amounts of maroon shale.

An exceptionally thick sandstone, 45 feet, is exposed along the east and west banks of Hominy Creek in the NW$\frac{1}{4}$ and the NE$\frac{1}{4}$ of sec. 29 and the E. 2/3 of sec. 20, T. 23 N., R. 9 E. This massive bed occupies the interval of the lower sandstone bed, the overlying shale and probably the lower part of the upper sandstone bed. The sandstone is buff, iron-stained, thin- to massive-bedded, highly cross-bedded and ripple-marked. This unit was probably deposited as a valley or channel filling.

The lower bed of the Wynona is well exposed in the former road bed of State Highway 20 in the N$\frac{1}{2}$ sec. 16, T. 22 N., R. 9 E. Eleven to 15 feet of light gray, fine- to medium-grained, laminar to massive-bedded, cross-bedded sandstone interbedded with gray siltstones is exposed in this cut (Fig. 15).

The interval between the lower and upper sandstone beds of the Wynona is occupied, for the most part, by maroon shales. Included within this interval are light gray siltstones up to four feet thick, and locally, sandstones similar to those of the upper and lower beds. The most complete exposure of this interval is located just east of Hominy in the first road-cut along State Highway 20 (Fig. 16). Cropping out here are 25 to 30 feet of maroon to deep maroon shales and light gray siltstones.

Upper sandstone bed of the Wynona member. The upper sandstone

Figure 15. An excellent example of channeling in the lower sandstone bed of the Wynona member. Near center N. line sec. 16, T. 22 N., R. 9 E.

Figure 16. The best exposure of the shale and siltstone on the interval between the lower and upper sandstone beds of the Wynona member. Near center sec. 6, T. 22 N., R. 9 E.

bed is, to say the least, a difficult unit to map. At and near the town of Wynona, it is a massive bed 15 to 20 feet thick. In the southern part of T. 24 N., and in T. 23 N., R. 9 E., this unit consists of at least two thin sandstone beds separated by maroon shale and thin siltstones. The base of this bed seems to merge into the massive 45-foot sandstone, previously mentioned, in the NW$\frac{1}{4}$ T. 23 N., R. 9 E. South of Hominy Creek in T. 22 N., R. 9 E., the upper bed is more distinct. In this area it caps most of the low hills.

The most accessible location for examining the upper bed in the northern part of the Barnsdall area is near the NE cor. sec. 26, T. 24 N , R. 9 E., along the road from Wynona to Barnsdall. Fifteen feet of reddish-buff, medium-grained, medium- to massive-bedded sandstone is exposed here.

Two distinct beds within this unit crop out along the section line road just south of the NW cor. sec. 14, T. 23 N., R. 9 E. The upper one forms a slight topographic break to the west and southwest. From this location a large part of the western tier of townships of the Barnsdall area can be viewed. The low hills to the south and southeast are capped by the upper bed of the Wynona. The buttes to the southwest are capped by the Elgin sandstone (Fig. 17).

The sandstones and shales of the upper bed of the Wynona member are exposed almost continuously along State Highway 99 between the towns of Hominy and Wynona (Fig. 18).

The upper bed crops out in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 29, T. 23 N., 9? R. 10 E.; here, 11 feet of yellow-buff, iron-stained, medium-bedded sandstone is exposed.

Figure 17. View, looking west, of an Elgin sandstone capped outlier. East $\frac{1}{2}$ sec. 9, T. 23 N., R. 9 E. Topographic break at right side of picture formed by the upper sandstone bed of the Wynona member.

Figure 18. Thin to massive bedding in the upper sandstone bed of the Wynona member. Along State Highway 99. SE$\frac{1}{4}$ sec. 7, T. 23 N., R. 9 E.

Slightly more than 15 feet of the upper bed is present in the NW¼ sec. 16, T. 22 N., R. 9 E. At this location the sandstone is light buff, iron-stained, medium-bedded and medium- to coarse-grained. It is doubtful if a full thickness of the unit is exposed, as it is capping a hill.

From 15 to 30 feet of maroon shale overlies the upper sandstone bed, the top of it is considered to be the top of the Wynona member.

Oread limestone member. This bed is essentially absent in the Barnsdall area but does crop out at two locations; near the cen. sec. 33, T. 24 N., R. 9 E., and the NW¼ sec. 5, T. 23 N., R. 9 E., between the M. K. and T. Railroad and State Highway 99. At the former location a few small slabs of light gray, fossiliferous limestone are exposed near an old well site. Some cream colored, limy nodules assumed to be Oread, crop out near the top of the knoll at the latter location. South of the Barnsdall area, Carl (personal communication, July, 1956) has found a thin, persistent, fossiliferous sandstone at the base of the Kanwaka shale, which may be equivalent to the Oread.

Kanwaka shale member. The term, Kanwaka, was applied to the beds occupying the interval between the top of the Oread limestone and the base of the Lecompton limestone by Beede (1902, p. 163). The base of this unit, in the Barnsdall area, is considered to be the base of the Shawnee group, where the Oread limestone is missing.

That part of the Kanwaka included in the interval between the top of the Wynona member and the base of the Elgin sandstone is discussed in this report.

The base of the Kanwaka member in the Barnsdall area is poorly defined as the Oread limestone is essentially absent. The upper part of the Wynona member consists of shale as does all of the Kanwaka member. Fortunately, there is a difference between the two; namely, the color of the shales. The Wynona shale is maroon and the Kanwaka is dark gray; therefore, the base of the Kanwaka member is set at the zone of color change. This zone is discernible at few places either on airplane photographs or in the field; consequently, the position of the line showing the base of the Kanwaka member appearing on Plate I is an approximation.

The thickness of this unit gradually increases from north to south. Shannon (1954, p. 96) measured 119 feet of Kanwaka in sec. 32, T. 24 N., R. 9 E. The bed is 140 feet thick near the SE cor. sec. 20, T. 23 N., R. 9 E., and reaches a maximum thickness of 177 feet in secs. 19 and 20, T. 22 N., R. 9 E., (Carl, personal communication, July, 1956).

Characteristically, the Kanwaka member consists of 20 to 30 feet of blue-gray, fossiliferous shale with ironstone concretions and 110 to 120 feet of gray-green non-fossiliferous shale. Thin sandstone beds 3 to 4 inches thick occur here and there throughout the complete section.

Because of the non-resistant nature of the Kanwaka, few good exposures exist; in addition, float from the overlying Elgin sandstone aids in obscuring the unit.

Two outliers of Kanwaka are located within the Barnsdall area proper. One is situated at the southern end of the Savage ranch in parts of secs. 20, 21, 28 and 29, T. 23 N., R. 9 E. The other covers the $N\frac{1}{2}$ sec. 16, the E 2/3 sec. 9 and projects slightly into secs. 4 and 10, T. 23 N., R. 9 E. No good exposures exist on the former outlier. The shale is exposed in gullies on the latter outlier, but no complete section is exposed in any single gully. The character of the shale exposed on these outliers is consistent with the general description given previously.

For further descriptions of this member refer to the work of Shannon (1954, pp. 15-20) and Russell (1955, pp. 12-15) who have mapped and described the unit west of the Barnsdall area.

The following fossils, all from the Kanwaka member in the $SE\frac{1}{4}$ $NW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 9, T. 23 N., R. 9 E., have been collected from the Vamoosa formation:

Coelenterata
- Lophophyllidium spinosum Jeffords

Brachiopoda
- Hustedia mormoni (Marcou)
- "Marginifera" sp.
- Orbiculoidea missouriensis (Shumard)
- Orbiculoidea capuliformis (McChesney)

Pelecypoda
- Allorisma terminale (Hall)
- Nucula sp.
- Nuculana bellistriata (Stevens)

Gastropoda
- Trepospira depressa (Cox)
- Worthenia tabulata (Conrad)

Cephalopoda
- Unidentified nautiloid

QUATERNARY ALLUVIUM

The major streams and many of the minor streams in the Barnsdall area have deposited a thick veneer of alluvium in their valleys.

This material, characteristically, is orange-buff to tan and shows little bedding, though locally zones of pebbles are included within the clay and silt-size particles. The most prominent feature of the alluvial deposits is their ability to stand in nearly vertical cliffs, as does loess.

The alluvium contains a high percentage of eolian material. It is doubtful that the wind-blown particles were deposited directly in the stream beds. Probably this material was deposited on upland surfaces during Pleistocene or Recent time. After deposition, streams eroded the eolian material and redeposited it as water-borne sediment. In most cases, the streams have cut through the alluvium and flow on bed rock.

Good exposures of alluvium are at the ford across Turkey Creek in the NE$\frac{1}{4}$ sec. 12, T. 23 N., R. 11 E., and where the road crosses Hominy Creek in the NE$\frac{1}{4}$ sec. 16, T. 22 N., R. 10 E. (Fig. 19).

Figure 19. Alluvium standing in vertical cliffs along Hominy Creek. NE$\frac{1}{4}$ sec. 16, T. 22 N., R. 10 E. Sandstone of the upper part of the Wann formation, possibly Clem Creek, exposed in the stream bed.

CHAPTER III

HISTORICAL GEOLOGY

The sediments cropping out in the Barnsdall and surrounding areas are a hybrid of two types of shallow water deposition: the marine deposits, high in carbonate content that are typically developed in Kansas, and the essentially clastic, marine to continental deposits present in Central Oklahoma. Characteristics of each type of sedimentation are displayed in the Barnsdall area, although there is no good example of either type.

Deposition was essentially continuous during Missouri and Virgil time, although periods of non-deposition and erosion interrupted the process intermittently.

Alternating transgressions and regressions of epicontinental seas have produced cyclic deposits. The cyclothems developed in Kansas, are not recognized in the Barnsdall area; however, a gross reflection of them is indicated by the alternation of shallow water marine and near shore to continental deposits. The cause of these cyclic deposits is closely related to the orogenic and epeirogenic movements of the unstable areas to the south and southeast.

The shelf areas in northern Oklahoma were in a delicate state of "balance" during Upper Pennsylvanian time. Slight positive or negative movements of the unstable areas to the south and southeast upset this "balance" easily. The area must have had little relief, so that eustatic rises inundated large areas and eustatic withdrawals or minor upwarping caused wholesale emergence. The regional persistence of certain coals and some thin limestones bears witness to the existence of uniform conditions of deposition over vast areas.

During Missouri time, the sediments were dominantly marine. The deposits of limestone and gray shale attest to this fact. In middle Wann and Okesa time, positive pulsations in the source areas caused an influx of sand. The maroon shales associated with some of the Okesa sandstones indicate that for short periods of time, continental or possibly deltaic environments prevailed.

The preponderance of sandstone and maroon shale in the Tallant formation is probably closely related to the Arbuckle disturbance of southern Oklahoma. Subsequent to the deposition of the Tallant, eustatic withdrawal or progressive uplift from south to north, exposed upper Missouri rocks to erosion. This hiatus is much more pronounced in south-central Oklahoma than in northern Oklahoma, as progressively older formations are truncated in the former area. The only evidence for this erosional interval in the Barnsdall area is the north to south thinning of the Tallant formation.

The alternation of near-shore and off-shore marine environments so characteristic of the Missouri series re-appears in the Virgil sediments. The Cheshewalla, Kiheki and Cochahee sandstones and associated shales probably represent near-shore sedimentation. The maroon shales and lensing sandstones of the Wynona may be deltaic in origin.

A definite off-shore environment existed during the deposition of the gray shales and thin limestones of the Vamoosa formation.

With few exceptions, the sand content of the units cropping out in the Barnsdall area increases from north to south. This increase implies that the source or sources of sediment lay to the south.

Tanner (1956, p. 27, Figure 9) on the basis of "oriented data" postulates that the shore lines of the seas during Missouri and Virgil time trended north-northwest in this general area. No evidence supporting this hypothesis was found in the Barnsdall area.

CHAPTER IV

STRUCTURAL GEOLOGY

The rocks of the Barnsdall area are a part of a post-Permian regional structure called the Prairie Plains homocline. This structure which extends from Nebraska to south-central Oklahoma, is characterized by low dipping beds (generally less than 100 feet per mile) that strike approximately N-S. The strata forming this structure converge toward the Arbuckle uplift in south-central Oklahoma. The sediments cropping out in the Barnsdall area, except where interrupted by folds, dip approximately 40 feet per mile to the west. The origin of the term Prairie Plains homocline is obscure; the geologists of the Indian Territory Illuminating Oil Company were probably among the first to use the term (Clinton, personal communication, July, 1956).

Major structures surrounding the Barnsdall area are: the Ozark dome, to the east; the Nemaha uplift, to the west and north; the Anadarko basin, to the southwest; the Ouachita-Arbuckle complex and the McAlester basin to the south.

Superimposed upon the homoclinal rocks in the Barnsdall and surrounding areas are numerous small anticlines, domes, noses and synclines. Powers (1931, p. 120) termed these flexures "plains type folds". The distribution of folds is irregular, but their axes trend northeast. In the Barnsdall area the occurrence of these flexures is quite common. Surface closure of these structures is generally less than 50 feet, but with depth the closure increases. The maximum surface closure in the Barnsdall area is 120 feet (White and others, 1922, p. 244). These upwarps are extremely important economically, for almost all of them produce or have produced petroleum.

Drilling has revealed that many of the folds are situated over pre-Pennsylvanian topographic highs, many of them being Precambrian igneous hills. Powers (1931, pp. 131-132) contends that:

> ...the position of practically all of the anticlines in Oklahoma was determined early in Pennsylvanian time and the position of most of them was influenced by pre-Ordovician topography or grain....Folding which terminated Paleozoic sedimentation in Oklahoma refolded the pre-existing anticlines...

The surface expression of some of the anticlines and domes is quite obvious. Hominy dome, sec. 18, T. 22 N., R. 9 E., Manion anticline, secs. 19 and 30, T. 23 N., R. 9 E., and Band Wheel dome, sec. 33, T. 24 N., R. 9 E., all visible from State Highway 99, appear as definite topographic highs. Dips of 3 to 4 degrees were measured on Birch Creek dome, sec. 27, T. 24 N., R. 11 E. This structure is especially prominent on airplane photographs.

Numerous linears and normal faults are present in the Barnsdall area. The alignment of these features is roughly parallel to the famous en échelon fault belt of central Osage County. The area mapped is located east of the major belt of en échelon faults mapped by Shannon (1955, Plate I), Russell (1954, Plate I) and others. As a general rule, the faults within the area are located in poorly defined bands trending northeast. Locally, faults are concentrated in the vicinity of structures. The prime example of this association is Birch Creek dome, secs. 29, 30, 31 and 32, T. 24 N., R. 11 E. This upwarp is cut by nine faults and/or linears.

Two-thirds of the faults are oriented N. 70 W. to N. 10 W., one-third trend N. 60 E. to N. 20 E. The dip of the fault planes is said to range from 45 to 65 degrees. Little economic importance is attached to these faults, as subsurface studies have revealed that few if any of them effect oil-bearing horizons. Most of the faults die out within the Pennsylvanian section.

Few of the faults are recognizable in the field, except where distinctive beds are affected. In most cases, relative movement was determined from the offsets of beds appearing on airplane photographs. Blackjack oak commonly grows along the fault traces, forming relatively straight dark lines on the photographs.

Near the cen. N$\frac{1}{2}$ sec. 13, T. 22 N., R. 11 E., the Avant limestone is cut by a NNW trending fault which displays a throw of 57 feet, the maximum displacement measured in the area. The fault in the SW$\frac{1}{4}$ sec. 27, T. 24 N., R. 11 E. displaces the exposed beds 15 feet. The south side of the fault is downthrown. The Red limestone is in contact with the Clem Creek sandstone along the NW trending fault in the NE$\frac{1}{4}$ sec. 31, T. 24 N., R. 11 E. Beds in the lower part of the Vamoosa formation are cut by a relatively long fault (2.1 miles) in secs. 2, 11 and 12, T. 22 N., R. 9 E., and sec. 35, T. 23 N., R. 9 E. The NE side of the fault is upthrown 30 feet. An easily accessible fault is located along State Highway 20 in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 14, T. 22 N.,

R. 9 E. Here, the west side of the fault is downthrown 15 feet (Fig. 14).

The faults in the Barnsdall area are generally less than one mile long and most have displaced beds less than 30 feet.

Several theories concerning the origin of the en échelon faults of northern Oklahoma have been proposed by structural geologists. Fath (1920, pp. 77-80) presented one of the earliest theories. In his opinion, horizontal movement in competent basement rocks caused drag in the overlying incompetent sediments, resulting in fractures at 45 degrees to the direction of deep-seated movement. Foley (1926, pp. 293-303) stated that the faulting was the result of rotational stress caused by the westward thrust of the Ozark dome being opposed by the Nemaha ridge of Kansas and Oklahoma. Sherrill (1929, pp. 31-37) indicated that torsional forces effecting the sediments, augmented by uplift might be the cause of en échelon faulting. Melton (1930, pp. 57-72), contrary to prevailing opinion, stated that the en échelon arrangement of the faults is "largely fallacious and unreal". He believed that their origin is closely related to the movements accompanying the Ouachita orogeny. Kramer (1933, pp. 243-248) postulated a

> ...westward thrust from the Ouachita mountains...as the force which created a shearing couple which caused elongation of the faulted area from northeast to southwest, thus causing the development of the northwest trending, en échelon, tension faults in belts above north-northeast trending major shear plains produced in the basement rocks by forces of the couple.

Others believe that the faults are a result of compaction over buried hills. The adherents of this theory cite the absence of the faults below the Pennsylvanian section as evidence in support of their contentions.

It is doubtful if any single theory will fully explain the causes of these faults.

CHAPTER V

ECONOMIC GEOLOGY

Oil and gas were discovered in the Barnsdall area as early as 1905 in T. 23 N., R. 11 E., but the height of drilling activity occurred between the years 1912 and 1923. Most of the fields within the area were discovered during this period. During the past six years, crude production in Osage County has tripled and extensive leasing activity is in progress in the Barnsdall area at the present time.

Osage County has become attractive to oil companys for several reasons: the wells are shallow, resulting in low drilling costs; the wells pay out in a short period of time (3 to 4 years); the ratio of productive oil wells to dry holes is extremely high; and water flooding projects have been successful (Revival in the Osage, 1956, pp. 44-47).

According to R. P. Clinton (personal communication, July, 1956) of the Pure Oil Company, extensive drilling will commence in the western part of the Barnsdall area within the near future.

Initial production from many wells, in the early days, was over 4,000 barrels of oil per day, now 50 barrels per day is considered excellent. At least 15 horizons yield oil and gas; these range from

Cambro-Ordovician to Upper Pennsylvanian in age. Several fields within the area produce from 10 different oil-bearing beds. The most prolific reservoir in the area is the Bartlesville sand.

Twenty-nine fields or portions of fields are located in the Barnsdall area. The largest field, the Avant, located in the vicinity of the town of the same name, has 561 producing wells.

At present there are 1,175 producing wells in the Barnsdall area; the total production from these wells for the month of December, 1955, was 2,717 barrels of oil per day (Vance Rowe Reports, 1955). The average daily production per well is 2.3 barrels per day. As most of the wells are old and have paid for themselves, it is still profitable to pump them for their small yield of oil.

While field work for this report was in progress, two producing wells were drilled on Four Mile dome, sec. 26, T. 24 N., R. 9 E., and several dry holes were drilled in T. 23 N., R. 10 E.

Two abandoned quarries are located in the area; S$\frac{1}{2}$ NW$\frac{1}{4}$ sec. 17, T. 23 N., R. 12 E., and NE$\frac{1}{4}$ sec. 9, T. 22 N., R. 12 E. At both of these locations, the Avant limestone was the rock quarried. The former (and larger) quarry was owned and operated by the Midland Valley Railroad at the turn of the century. The rock taken from this quarry was probably used as railroad ballast. The material from the other quarry has been used as road metal on the county roads in the area.

The Muncie Creek shale is said to be highly radioactive (Branson, Burwell and Chase, 1955, p. 19) but does not contain commercial quantities of radioactive minerals.

The thick shales of the Wann, Barnsdall and Vamoosa formations support a heavy growth of blue-stem grass, which is used for grazing by the several cattle ranches within the area.

Some of the numerous sandstones cropping out in the area have been used locally as building stone.

CHAPTER VI

SUMMARY

Several beds mapped to the north of the Barnsdall area were successfully traced through the area. Two of these beds, the Kiheki and Cheshewalla sandstone members of the Vamoosa formation form prominent benches throughout their outcrop.

Possible evidence supporting the existence of a pre-Chanute, post-Dewey unconformity and a post-Tallant, pre-Vamoosa unconformity was found in the Barnsdall area.

The lithologies of the units cropping out indicate that the majority of the beds were deposited in marine environments. With few exceptions, the clastic content of the strata increases from north to south.

The homoclinal dip of the rocks is interrupted locally by small structures, some of which are expressed on the surface as topographic highs or lows. Normal faults of short length and of small displacement are common in the area.

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APPENDIX

MEASURED STRATIGRAPHIC SECTIONS

IN

THE BARNSDALL AND ADJACENT AREAS

Township 22 North

1. Secs. 15 and 16, T. 22 N., R. 9 E.; from cen. E. line sec. 16, up the hill to the oil well near the cen. W. line sec. 15.

	Feet
Vamoosa formation	
Wynona member	
Upper sandstone bed	
Sandstone, orange-buff, medium-grained, medium- to massive-bedded, cross bedded. . . .	18.0
Covered interval, sandstone and shale?.	8.0
Sandstone, thin- to medium-bedded, weathers parallel to bedding planes, limy.	11.0

2. Sec. 16, T. 22 N., R. 9 E.; measured along old route of State Highway 20 in the NE$\frac{1}{4}$ and NW$\frac{1}{4}$.

	Feet
Vamoosa formation	
Wynona member	
Upper sandstone bed	
Sandstone, medium-bedded, light buff, iron-stained, medium- to coarse-grained, not measured	
Shale, maroon, fissile, interbedded with thin, gray siltstone	25.0
Lower sandstone bed	
Sandstone, light gray, fine- to medium-grained massive- to medium-bedded, contains thin siltstones, highly cross-bedded, channeling present.	15.0
Shale, maroon, fissile, interbedded with light gray thinly laminated, cross-bedded siltstone.	6.5
Siltstone, light gray, very fine- to fine-	

Feet

grained, laminated, cross-bedded. 5.5
Shale, maroon, fissile, not measured

3. Sec. 15, T. 22 N., R. 9 E.; measured in the SW$\frac{1}{4}$ from the base of the Cochahee sandstone west up the lease road.

Vamoosa formation
Wynona member
Upper sandstone bed
Sandstone, light gray to buff, poorly exposed, not measured.
Covered interval, maroon shale and siltstone? 27.0
Lower sandstone bed
Siltstone, light gray, interbedded with light buff sandstone 7.0
Sandstone, light gray, thin- to medium-bedded, fine- to medium-grained, surface pitted. . . 4.0
Covered interval 11.1
Sandstone and siltstone, poorly exposed. . . . 5.5
Covered interval 16.9
Cochahee sandstome member
Sandstone, orange-buff, medium-grained, compact, medium-bedded, cross-bedded, jointed. 6.0

4. Sec. 5, T. 22 N., R. 9 E.; measured from the creek in the S$\frac{1}{2}$, up the slope past the farm house to the top of the hill.

Vamoosa formation
Wynona member
Upper sandstone bed
Sandstone, medium to massive, buff, medium-grained, pitted, iron-stained, forms bench, not measured
Covered interval 11.0
Sandstone, buff, medium- to fine-grained, medium-bedded. 5.5
Covered interval, maroon shale?. 28.0
Lower sandstone bed
Sandstone, light gray to buff, fine- to medium-grained, thin- to massive-bedded, contorted, interbedded with maroon shale and light gray siltstone, base not exposed 12.0

5. Sec. 23, T. 22 N., R. 10 E.; measured along State Highway 20 in the NE$\frac{1}{4}$.

Barnsdall formation

	Feet
Okesa member	
Sandstone, not measured.	
Wann formation	
Sandstone, light buff, iron-stained, ripple-marked.	0.3
Shale and siltstone, poorly exposed.	2.0
Sandstone, buff to light brown, fine- to medium-grained, occurs in one bed, ripple-marked, fucoids on base.	0.7
Shale, gray-green, blocky, contains thin beds of light gray siltstone.	16.0
Sandstone, dirty buff, medium- to coarse-grained, thin- to medium-bedded, ripple marked.	2.0
Shale, olive to khaki, sandy	2.5
Sandstone, rusty buff, contains molds and casts.	0.4
Shale, olive to dark gray, iron-stained. . . .	4.0
Clem Creek sandstone member	
Sandstone, buff, fine- to medium-grained, thin- to massive-bedded, bench former. . . .	29.0

6. Sec. 12, T. 22 N., R. 10 E.; measured in the NW$\frac{1}{4}$ from the upper part of the Clem Creek sandstone westward up the slope.

	Feet
Barnsdall formation	
Okesa member	
Sandstone, thin- to medium-bedded, yellow-buff, fine- to medium-grained, not measured	
Wann formation	
Shale, gray-green to maroon, includes some thin sandstones.	62.5
Clem Creek sandstone member	
Sandstone, light buff, fine- to medium-grained, iron-stained, upper surface pitted.	11.1
Covered interval	23.0
Sandstone, yellow-buff, medium-grained, micaceous, medium- to massive-bedded, not measured	

7. Sec. 6, T. 22 N., R. 10 E.; measured along the creek in the SW$\frac{1}{4}$.

	Feet
Vamoosa formation	
Cheshewalla sandstone member, not measured	
Tallant formation	
Sandstone, buff, not measured	
Covered interval	13.0
Sandstone and siltstone.	10.5
Covered interval	13.5
Sandstone, light buff, medium-grained.	14.0

	Feet
Covered interval, maroon shale?	8.0
Bigheart sandstone member	
Sandstone, buff, medium-grained, medium-bedded	11.0
Covered interval, shale?	4.5
Sandstone, massive, bench former	23.0
Barnsdall formation	
Shale, green to olive, blocky.	27.0
Wildhorse dolomite lentil	
Dolomite, light gray, medium to coarsely crystalline, weathers maroon, wavy-bedded. .	20.0

8. Secs. 27 and 22, T. 22 N., R. 11 E.; measured up the road from the $SE\frac{1}{4}$ sec. 27 to the N. line $SE\frac{1}{4}$ sec. 22.

Wann formation	
Clem Creek sandstone member	
Sandstone, massive, medium-grained, iron-stained, breaks into rectangular blocks, top eroded	19.0
Sandstone, badly weathered	5.5
Sandstone, light buff, poorly cemented, bench former	6.0
Covered interval	9.5
Sandstone, buff, massive	4.0
Sandstone and siltstone, thin-bedded	3.0
Sandstone, yellow, fine- to medium-grained, cross-bedded, high in iron content, inter-bedded with siltstone and maroon shale . . .	14.0
Covered, shale?.	17.0
Sandstone, buff to yellow, fine- to medium-grained, upper 25 feet are medium- to massive-bedded, lower 0.2 feet packed with molds and casts of fusulinids	28.0
Shale, dark gray, blocky, interbedded with thin siltstone and sandstone stringers . . .	44.0
Sandstone, buff, medium-grained.	1.5
Shale and sandstone.	5.0
Shale, dark gray, locally limy	11.0
Sandstone, buff, medium-grained, molds and casts along bedding planes, ripple marks common	1.5
Shale, dark gray, blocky, calcareous	9.5
Shale, gray-blue, blocky, thin silty zones and sandstone at top of unit	7.8
Sandstone and shale.	6.0
Shale, olive to dark gray, blocky, contains thin sandstone stringers	2.2
Sandstone, rusty buff, fine- to medium-grained.	1.0

Feet

Shale, dark gray, blocky, contains ironstone concretions. 17.5
Sandstone, dirty buff, fine- to medium-grained, forms slight bench. 0.5
Shale, dark gray, clayey, deeply weathered . . 31.0

Iola formation
Avant limestone member
Limestone, medium-crystalline, wavy-bedded, not measured.

9. Sec. 16, T. 22 N., R. 12 E.; measured along the road and driveway in the SE$\frac{1}{4}$.

Nellie Bly formation
Sandstone, buff, medium-grained, poorly exposed 20.0
Shale, dark gray, interbedded with limestone lenses 27.5
Siltstone and shale, dark gray to olive. . . . 39.0

10. Sec. 18, T. 22 N., R. 12 E.; measured from the E$\frac{1}{2}$ SE$\frac{1}{4}$, NW up the hill, along the road.

Wann formation
Sandstone, orange-buff, fine- to medium-grained, massive, breaks into angular fragments, interbedded locally with thin stringers of siltstone, top eroded. 58.0
Shale, gray-green, blocky, clayey, contains thin lenses of sandstone, sandy toward top . 66.0

Iola formation
Avant limestone member
Limestone, reddish-purple, medium-crystalline, wavy-bedded, fossiliferous, weathers yellow to light gray. 35.0
Muncie Creek shale member
Shale, dark gray to gray-green, fissile to blocky, phosphatic nodules in ditch along road 59.0
Paola limestone member
Covered, presence indicated by line of persimmon trees, not measured.

11. Sec. 16, T. 22 N., R. 12 E.; measured along the stream in the SW$\frac{1}{4}$ NE$\frac{1}{4}$.

Iola formation
Avant limestone member
Limestone, wavy-bedded, reddish-gray, jointing prominent, top eroded 18.0

	Feet
Muncie Creek shale member	
Shale, dark gray, poorly exposed, phosphatic nodules in stream bed	39.0
Paola limestone member	
Limestone, sandy, fossiliferous, not in place .	2.0
Chanute formation	
Cottage Grove sandstone member	
Sandstone, medium-grained, thin to massive, interbedded with siltstone and shale	19.0
Shale, poorly exposed.	21.0
Dewey formation	
Limestone, gray, medium to coarsely crystalline, yellow when weathered, fossiliferous.	1.0
Shale, yellow-green, calcareous, contains marly limestone streaks, fossiliferous	11.5
Limestone, purple-gray, dense, fossiliferous .	2.0
Nellie Bly formation	
Sandstone and siltstone, poorly exposed, not measured.	

12. Secs. 16 and 17, T. 22 N., R. 12 E.; measured from the N end of the pond back of the farm house in the SE$\frac{1}{4}$ sec. 17 to the top of the Avant outlier in the SW$\frac{1}{4}$ sec. 16.

Iola formation	
Avant limestone member	
Limestone, medium-crystalline, pinkish-gray, wavy-bedded, light gray on weathered surfaces, fossiliferous, top eroded, not measured.	
Muncie Creek shale member	
Shale, dark gray to black, fissile to blocky, contains phosphatic nodules and ironstone concretions, fractures in concretions filled with calcite.	58.0
Paola limestone member	
Covered interval	2.0?
Chanute formation	
Cottage Grove sandstone member	
Covered interval, shale and siltstone?	22.0
Sandstone, buff to rusty buff, medium-grained, flaggy	5.8
Shale, gray-green, deeply weathered.	32.0
Dewey formation	
Limestone, steel gray, medium-crystalline, yellow to cream color on weathered surfaces, base covered, not measured.	

13. Sec. 10, T. 22 N., R. 12 E.; measured from approximate base of

Feet

Dewey to top of bluff on the W. side of the road in the NW$\frac{1}{4}$.

Chanute formation
Cottage Grove sandstone member?
Sandstone, buff to dirty buff, poorly cemented, thin-bedded, bench former, not measured.
Shale, olive-green, clayey, contains limestone conglomerate near the base 22.0
Dewey formation
Limestone, blue-gray, medium-crystalline, fossiliferous, occurs as a single bed, forms bench around knoll to the E. 1.5
Shale, greenish-yellow, calcareous, contains marly limestone nodules, fossiliferous . . . 16.5
Limestone, similar to that above, badly covered by rubble. 1.0

Township 23 North

14. Sec. 29, T. 23 N., R. 9 E.; measured up the W. bank of Hominy Creek in the W$\frac{1}{2}$.

Vamoosa formation
Wynona sandstone member
Lower sandstone bed and part of the upper sandstone bed?
Sandstone, buff to pinkish, iron-stained, thin- to massive-bedded, highly cross-bedded, ripple marked, forms prominent cliff. 45.0

15. Sec. 29, T. 23 N., R. 9 E.; measured up the small creek in the NE$\frac{1}{4}$ to the top of the Elgin capped outlier.

Vamoosa formation
Elgin sandstone member
Sandstone, tan to brown, medium-bedded, jointed, contains molds and casts locally, not measured.
Kanwaka shale member
Shale, deeply weathered, gray-green where exposed, covered with Elgin float. 145.0
Wynona sandstone member
Shale, maroon, poorly exposed. 20.0
Upper sandstone bed
Sandstone, medium-bedded, yellow-buff, iron-stained, fine- to medium-grained 11.0
Covered interval 5.5
Lower sandstone bed
Sandstone, similar to that in measured

	Feet
section 14	45.0

16. Secs. 13 and 14, T. 23 N., R. 9 E.; measured along the road crossing Sunset Creek, from the creek in the SW$\frac{1}{4}$ sec. 13 into the SE$\frac{1}{4}$ sec. 14.

	Feet
Vamoosa formation	
Wynona sandstone member	
Upper sandstone bed	
Sandstone, medium-grained, thin- to massive-bedded, top eroded, not measured.	
Covered interval, shale.	28.0
Lower sandstone bed	
Sandstone and siltstone, poorly exposed. . . .	5.5
Sandstone, rusty buff, medium-grained, medium- to massive-bedded.	9.5
Shale, light gray to maroon.	8.0
Sandstone, light gray, fine-grained, calcareous	1.5
Siltstone, light gray, very thin-bedded. . . .	4.5
Sandstone, light gray, thin- to medium-bedded, fine-grained, iron-stained, ripple-marked, cross-bedded.	7.5
Sandstone, gray, shaly, calcareous, thin-bedded	0.3
Shale, maroon, blocky, contains thin siltstone streaks.	11.0
Sandstone, light buff to yellow-buff, thin- to medium-bedded, fine- to medium-grained, iron-stained	5.6
Shale, light gray to maroon, base covered. . .	10.0

17. Sec. 16, T. 23 N., R. 9 E.; from creek bed, near fence eastward to top of Elgin capped outlier in the NW$\frac{1}{4}$.

	Feet
Vamoosa formation	
Elgin sandstone member	
Sandstone, buff to brown, fossiliferous, jointed, not measured.	
Kanwaka shale member	
Shale, gray-blue to gray-green, blocky, contains local sandstone beds.	140.0
Wynona sandstone member	
Covered interval	30.0
Upper sandstone bed	
Sandstone, buff to brown, medium-grained, medium-bedded.	11.0
Covered interval, shale?	8.5
Sandstone, massive- to thin-bedded, light	

		Feet
	buff, medium-grained, cross-bedded, base covered	9.0

18. Sec. 25, T. 23 N., R. 9 E., and Sec. 31, T. 23 N., R. 10 E.; measured NW up the tributary of Sand Creek from point of junction in the NW¼ NW¼ sec. 31, to top of Cochahee capped hill in the NW¼ SE¼ sec. 25.

		Feet
Vamoosa formation		
	Sandstone, forms slight bench, not measured	
	Covered interval, shale.	14.0
Cochahee sandstone member		
	Sandstone, pinkish-buff, medium-grained, medium-bedded.	8.0
	Covered, shale?, probably contains upper bed of the Kiheki member	58.0
Kiheki sandstone member		
	Sandstone, medium-grained, orange-buff, thin- to massive-bedded, weathers into rounded boulders	28.0
	Covered, maroon shale?	23.0
Cheshewalla sandstone member		
	Sandstone, buff to orange-buff, medium- to coarse-grained, medium- to massive-bedded, cross-bedded, well exposed in stream bed .	25.0

19. Sec. 32, T. 23 N., R. 10 E.; measured along the creek in the NW¼ NW¼ toward old pump house at top of hill.

		Feet
Vamoosa formation		
Cheshewalla sandstone member		
	Sandstone, medium- to coarse-grained, cross-bedded, appears in three benches, poorly exposed.	24.0
Tallant formation		
	Covered interval, shale and sandstone?	18.0
	Sandstone, reddish-yellow, fine- to medium-grained, pitted surface.	6.0
	Covered interval	12.0
	Sandstone, yellow, thin- to medium-bedded, cross-bedded, bench former	24.0
	Sandstone, buff, fine-grained.	5.0
Bigheart sandstone member		
	Sandstone, buff, fine- to medium-grained, micaceous.	6.0
	Covered, shale and siltstone?.	12.0
	Sandstone, thin- to massive-bedded, medium- to coarse-grained, locally cross-bedded, excellent bench former	30.0

Feet

Barnsdall formation
Covered interval, shale? 18.0

20. Sec. 33, T. 23 N., R. 10 E.; measured along the road from the top of the Okesa sandstone, westward up the hill in the $SE\frac{1}{4}$.

Tallant formation	
Bigheart sandstone member	
Sandstone, thin-bedded, buff	8.0
Covered, shale?	18.0
Sandstone, massive, buff, medium- to coarse-grained, bedding contorted at base, cross-bedded toward top	24.0
Barnsdall formation	
Shale, light gray-green, blocky	22.0
Wildhorse dolomite lentil	
Dolomite, light gray, dense to medium-crystalline, wavy-bedded, weathers brown	15.0
Shale, gray-green, fissile to blocky, locally fossiliferous	50.0

21. Sec. 27, T. 23 N., R. 10 E.; measured from Bull Creek, eastward to top of Wildhorse capped outlier in the $SE\frac{1}{4}$.

Barnsdall formation	
Wildhorse dolomite lentil	
Dolomite, light gray, dense, wavy-bedded, yellow-buff on weathered surfaces, top eroded	12.0
Shale, dark gray, blocky to fissile	54.0
Okesa sandstone member	
Sandstone, thin to massive-bedded, fine- to medium-grained, light to rusty buff, cross-bedded, contorted, ripple marks common, some beds bottom marked, gray and maroon shale included in the interval	60.0

22. Sec. 14, T. 23 N., R. 10 E.; measured from the top of the Okesa member NNE up the slope in the $N\frac{1}{2}$.

Tallant formation	
Bigheart sandstone member	
Sandstone, buff, medium-grained, massive, locally cross-bedded	22.0
Covered interval	11.0
Sandstone, appears as fragmental material, contorted, rusty buff	23.0
Barnsdall formation	
Shale, gray-green, to dark gray, poorly exposed	67.0

	Feet
Okesa sandstone member	
Sandstone, buff to rusty buff, cross-bedded, not measured.	

23. Sec. 8, T. 23 N., R. 10 E.; measured along the section line road from the creek northward.

Vamoosa formation	
Wynona sandstone member	
Lower sandstone bed	
Sandstone, poorly exposed, buff, medium-bedded, not measured.	
Shale, maroon, blocky.	19.0
Sandstone, massive, light buff, iron-stained, breaks into rectangular blocks	5.5
Sandstone, siltstone and shale	11.0
Covered interval	3.0
Sandstone, massive, rusty buff, pitted surface, interbedded with maroon shale.	12.0
Sandstone and maroon shale, poorly exposed . .	5.0
Cochahee sandstone member	
Sandstone, rusty buff, thin- to massive-bedded, coarse-grained, highly iron-stained.	11.0
Shale, light gray, not measured.	

24. Sec. 6, T. 23 N., R. 10 E.; measured along the ranch drive and in the pasture in the SE$\frac{1}{4}$.

Vamoosa formation	
Wynona sandstone member	
Upper sandstone bed	
Sandstone, rusty buff to orange-buff, medium- to coarse-grained, thin- to massive-bedded, ripple-marked, top eroded, not measured.	
Covered, shale?.	14.0
Lower sandstone bed	
Sandstone, buff to rusty buff, medium-grained, medium-bedded, pitted surface.	21.0
Shale, maroon, blocky, contains thin sandstone stringers.	16.5
Sandstone, brown, medium-grained, thin to medium-bedded.	5.5
Covered, shale and siltstone?.	17.0
Sandstone, dark brown, medium- to coarse-grained, massive	3.0
Covered interval	5.0
Cochahee sandstone member	
Sandstone, buff, coarse-grained, massive, poorly cemented.	6.0

		Feet
25.	Sec. 7, T. 23 N., R. 11 E.; measured along the road in the $SW\frac{1}{4}$, from the base of the hill southward, up the slope.	
	Barnsdall formation	
	Okesa sandstone member	
	Sandstone, buff, thin- to medium-bedded, medium-grained, interbedded with maroon shale and gray siltstone, top eroded	11.0
	Shale, maroon, blocky, grades vertically into gray, sandy shale.	26.5
	Sandstone, buff, thin- to massive-bedded, contorted, cross-bedded.	17.0
	Shale, dark gray, blocky	7.0
	Birch Creek limestone member?	
	Limestone, pink, sandy, dense.	0.5
	Wann formation	
	Shale, dark gray, blocky	8.0
	Sandstone, limy, fine-grained.	1.0
	Shale, gray-green, blocky.	43.0
	Covered interval	6.0
	Sandstone, rusty buff, thin-bedded, bottom-marked	5.5
	Covered interval	5.5
	Clem Creek sandstone member?	
	Sandstone, greenish-buff to rusty buff, medium-grained, contorted, cross-bedded, interbedded with gray shale, base covered. .	11.5
26.	Sec. 9, T. 23 N., R. 11 E.; measured from pipe line crossing Clem Creek, southward up the slope in the $NW\frac{1}{4}$.	
	Barnsdall formation	
	Okesa sandstone member	
	Sandstone, buff to orange-buff, medium- to coarse-grained, contorted, Birch Creek member not present, not measured.	
	Wann formation	
	Shale, dark gray, blocky, clayey	61.0
	Sandstone, light buff, thin- to medium-bedded, fucoidal development on the base . .	5.0
	Shale, dark gray, blocky	16.7
	Clem Creek sandstone member	
	Sandstone, buff, thin- to massive-bedded, medium- to coarse-grained, cross-bedded, locally contorted, base not exposed.	17.0
27.	Secs. 10 and 11, T. 23 N., R. 11 E.; measured from the top of the Red limestone in sec. 11, westward along the road to the top of the Clem Creek member in sec. 10.	

	Feet
Wann formation	
Clem Creek sandstone member	
Sandstone, light to rusty buff, thin- to medium-bedded, ripple marked	5.0
Sandstone, light buff, fine-grained, thin-bedded, ripple-marked, upper 10 feet consist of gray siltstone and shale.	22.0
Shale, gray.	11.0
Sandstone, thin- to massive-bedded, buff to rusty buff, fine- to coarse-grained, contorted, interbedded with gray siltstone and shale.	33.5
Covered interval, gray shale?.	17.0
Limestone, rusty red, sandy, sparingly fossiliferous, base covered.	4.0

28. Sec. 33, T. 23 N., R. 12 E.; measured in the $N\frac{1}{2}$, from the foundation of the old school house, N and W along the winding road.

Wann formation	
Limestone, pinkish-purple, medium-crystalline, fossiliferous, yellow on weathered surface, "Fusulina-bearing limestone" equivalent? . .	1.0
Covered interval, sandstone rubble	13.0
Sandstone, light buff, medium-bedded, medium-grained.	5.6
Shale, gray, clayey, poorly exposed.	16.7
Sandstone, buff to rusty brown, thin- to medium-bedded, local channeling, cross-bedded, some layers packed with molds and casts of brachiopods, upper part of unit massive.	40.0
Sandstone, rusty buff, medium-bedded, iron-stained, cross-bedded, ripple-marked, bottom markings common, interbedded with thin shale and siltstone.	39.0
Shale, gray-green, blocky, poorly exposed. . .	67.0
Iola formation	
Avant limestone member	
Limestone, purple-gray, massive- to wavy-bedded, fossiliferous, weathers light gray .	22.5
Muncie Creek shale member	
Shale, dark gray, poorly exposed	40.0
Paola limestone member	
Limestone, gray to yellow, sandy at base . . .	2.0
Chanute formation	
Cottage Grove sandstone member	
Sandstone and siltstone, fine-grained, thin-bedded, interbedded with gray shale.	18.0

	Feet
Siltstone and sandstone, platy, buff, increasingly sandy toward top of interval. .	12.0
Shale, dark gray to gray-green, blocky, clayey	17.6
Dewey formation	
Limestone, steel- to purple-gray, yellow on weathered surface, compact, fossiliferous. .	2.6
Shale, dark green to yellow, calcareous, contains numerous lenses and stringers of limestone.	12.0
Limestone, gray to blue-gray, thin- to medium-bedded, dense to medium-crystalline, fossiliferous, interbedded with calcareous shale like that above, base indefinite . . .	6.0

29. Secs. 20 and 21, T. 23 N., R. 12 E.; measured along the farm road, from the base of the hill in the NW$\frac{1}{4}$ sec. 21, westward up the slope into the NE$\frac{1}{4}$ sec. 20.

Wann formation	
Sandstone, yellow to yellow-buff, fine- to medium-grained, massive, fossiliferous, contains several thin siltstone beds, top eroded	11.0
Covered interval	8.0
Sandstone, yellow-buff, fine-grained, medium- to massive-bedded, locally limy, fossiliferous.	14.0
Shale, gray-green, blocky, iron-stained. . . .	45.0
Iola formation	
Avant limestone member	
Limestone, light to purple-gray, coarsely crystalline, wavy-bedded, upper surface pitted by solution	16.5
Muncie Creek shale member	
Shale, dark gray, fissile, contains ironstone concretions and phosphatic nodules	33.0
Paola limestone member, not exposed	
Chanute formation	
Cottage Grove sandstone member	
Sandstone, fine- to medium-grained, medium-bedded, yellow-buff.	7.0
Siltstone and shale, greenish.	1.5
Thayer coal	
Coal, poorly developed, smutty	0.3
Siltstone, light green	1.0
Shale, dark gray-green, blocky, weathers light green.	27.0
Nellie Bly formation	

	Feet
Sandstone, yellow-buff, medium-grained, poorly cemented, not measured.	

30. Secs. 17 and 18, T. 23 N., R. 12 E.; measured up the creek in the SW$\frac{1}{4}$ sec. 17 from its junction with Bird Creek, westward through the quarry, up the dim lease road, toward the central pump station near cen. sec. 18.

	Feet
Wann formation	
Sandstone, orange-red to buff, medium-grained, soft, massive-bedded, ripple-marked, caps hill, top eroded	20.0
Sandstone, dark buff to orange, medium-bedded, contorted, interbedded with calcareous siltstone and shale	14.0
Covered interval	12.0
Sandstone, rusty buff to dirty gray, medium- to fine-grained, cross-bedded, contains thin siltstone partings	8.0
Sandstone, calcareous, thin- to massive-bedded, alternates with bed of limestone and calcareous siltstone, forms first bench above the Avant limestone, highly fossiliferous	20.0
Shale, maroon to gray, blocky, poorly exposed	54.0
Shale, dark gray to yellow	10.0
Iola formation	
Avant limestone member	
Limestone and calcareous shale, gray to cream color, extremely fossiliferous, limestone is wavy-bedded	5.0
Limestone, massive, medium-crystalline, steel-gray, surface pitted by solution	48.0
Muncie Creek shale member	
Shale, dark gray to gray-green, fissile to blocky, base not exposed, measurement approximate	40.0
Alluvium, not measured.	

31. Secs. 7 and 18, T. 23 N., R. 12 E.; measured from the top of the Avant limestone up the slope, along the road to Avant, from the SW$\frac{1}{4}$ sec. 7, to the cen. sec. 18.

	Feet
Wann formation	
Limestone, purple-gray, medium to coarsely crystalline, upper surface covered with fusulinids, "Fusulina-bearing" limestone of Emery	1.0
Covered interval, limestone float	5.5

	Feet
Sandstone, light buff to rusty buff, medium- to massive-bedded, bottom markings, interbedded with siltstone	16.8
Shale and sandstone, poorly exposed.	39.0
Sandstone, rusty buff to buff, medium-grained, thin- to medium-bedded, limy, interbedded with siltstone	4.0
Limestone, steel-gray, dense, interbedded with calcareous shale.	6.0
Covered interval, shale?	11.0
Sandstone, siltstone, shale and limestone, alternating; sandstone, dark buff, iron-stained, fine- to medium-grained; shale and siltstone light to dark gray, limy; limestone dark gray, dense, locally fossiliferous.	33.0
Shale, gray-green to dark gray, blocky contains thin sandstone and siltstone lenses.	72.5
Iola formation	
Avant limestone member	
Limestone, coarsely crystalline, wavy-bedded, crinoid stems common on upper surface, base covered, not measured.	

32. Sec. 10, T. 23 N., R. 12 E.; measured from the approximate position of the Paola limestone, in the creek bed near the N-S fence, northward up the slope in the SE$\frac{1}{4}$.

	Feet
Wann formation	
Limestone, light to dark gray, weathers red, sandy, sparingly fossiliferous, Red limestone of Emery	6.0
Covered interval	11.5
Sandstone, medium-bedded, jointed, poorly exposed.	10.1
Limestone, dark gray, thin-bedded, packed with fusulinids, "Fusulina-bearing" limestone.	1.0
Covered interval, shale?	4.0
Limestone, steel-gray, platy, fossiliferous. .	1.0
Sandstone, orange-buff, thin-bedded, contains molds and casts of brachiopods	1.0
Covered interval, shale and limestone?	30.5
Sandstone, light brown, fossiliferous, appears as float	5.6
Covered interval	11.1
Limestone, dark gray, medium-crystalline, thin-bedded, fossiliferous	5.8
Shale, poorly exposed.	56.0
Iola formation	

	Feet
Avant limestone member	
Limestone, reddish-gray to gray, medium to coarsely crystalline, massive- to wavy-bedded, fossiliferous, crinoid stems common, surface pitted, weathers light to dirty gray	30.5
Muncie Creek shale member	
Shale, dark gray, fissile, phosphatic nodules present in creek bed	39.0

33. Sec. 6, T. 23 N., R. 12 E.; measured along the N-S road from the base of the first limestone, northward up the hill in the $E\frac{1}{2}$.

Wann formation	
Clem Creek sandstone member	
Sandstone, buff to yellow-buff, medium-grained, medium- to massive-bedded, interbedded with green shale and light gray siltstone, top eroded	19.0
Shale, gray-green, blocky, calcareous, contains thin sandstone stringers	20.7
Limestone, reddish-gray, medium-crystalline, fossiliferous, upper bed of the Red limestone.	1.2
Covered interval	7.5
Limestone, rusty gray, upper part fossiliferous, lower bed of the Red limestone	5.0
Shale, greenish-brown, blocky.	11.0
Limestone, light gray to reddish-gray, massive, medium-crystalline, sandy toward top	3.5
Sandstone, buff to orange-buff, medium-grained, medium-bedded, contains several calcareous streaks.	2.5
Limestone, purple-gray, medium-crystalline, upper surface covered with fusulinids, "Fusulina-bearing" limestone	0.7
Sandstone, yellow to orange-yellow, massive. .	2.0
Shale, dull brown to green, blocky	10.6
Sandstone, reddish-gray to buff, limy.	1.0
Shale, dull brownish-green, blocky, calcareous	26.5
Limestone, gray to reddish-gray, thin- to medium-bedded, dense to medium-crystalline, fossiliferous.	3.0
Shale, olive-green to gray-green, fissile to crumbly, interbedded with gray, dense limestone lenses	11.0
Limestone, gray to reddish-gray, medium-crystalline to dense, fossiliferous	3.5

Township 24 North

34. Sec. 26, T. 24 N., R. 9 E.; measured westward along the E-W section-line road, from the creek in the NE$\frac{1}{4}$.

	Feet
Vamoosa formation	
Wynona sandstone member	
Upper sandstone bed	
Sandstone, rusty buff to orange-buff, medium- to coarse-grained, thin- to massive-bedded, cross-bedded, ripple-marked, top eroded	15.0
Shale, dark maroon, blocky, some olive-green shale streaks included within the interval .	19.0
Lower sandstone bed	
Sandstone, buff to rusty brown, medium-grained, thin- to massive-bedded.	16.8
Shale, maroon, blocky, contains streaks of calcareous siltstone	13.0
Sandstone, yellow-buff, medium-grained, iron-stained, not measured.	

35. Secs. 22 and 27, T. 24 N., R. 10 E.; measured from Birch Creek in cen. sec. 22, up bank, thence up the hill, along the SE trending pipeline into sec. 27.

Vamoosa formation	
Sandstone, yellow to brown, high in iron content, fossiliferous (molds and casts).	1.0
Shale, poorly exposed.	5.0
Kiheki sandstone member	
Sandstone, buff, medium-grained, thin- to medium-bedded.	10.0
Covered interval, shale?	6.0
Sandstone, buff to tan, fine- to medium-grained, interbedded with light gray siltstone.	16.0
Shale, maroon, poorly exposed.	16.0
Cheshewalla sandstone member	
Sandstone, buff to rusty buff, medium- to coarse-grained, interbedded with maroon shale.	28.0
Tallant formation	
Covered interval	11.0
Revard sandstone member	
Sandstone, thin- to medium-bedded, light buff	22.0
Covered, sandstone float	27.5
Bigheart sandstone member	
Sandstone, buff, fine- to medium-grained, massive.	46.5

	Feet
Covered interval	5.6
Sandstone and siltstone, light gray to buff, thin-bedded.	16.0
Shale, maroon to gray, blocky.	5.5
Sandstone, light buff, very fine- to fine-grained, medium-bedded	12.0
Shale, maroon to light gray.	11.5
Sandstone, light buff to gray, fine-grained, ripple-marked, exposed in bed of Birch Creek, not measured.	

36. Sec. 31, T. 24 N., R. 11 E., and sec. 6, T. 23 N., R. 11 E.; measured along the N-S road, southward from the SE$\frac{1}{4}$ sec. 31, up the hill into the NE$\frac{1}{4}$ sec. 6.

	Feet
Barnsdall formation	
Okesa sandstone member	
Sandstone, rusty buff, medium-grained, medium-bedded, cross-bedded, casts and molds present in several layers.	10.0
Shale and siltstone.	3.0
Sandstone, greenish-buff, fine- to medium-grained, massive, contorted.	2.5
Shale and siltstone, gray-green.	3.0
Sandstone, greenish-buff, medium-grained, iron-stained, massive.	4.0
Shale and siltstone, light to dark gray. . . .	3.0
Sandstone, light gray, massive	5.0
Shale, gray-green.	1.5
Sandstone, gray to buff, medium-grained, thin- to medium-bedded, ripple marked.	2.0
Shale and siltstone, light gray to gray-green.	1.0
Sandstone, rusty brown, medium-grained, contains molds and casts, thin- to medium-bedded, bottom-marked	5.0
Covered interval	1.5
Birch Creek limestone member?	
Sandstone, light gray to red, medium-grained, limy	1.0
Sandstone, light gray to buff, poorly cemented, occurs in one bed.	2.0
Wann formation	
Shale, gray-green, blocky, not measured.	

37. Secs. 19 and 30, T. 24 N., R. 11 E.; measured from the base of the Barnsdall formation in the NW$\frac{1}{4}$ sec. 30, along the pipeline to the Bigheart bench at the S edge of the SW$\frac{1}{4}$ sec. 19.

Tallant formation

	Feet
Bigheart member	
Sandstone, yellow to buff, coarse-grained, contorted appears as float at tree line above shale prairie, not measured.	
Barnsdall formation	
Shale, poorly exposed, probably gray-green . .	58.0
Okesa sandstone member	
Sandstone, rusty buff, fine- to medium-grained, medium-bedded, surface pitted . . .	5.5
Covered interval	5.5
Sandstone, buff to orange-buff, medium-bedded.	7.5
Covered interval, shale and siltstone?	11.7
Sandstone, buff, medium- to coarse-grained, massive, cross-bedded, contorted	7.0
Covered interval	10.0
Birch Creek limestone member	
Limestone, steel-gray, dense, platy to medium-bedded, dolomitic, sandy, weathers maroon. .	3.5

38. Sec. 30, T. 24 N., R. 12 E., and sec. 25, T. 24 N., R. 11 E.; measured from the base of the Clem Creek member in the draw N of the road, in the NW$\frac{1}{4}$ sec. 30, to top of hill, along the dirt road in the NE$\frac{1}{4}$ sec. 25.

Barnsdall formation	
Birch Creek limestone member	
Limestone, rusty gray, thin-bedded at base, medium-bedded at top, very sandy, weathers into rounded, maroon boulders, sparingly fossiliferous.	3.0
Wann formation	
Sandstone, brownish-buff, fine- to medium-grained, medium-bedded, contorted, Torpedo sandstone equivalent?.	7.5
Shale, gray green, blocky.	72.0
Clem Creek sandstone member	
Sandstone, buff to yellow-buff, medium- to coarse-grained, medium- to massive-bedded, contorted.	20.0

39. Sec. 30, T. 24 N., R. 12 E.; measured from the pipeline crossing the creek, up the lease road, southeastward to the top of the hill in the SE$\frac{1}{4}$.

Wann formation	
Clem Creek sandstone member?	
Sandstone, yellow-buff, fine- to medium-grained, numerous molds and casts, top eroded	16.0
Covered interval, shale and limestone?	16.5

	Feet
Limestone, rusty to light gray, medium to coarsely crystalline, weathers deep maroon, Red limestone.	10.0
Covered interval	4.0
Limestone, reddish-gray, wavy-bedded, fossiliferous.	1.0
Limestone and shale, purple-gray, dense, sandy, locally medium-crystalline and fossiliferous.	7.5
Covered interval, shale?	9.0
Sandstone, brown, medium-grained, thin- to massive-bedded, contorted, poorly exposed, may include gray shale	28.0
Shale and siltstone.	11.0
Shale, gray-green.	9.0
Sandstone, buff, thin- to medium-bedded. . . .	6.0
Shale, gray-green, calcareous.	8.0
Sandstone, yellow to tan, medium-grained, massive.	6.0
Shale, dark gray-green, blocky	33.0
Limestone, dark gray, dense, platy, fossiliferous.	1.0

40. Composite measured section of the N$\frac{1}{2}$ T. 24 N., Rs. 10 and 11 E., after Tanner (1956, pp. 64-66).

Vamoosa formation	
Wynona sandstone member	
Shale, interval to horizon of Middle Oread limestone.	15.0
Upper sandstone bed	
Sandstone, buff, thin to thick-bedded.	24.0
Shale, covered	20.0
Lower sandstone bed	
Sandstone, buff, very fine-grained, or siltstone, shale lenses locally, laminated to massive, low angle cross-bedding	26.0
Shale and soft silt.	18.0
Sandstone, soft.	8.0
Sandstone, buff, very fine-grained, ledge. . .	6.0
Shale.	10.0
Sandstone, buff, very fine-grained, siltstone.	2.0
Shale, covered	14.0
Sandstone, buff, soft, contorted	12.0
Shale, covered	20.0
Cochahee sandstone member	
Sandstone, buff, Four Mile sandstone	10.0
Shale, khaki-colored, few siltstone and sandstone ledges up to one foot thick.	55.0

	Feet
Kiheki sandstone member	
Sandstone and siltstone, buff, very fine-grained, locally contorted	8.0
Shale.	6.0
Sandstone, siltstone and some shale, alternating, buff and gray-green, sandstone very fine-grained.	11.0
Shale, light and dark gray-green	35.0
Cheshewalla sandstone member	
Sandstone, buff, massive, low angle cross-bedding.	17.0
Tallant formation	
Shale, covered	25.0
Sandstone, buff, soft, thin-bedded	8.0
Shale, gray-green.	5.0
Sandstone, buff, medium-bedded	5.0
Sandstone, brown, very fine-grained, locally siltstone, contorted and cross-bedded. . . .	12.0
Sandstone, buff.	10.0
Shale and silt	8.0
Revard sandstone member	
Siltstone and very fine-grained sandstone, shale lenses buff and gray-green	15.0
Shale, maroon.	12.0
Shale, white, maroon, gray-green	15.0
Siltstone and shale, alternating, siltstone thin-bedded and cross-bedded	14.0
Bigheart sandstone member	
Sandstone, buff, thin to massive, locally siltstone, locally clay pebble conglomerate, cross-bedded	45.0
Shale and silt, red.	3.0
Shale, red and gray-green.	8.0
Sandstones, siltstones and shales, soft, thin-bedded.	11.0
Shale, red	5.0
Siltstone and sandstone, buff and gray-green .	2.0
Shale, red and gray-green.	4.0
Siltstone and shales, alternating, gray-green, lenses of sandstone.	12.0
Sandstone, buff, weathers pinkish, shale lenses to one foot thick.	12.0
Shale, red and gray-green.	3.0
Sandstone, buff, fine-grained, thin-bedded to massive, low angle cross-bedding common, locally siltstone, locally laminated	9.0
Barnsdall formation	
Shale, partly covered, considerable float. . .	82.0
Okesa sandstone member	

	Feet
Siltstone, gray-green, thin-bedded to laminated, calcareous, bottom markings . . .	5.0
Shale, gray-green.	22.0
Siltstone, as above.	3.0
Shale, gray-green.	4.0
Siltstone, as above.	9.0
Sandstone, buff, thick-bedded, fine- to very fine-grained.	5.0
Birch Creek limestone member.	----