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THE GEOLOGY OF THE PAWHUSKA AREA, OSAGE COUNTY, OKLAHOMA

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PATRICK JOSEPH SHANNON

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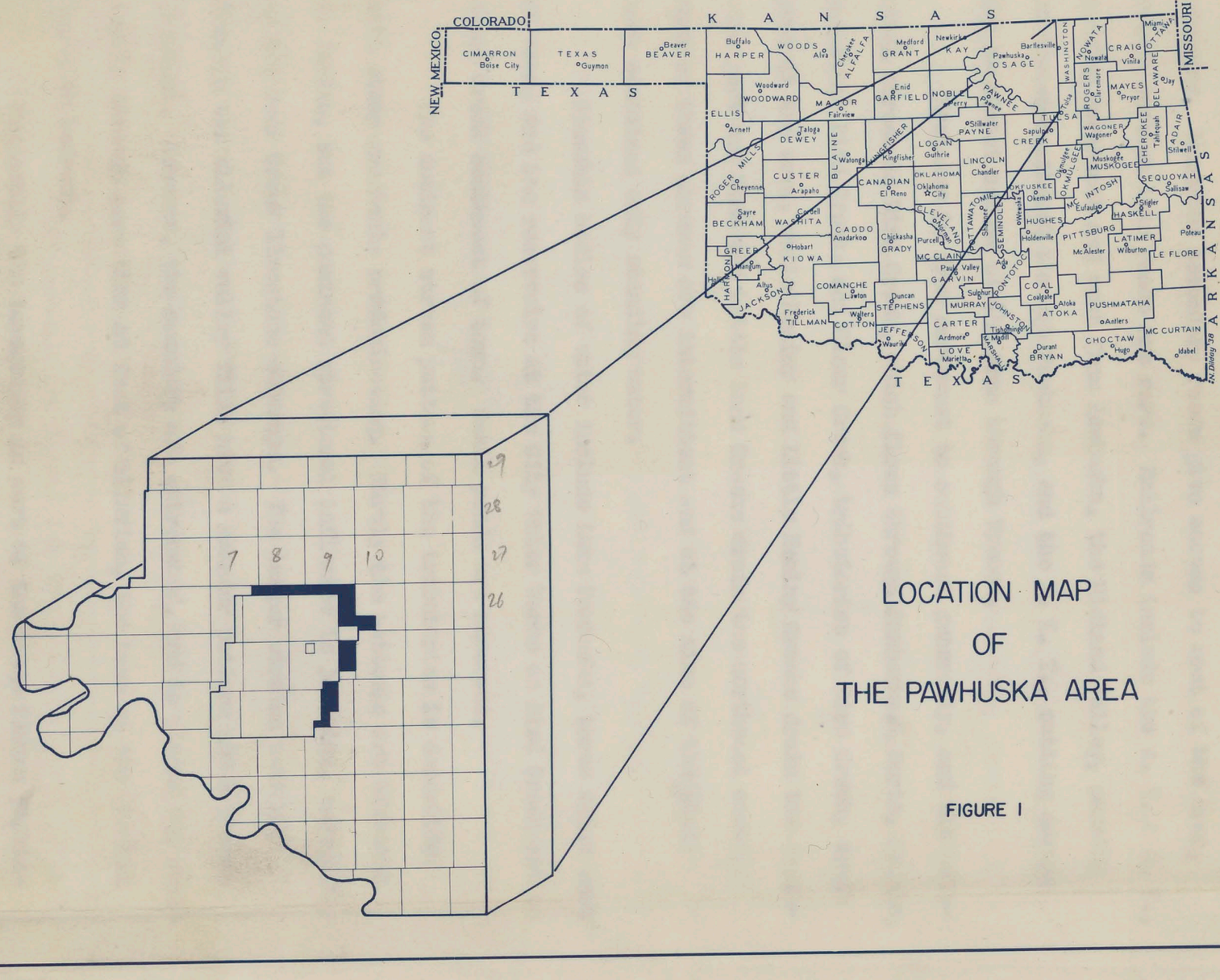
CHAPTER I

INTRODUCTION

The Pawhuska area lies in the approximate center of Osage County, Oklahoma, and includes Townships 24, 25, and 26 North, Ranges 8 and 9 East and parts of Ranges 7 and 10 East, the eastern boundary being the outcrop of the Oread limestone and the western boundary the outcrop of the Wakarusa limestone. The principal town is the county seat, Pawhuska, population over 5,300 according to the 1950 census. Other communities include Wynona, population approximately 680, Naval Reserve Village, and the Texas Company Atlantic Field Camp.

The purpose of this thesis is to present a detailed report of the surface stratigraphy of rocks of the Virgil Series (upper Pennsylvanian) between the middle bed of the Oread limestone and the Wakarusa limestone, with emphasis on the change in lithology along the general north-south strike, and to map the areal geology by tracing outcrops of selected marker beds. Study of the structure is confined to surface faults and regional dip. Field work was done from mid-September to mid-December, 1953.

Running north-south completely across the eastern part of the area is State Highway 99, which is joined by State Highway 11 and U.S.



LOCATION MAP OF THE PAWHUSKA AREA

FIGURE 1

Highway 60. Highway 60 also runs west from Pawhuska past the western boundary. Numerous secondary roads give access to most of the area, though section line roads are rare. Railroads include the A. T. & S. F., running northeast and west from Pawhuska, the Midland Valley, passing northwest-southeast through Pawhuska, and the M. K. T., cutting across the southeast corner of the area through Wynona.

Drainage is from northwest to southeast generally, and the principal stream is Bird Creek, which flows through Pawhuska. North, Middle, and South Bird Creeks and Clear Creek, tributaries of Bird Creek, drain most of the area, while Hominy and Little Hominy Creeks drain the southwest part and Sand and Little Sand Creeks drain the northeast corner. Most of these streams are intermittent and at the time of the field work contained only standing water.

Sizeable bodies of water include Lake Pawhuska, three miles west of town, and the reservoirs at the City Water Works on Bird Creek and on Clear Creek southwest of town. Small ponds are numerous.

The dominant stream pattern of the tributaries is dendritic, with steep gradients predominating. Rarely the patterns are affected by faults, but the dominant structural influence is jointing, especially in the Deer Creek limestone outcrops. The larger streams cutting through the alluvial valley fills have a meander pattern and a lesser gradient. However, the meanders are entrenched, and in places cut vertically through more than 40 feet of alluvium, the base of the channel being on bedrock.

Regionally the topography is part of the Osage Plains physiographic province, and locally is situated in that part of the Sandstone

Hills known as the Chautauqua Hills. The western boundary of the area extends to the base of the Flint Hills[1]. Locally the topography is determined by the alternating beds of shale, sandstone, and limestone dipping gently to the west-northwest. (how fast?)

Running along the eastern edge of the mapped area is a series of prominent hills capped by the massive Elgin sandstone, above wide, alluvial filled valleys cut in the less resistant Kanwaka shales. Most of the hills are thickly covered with scrub oak, which gives way to grass cover in the shales below. These hills are readily observed west of Highway 99, which runs along the valley roughly parallel to them.

Westward the country rises in a series of east-facing cuestas capped by the more resistant limestones and sandstones and forming rolling prairie. These cuestas are mostly grass-covered, with occasional belts of scrub trees marking the outcrops of thick sandstones and streams. In the southern part of the area the tree cover increases, tending to obscure outcrops. The most easily recognizeable of the cuesta escarpments is that formed on the 15 to 35 foot thick Deer Creek limestone. Less prominent are the escarpments of the Little Hominy limestone, which is sandy along much of its outcrop, the Turkey Run limestone, and the Bird Creek limestone. The Wakarusa limestone, the highest bed mapped, does not form a prominent escarpment but crops out at the base of the Flint Hills and is poorly exposed or covered by slumpage of overlying beds and by soil along most of the outcrop.

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[1] William Eugene Ham. Origin and Age of the Pawhuska Rock Plain of Oklahoma and Kansas, unpublished Master's Thesis, Univ. of Okla., Norman, Okla., 1939.

Figure 2. The grass-covered, rolling prairie of the western part of the Pawhuska area. This view was taken looking northward from the large hill in the southwest quarter of sec. 11, T. 26 N., R. 8 E.

The most prominent topographic features are in most cases capped by the Elgin sandstone. These include Wooster Mound, four miles south of Pawhuska; the large hill rising in the north section of the town, known as "Flannigan's Hill"; "Lovers' Leap", approximately 0.75 mile north of the City Water Works; and Hominy Falls on Hominy Creek in the southwest part of the area.

The regional dip is approximately 40 feet per mile, N. 80° W., as computed by the three point method, using elevations from the U.S.G.S. topographic maps of the Pawhuska Quadrangle, edition of April, 1910, reprinted in 1923, and the Fairfax Quadrangle, edition of 1932.

Measurement of stratigraphic sections was made by use of the hand level and tape method. A six foot steel tape graduated in inches was used and these measurements converted to tenths of feet. For vertical sections of greater than six feet a 40 foot weighted cord graduated in feet was used. Since the regional dip is slight, it was disregarded in measuring the sections at most localities; however, some local structures made corrections necessary.

The mapping of marker beds was done on aerial photographs having scales of from 2.8 to 3.4 inches per mile. This, along with drainage, roads, and other culture, was transferred to a base map having a scale of 3 inches per mile.

The Pawhuska area is perhaps most widely known as the type locality of the Pawhuska formation, which was first described by Smith in 1894 and known originally as the "Pawhuska limestone".[2]

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[2] J.P. Smith, "The Arkansas Coal Measures in Their Relation to the Pacific Carboniferous Province", Journal of Geology, Vol. II (1894), p. 199.

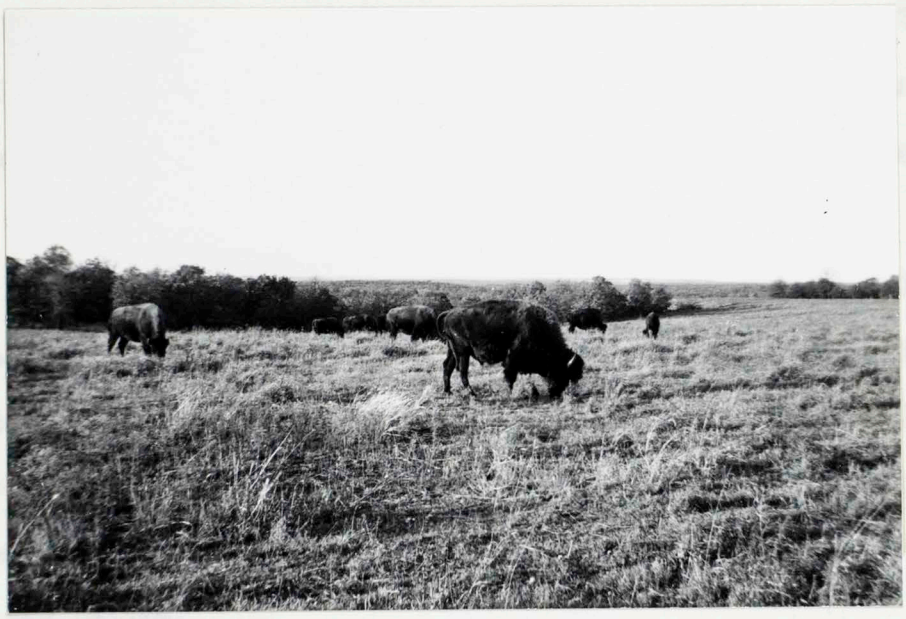

Figure 3. Grass-covered Pawhuska formation and underlying, tree-covered Elgin sandstone, in the southeast quarter of sec. 21, T. 25 N., R. 9 E. Domestic buffalo in foreground.

Other previous work in the area was done by K. C. Heald and others and published in 1922 [3], with the primary purpose of recommending drilling locations for oil and gas in Osage County. Their work consisted of mapping local structures on selected marker beds and descriptions of these beds, with little attention given to intermediate beds. Marker beds used included, from top to bottom, the "Cryptozoon-bearing limestone" (Wakarusa limestone), Bird Creek limestone, Turkey Run limestone, Little Hominy limestone, Deer Creek limestone, Plummer limestone, Lecompton limestone, Okay limestone, Elgin sandstone, and Oread limestone.

In 1928, J.T. Beckwith [4] published a report on the geology of Osage County including an outcrop map of the important marker beds and the major faults. Descriptions of the beds are included, but little was added to the surface work done by Heald. The report was a compilation of the work of different geologists and was intended primarily as an oil and gas report.

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[3] K. C. Heald and others, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma", U. S. Geol. Survey Bull. 686, 1922.

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

CHAPTER II

STRATIGRAPHY AND LITHOLOGY

Virgil Series

The Virgil is the uppermost series of the Pennsylvanian system of the Mid-Continent region and is bounded above and below by unconformities throughout much of the region, the upper boundary being the base of the Indian Cave channel sandstone and the lower the base of the Tonganoxie channel sandstone in Kansas. R. C. Moore [5] has, in his latest report, divided the Virgil series of Kansas into three groups, in descending order, Wabaunsee, Shawnee, and Douglas.

In central Oklahoma a different grouping of the beds has been used. Morgan [6] divided the series into three formations, from top to bottom, Vanoss, Ada, and Vamoosa. The Vanoss and Ada formations are equivalent to the Wabaunsee group and the upper part of the Shawnee group; and the Vamoosa formation is equivalent to the lower part of the Shawnee group and the Douglas group.

The base of the Shawnee group in Kansas is drawn at the base of the Oread limestone. This bed crops out in the northern part of the

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[5] R. C. Moore and others, "The Kansas Rock Column", Kansas Geol. Survey Bull. 89, 1951.

[6] George D. Morgan, "Geology of the Stonewall Quadrangle, Oklahoma", Oklahoma Bureau of Geology, Bull. No. 2 (1924), pp. 125-128.

Pawhuska area, is poorly exposed across most of the area and does not crop out as a well defined bed south of Township 25 North.

Therefore the grouping of beds in the Pawhuska area used in this thesis is a combination of the usages of geologists of the two states. The base of the Oread limestone is the base of the Shawnee group, the top of the Douglas group, and also the base of the upper Vanoosa formation. The formation names Ada and Vanoss are not used, the top of the Shawnee group being drawn at the top of the Turkey Run limestone, and above that is the Wabaunsee group.

In the Pawhuska area the Virgilian is predominantly marine and non-marine shale, alternating with thin to thick sandstone beds and numerous thin limestone beds. A few of the sandstone beds contain marine fossils, but most show cross-bedding and ripple marks, indicating non-marine or shallow marine deposition. The thickness and number of the sandstones increases southward across the area. Most of the limestone beds are continuous across the area with little change in thickness or appearance.

The total thickness of the section decreases from about 560 feet in the northern part of the area to about 500 feet in the southern part.

The alternation of limestones, shales, and sandstones suggests cyclic sedimentation. One coal bed, the Rhea coal, crops out in the northern part of the area. Black, fissile shale beds occur above the Oread, Plummer, and Bird Creek limestones; fossiliferous shales occur associated with them, and also above the Deer Creek limestone. However, grouping of the stratigraphic units as cyclothems has not been attempted, due to the lack of good exposures of the complete section.

Shawnee Group

The Shawnee group was originally described by Haworth [7] in 1898, as being a succession of alternating limestones and shales between the top of the Oread limestone and the bottom of the Burlingame limestone, type locality in Shawnee County, Kansas. R. C. Moore [8] redefined the group in 1931 by lowering the base to the base of the Oread limestone and lowering the top to the top of the Topeka limestone.

Since, according to Moore, the Turkey Run limestone of the Pawhuska area is equivalent to the Topeka, it is taken as the upper boundary.

The group consists predominantly of shale and includes numerous sandstone beds. Several thin limestone beds occur in the upper part, while only one continuous bed is found in the lower part, and that at the base. This presents a natural division into two formations, the upper Vamoosa (at the base) and the Pawhuska.

Vamoosa Formation

History of nomenclature. G. D. Morgan [9] originally described the formation from an exposure near Vamoosa, Oklahoma, in the northern part of the Stonewall Quadrangle. In that area it consists mainly of

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[7] E. Haworth, "Stratigraphy of the Kansas Coal Measures", Kansas Univ. Geol. Survey, vol. III, Pt. I (1898), p. 93.

[8] R.C. Moore, Kansas Geol. Soc. Fifth Annual Field Conference Guidebook, 1931, Correlation Chart.

[9] Morgan, op. cit., 1924, pp. 125-128.

chert conglomerate with sandstones and red shales, and a dark shale layer at the base.

Correlation. The base is marked by an unconformity in central Oklahoma according to Green [10]. The stratigraphic position of this unconformity, the base of the Cheshewalla sandstone, was traced northward to the Kansas line by Oakes [11], who found that the horizon is conformable at some places and unconformable at others. Due to the difficulty of tracing sandstone beds and the poor exposures, he has stated that the base of the Cheshewalla is, at best, a doubtful equivalent of the base of the Tonganoxie sandstone (base of the Virgil) of Kansas.

By comparing the author's map with Oakes' unpublished map, it was found that the base of the Vamoosa formation in the Pawhuska area lies approximately 150 feet below the Oread limestone. Since the Oread also lies approximately 150 feet below the base of the Lecompton limestone (base of the Pawhuska formation), it may be considered the "middle" of the Vamoosa formation. On this basis the Vamoosa has been arbitrarily divided into an upper and a lower division. This thesis includes only beds of the upper Vamoosa formation, since the Oread limestone was the lowest bed studied.

Oread Limestone Member

History of nomenclature. The Oread limestone was originally

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[10] Darsie A. Green, "Permian and Pennsylvanian Sediments Exposed in Central and West-Central Oklahoma", Amer. Assoc. Petroleum Geol. Bull., vol. 20 (1936), pp. 1459-1460.

[11] M.C. Oakes, personal communication, 1954.

described by Haworth [12] in 1894 in the vicinity of Lawrence, Kansas, and named for Mount Oread. Although for many years it was considered the topmost formation in the Douglas group in Kansas, it is now considered the basal formation of the Shawnee group.

Correlation. Moore [13] described the formation as being approximately 100 feet thick in southern Kansas and as consisting of four limestone members and three shale members. In the Pawhuska area only one of these limestone members is found and this has been correlated by Carter [14] with the Leavenworth member. This same correlation was made previously by Heald [15] and Winchester [16], who called it simply the middle member of the Oread limestone. In this thesis it is called the Oread limestone without reference to member names.

Description and Areal Extent. The Oread limestone crops out across most of the area at the base of the hills capped by the Elgin sandstone. Since the bed also thins southward, good exposures are rare, and much of the mapping of the bed was done on the basis of small limestone fragments or nodules littering the surface. It does not form escarpments, and only rarely is its position indicated by terraces.

At an exposure approximately one mile north of the Pawhuska area, in the N.E. ¼ of sec. 36, T. 27 N., R. 8 E., it consists of 1.5

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[12] F. Haworth, "A Geologic Section Along the A. T. & S. F. R. R. from Cherryvale to Lawrence, and from Ottawa to Holliday", Kansas Univ. Quart., vol. 2 (1894), p. 123.

[13] Moore and others, op. cit., 1951, p. 67.

[14] J.A. Carter, personal communication, 1954.

[15] K.C. Heald, U.S. Geol. Survey Bull. 686-E (1922), P. 27.

[16] D.E. Winchester, U. S. Geol. Survey Bull. 686-C (1922), P. 11.

feet of pebble limestone overlain by 0.2 foot of light gray, dense, fossiliferous, fusulinid limestone, with a thin shale parting between the two beds.

In the S. E. ¼ of sec. 12, T. 26 N., R. 8 E., is a small hill supported by the bed, which is not well exposed. However, fragments of gray, fusulinid limestone litter the sides of the hill, indicating its approximate position.

Farther south the Creed crops out in a railroad cut beneath the gravel road overpass just east of Highway 60 in the S. W. corner of sec. 23, and in a pond excavation in the S. W. ¼ of sec. 24, both in T. 26 N., R. 9 E. It consists of 1.5 feet of "crumbly", fossiliferous, fusulinid limestone cut by numerous vertical joints and weathering orange-brown.

On the south side of the A. T. & S. F. railroad cut just west of the fault in the S. E. ¼ of sec. 9, T. 25 N., R. 9 E., is a poor exposure of a one foot bed of light brown, conglomeratic limestone, which is probably the Creed limestone, although the intervals above and below are covered.

South of this locality no exposures of the Creed as a definite bed were found by the author, and the limestone fragments and nodules previously mentioned were found at few places. In T. 24 N., R. 8 E., the mapping was done mainly on the position of the fossiliferous shale at the base of the Kamaka shale and the base of the escarpment formed on the Elgin sandstone.

Paleontology. Fossils found in the member include:

Tritoites sp.
brachiopods (unidentifiable)

Kanwaka Shale Member

History of nomenclature. Beede [17] in 1902 named the member from G. I. Adam's unpublished manuscript, in which it was named from Kanwaka Township, Douglas County, Kansas.

Originally the Kanwaka shale was treated as the base of the Shawnee group; later the base of the group was lowered to include the Oread limestone.

Correlation. The Kanwaka is the topmost member of the Vanoosa formation and is bounded above by the base of the Lecompton limestone. The base of the member is the top of the Oread limestone and, where this is absent, the base is marked by the dark gray, fossiliferous zone in the lower part.

Description and areal extent. The Kanwaka is predominantly shale, which contains numerous sandstone beds. The lower approximately 20 feet is dark, calcareous, and fossiliferous. Above this section lies about 60 feet of light, sandy, non-fossiliferous shale. The upper portion contains numerous sandstone beds and one massive sandstone unit near the top, called the Elgin sandstone, which varies from 20 to 40 feet thick. The top of the Elgin is separated from the base of the Lecompton by a green and maroon shale which varies from five to ten feet thick in the north to ten to forty feet farther south and which is exposed at few places. At one locality a limestone bed crops out in the shale below the Elgin. The thickness of the member is about 150 feet.

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[17] J.N. Beede, "Coal Measures Faunal Studies II", Kansas Univ. Science Bull., vol. 1, no. 7, 1902.

Although the Kanwaka shale outcrop is poorly exposed and covered by talus from the Elgin sandstone in most places, several man-made excavations in the Pawhuska area reveal the complete thickness and are spaced widely enough over the area to give an accurate picture of the lateral variations.

The lower part is well exposed in the railroad cut previously mentioned, beneath the gravel road overpass east of Highway 60 in the S. W. corner of sec. 23, T. 26 N., R. 9 E. Above the Oread limestone lies 25 feet of shale, the bottom six feet of which is black, fissile, and fossiliferous; above, the shale becomes greenish-gray, nodular, with few fossils and numerous limonitic concretions. No fossils were found in the upper twelve feet. Worthenia tabulata and Trepospira discoidalis are the most common fossils, and this locality is the only one where the author found Paraconularia crustula.

East of the Midland Valley Railroad in the eastern half of sec. 30, T. 26 N., R. 9 E., and in the S. E. ¼ of sec. 19, T. 26 N., R. 9 E., approximately 125 feet is exposed, and at this locality more sandstone is included in the member than at any other exposure. It consists of 15 feet of gray, silty shale, which locally thins to five feet, overlain by five feet of irregularly cross-bedded sandstone, which locally thickens to 25 feet at the expense of the underlying and overlying shales. Above this is 40 to 50 feet of buff shale containing occasional thin sandstone beds. The only limestone bed in the Kanwaka (below the Elgin sandstone) is exposed at this locality 25 feet above the thick sandstone. It is a 1.8 foot bed of gray, coarsely crystalline, fossiliferous limestone which weathers gray with the fossils standing in relief and

bleached white, and caps a four foot bed of cross-bedded sandstone. The total section is capped by 25 feet of Elgin sandstone.

At the abandoned shale quarry of the old Pawhuska Vitrified Brick and Tile Co. just west of the city limits in the east central part of sec. 5, T. 25 N., R. 9 E., is an excellent exposure. The base of the quarry lies about 15 feet above the base of the member. Eighty feet of shale is exposed, capped by 55 feet of the Elgin sandstone, which is poorly exposed. The shale is dark gray at the base, grading upward to olive drab at the top; it contains occasional thin calcareous sandstone and siltstone layers, occasional ferruginous streaks, and limonite concretions in the middle third of the exposure. No fossils were found.

All except the lower part of the Kanwaka is well exposed in a road cut in the N. E. ¼ of sec. 16, T. 24 N., R. 8 E., where it consists of approximately 80 feet of light colored shale with a few siltstone layers, overlain by 25 feet of Elgin sandstone, which in turn is overlain by about 15 feet of buff shale, and topped by a two foot layer of red shale.

The best exposure for fossil collecting is at an old excavation and pond northeast of the abandoned race track in the N. E. ¼ of sec. 32, T. 24 N., R. 9 E. The lower part of the hillside is literally covered with fossils, the most numerous being Worthenia tabulata and Trepospira discoidalis. The lower 22 feet is dark gray to black, fissile to nodular shale containing numerous limonite concretions and dark gray, silty limestone layers, out of which the fossils appear to weather. Above this is 50 feet of poorly exposed, buff shale containing abundant limonite concretions and a few fossils.

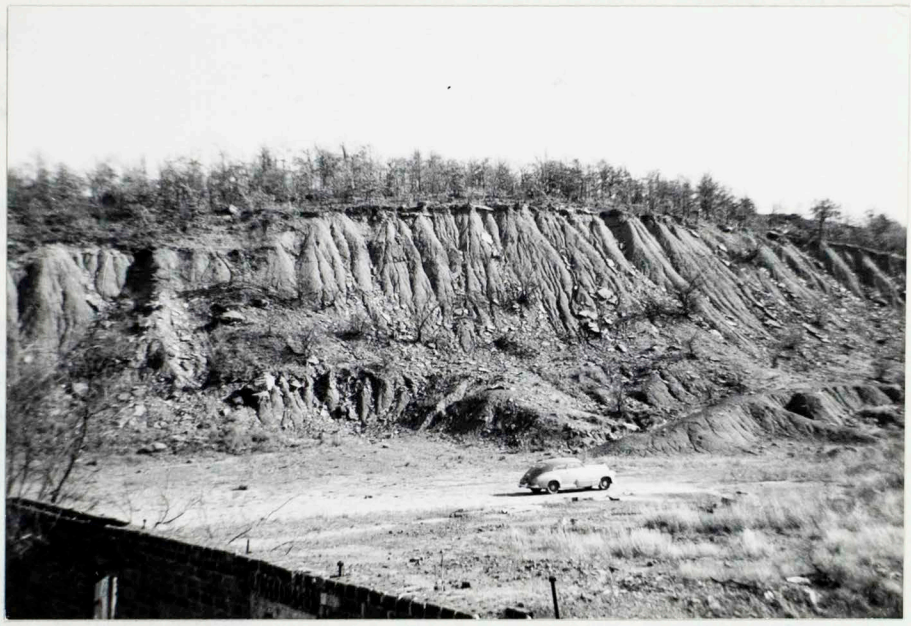

Figure 4. Kanwaka shale, in abandoned shale quarry of old Pawhuska Vitrified Brick & Tile Co., just west of Pawhuska city limit in the east central part of sec. 5, T. 25 N., R. 8 E.

That part of the Kanwaka shale above the Elgin sandstone is, as previously mentioned, rarely well exposed. At the west end of the Lake Pawhuska dam in sec. 13, T. 25 N., R. 8 E., seven feet of maroon shale is capped by a three foot layer of light tan, calcareous sandstone, which is approximately the base of the Lecompton. Farther south, in the N. W. ¼ of sec. 6, T. 24 N., R. 9 E., approximately 15 feet of green and maroon shale crops out below the lowest limestone of the Lecompton.

Paleontology. Fossils found in this member include:

Coelenterata

Lophophyllidium sp.
Paraconularia crustula (White)

Brachiopoda

Crurithyris planoconvexa (Shumard)
Lingula carbonaria Swallow
Linoproductus sp.
Orbiculoidea missouriensis (Shumard)
Wellerella osagensis (Swallow)

Pelecypoda

Allorisma granosum (Shumard)
Astartella vera Hall
Conocardium sp.
Cypricardinia sp.
Nuculana bellistriata (Stevens)
Nuculopsis ventricosa (Hall)
Yoldia glabra Beede and Rogers

Gastropoda

Glabrocingulum grayvillense (Norwood and Pratten)
Meekospira sp.
Strobeus sp.
Trepospira discoidalis (Newell)
Worthenia tabulata Conrad

Cephalopoda

Euphemites regulatus Moore
Gastrioceras sp.
Schistoceras hildrethi (Morton)

Fossil collecting localities. Good collecting localities include: N.E. ¼ of sec. 32, T. 24 N., R. 9 E., south-facing hill point northeast of old race track.

S.W. corner of sec. 23, T. 26 N., R. 9 E., railroad cut below gravel road overpass east of Highway 60.

Elgin Sandstone Unit

History of nomenclature. The Elgin sandstone was first described by Haworth [18] in 1898 at the suggestion of G. I. Adams, and named for its exposures near Elgin, Kansas, where it is approximately 140 feet thick.

Correlation. The Elgin sandstone of southern Kansas is tentatively correlated with the topmost (Stull shale) member of the Kanwaka shale by Moore and others [19]. The Elgin of Oklahoma is mapped by Miser [20] as the top of the Vamoosa formation.

Description and areal extent. The Elgin sandstone varies laterally from a single thick, massive bed to numerous thin beds alternating with shale. At those places where it is a single massive bed or two massive beds it is usually well exposed due to its resistance to weathering, but the shaley portions are covered at most places. Therefore the unit is better known as a massive sandstone, with little known about the shales or thin sandstones. The included shales, when present, make it difficult to separate from the rest of the Kanwaka shale. This variation is only local, with no consistent thickening of the sandstone or shale along the strike in the Pawhuska area.

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[18] E. Haworth, "Stratigraphy of the Kansas Coal Measures", Kansas Univ. Geol. Survey, vol. III, Pt. I (1898), p. 64.

[19] Moore and others, op. cit., 1951, p. 67.

[20] H.D. Miser, Geologic Map of Oklahoma, (manuscript copy), April, 1953.

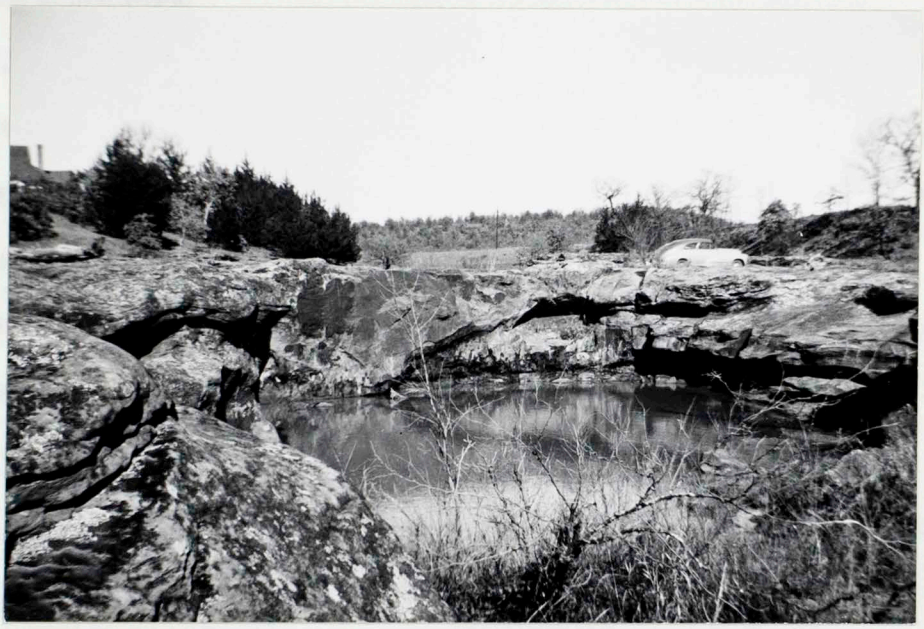

Figure 5. Elgin sandstone, at Hominy Falls on Hominy Creek in the southwest quarter of sec. 29, T. 24 N., R. 8 E.

At all exposures observed by the author the massive Elgin sandstone consists of medium grained, clean sandstone with sub-rounded grains, which weathers dark brown to gray, with a few exposures weathering pink to orange. Massive, irregular cross-bedding accompanies rapid variation in thickness locally. The top of the bed is at most places marked by ripple marks. The sand was probably deposited in a shallow water or non-marine environment.

The Elgin sandstone consists of a single massive bed varying locally to numerous thin beds across most of the area; however, in the ravine downstream from the Lake Pawhuska Dam it consists of two massive beds separated by from 10 to 20 feet of probably maroon shale. The lower bed is over 43 feet thick, and massive-bedded, and the upper is 20 feet thick and thin-bedded. Both are cross-bedded.

The thickness varies up to a maximum of 55 feet, which thickness is found northwest of Pawhuska in the Bluff known locally as "lovers' leap" (N. W. corner of sec. 4, T. 25 N., R. 9 E.). Near the northern boundary of the area in the S. W. ¼ of sec. 1, T. 26 N., R. 8 E., approximately 50 feet of the unit is exposed, of which only the lower 21 feet is a massive bed, above that being thick-bedded sandstone alternating with shale. In the road cut in the N. E. ¼ of sec. 16, T. 24 N., R. 8 E., it is 25 feet thick, and at Hominy Falls in the S. W. ¼ of sec. 29, T. 24 N., R. 8 E., it is about 20 feet thick.

The only limestone found in the Elgin sandstone crops out in the S. E. ¼ of sec. 11, T. 26 N., R. 8 E. Capping the sandstone is 2.75 feet of light brown, sandy limestone grading upward to 0.5 foot of light gray, algal, fusulinid limestone.

No fossils are found in the unit other than those in the limestone bed just mentioned.

Pawhuska Formation

History of nomenclature. J.P. Smith [21] published the first description of the Pawhuska formation in 1894, from the field description of Herbert C. Hoover of the Arkansas Geological Survey, who described it as "... a bed of massive limestone about 100 feet thick ... found at the government lime kiln, three miles northwest of Pawhuski, Oklahoma Territory ...." [22].

This description was apparently an error in transferring from field notes to publication, since the only thick limestone bed in the vicinity of Pawhuska is about 20 feet thick. In spite of this original error, later geologists working in the area have continued to use the hundred foot figure for the thickness. The spelling of the town name also has changed since Hoover's work. Therefore, Smith's "Pawhuski limestone" is now known as a member of the Pawhuska formation.

More definite limits and descriptions were given for the formation in the northwest part of the Pawhuska Quadrangle in 1918 by K. C. Heald [23], who placed the top at the top of the "red lime" and the base at the top of the Elgin sandstone. He described it as being

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[21] Smith, op. cit., 1894, pp. 199-200.

[22] Ibid., 1894, p. 199.

[23] K. C. Heald, "Geologic Structure of the Northwestern Part of the Pawhuska Quadrangle, Oklahoma", U.S. Geol. Survey Bull. 691-C, 1918.

130 to 180 feet thick and consisting of shale alternating with thin sandstone beds and containing seven limestone beds, the thickest of which is about ten feet.

Present usage, according to C. C. Branson [24], places the top of the Pawhuska formation at the top of the Turkey Run limestone and the base at the base of the Lecompton limestone.

Correlation. The Pawhuska formation is equivalent in age to the upper part of the Shawnee group of Kansas and to the lower part of the Vanoss-Ada formation of Oklahoma, as mapped by Miser [25]. Tanner [26] has stated that the stratigraphic position of the Pawhuska formation in Okfuskee County, Oklahoma, is between the Ada and Vanoss formations and that it disappears southward due to truncation by the overlying Ada formation, the southernmost exposures being found in the western part of Okfuskee County.

Description and areal extent. The formation consists largely of shale, with several thick sandstone beds near the top, numerous thin limestone beds and one thick bed near the base, and three thin limestone beds in the upper part.

The thickness varies from 180 feet in the northern part of the area to 210 feet in the southern part. This thickening is accompanied by an increase in the total thickness of the sandstone beds and a

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[24] Carl C. Branson, personal communication, 1954.

[25] Miser, op. cit., 1953.

[26] William F. Tanner, Jr., The Geology of Seminole County, Oklahoma, Ph. D. Thesis, Univ. of Okla., 1953, p. 175.

decrease in the total thickness of the limestone beds.

The Pawhuska formation contains six named limestone members separated by unnamed shales and sandstones in the northern part of the area. In ascending order the members are the Lecompton, Plummer, Deer Creek, Little Hominy, Pearsonia, and Turkey Run. The Little Hominy and Pearsonia members disappear southward in the Pawhuska area. The discussions of the shales follow the discussions of the underlying limestones.

Lecompton Limestone Member

History of nomenclature. Haworth [27] in 1895 named the member from exposures near Lecompton, Kansas.

Correlation. In his work in the northwestern part of the Pawhuska Quadrangle, Heald [28] correlated the lowest limestone in the Pawhuska formation with the Lecompton limestone of Kansas. Recently Carter [29] has made the same correlation except that he has correlated the lowest bed in the Pawhuska formation with the base of the Lecompton of Kansas and has included several of the overlying thin limestones as equivalents of the upper parts.

South of the Pawhuska area in the Hominy area, Russell [30] has described a massive limestone bed about 20 feet thick in the basal part

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[27] E. Haworth, "The Stratigraphy of the Kansas Coal Measures", Kansas Univ. Quart., vol. III (1895), no. 4, p. 278.

[28] K.C. Heald, U.S. Geol. Survey Bull. 686-H (1922), p. 29.

[29] J.A. Carter, personal communication, 1954.

[30] O.R. Russell, personal communication, 1954.

of the Pawhuska formation, which has a similar stratigraphic position to that of the Lecompton of Kansas. Russell and the author have correlated the Plummer limestone with the top of this massive limestone.

Therefore, in the Pawhuska area the author has assigned to the Lecompton limestone member all beds lying between the base of the lowest limestone above the Elgin sandstone, or its stratigraphic equivalent, and the base of the Plummer limestone member.

Description and areal extent. In the Pawhuska area the Lecompton limestone is not a continuous limestone member but is a succession of shale and sandstone beds with numerous thin limestone lentils of limited lateral extent occurring irregularly throughout the interval. None of these limestone beds is continuous across the area, nor are the outcrops of the beds sufficiently well exposed to permit accurate mapping. The total thickness varies from 34 feet at the northern edge of the area to about 30 feet at Lake Pawhuska and increases to about 65 feet near the southern boundary.

Since the lowest limestone beds in the member are at most places only a few feet above the Elgin sandstone, the position of the Lecompton may be approximately placed on the accompanying map between the outcrop lines of the Plummer limestone and the Elgin sandstone.

The most nearly continuous bed in the Lecompton and the most easily identifiable is a maroon and green, shaly, fusulinid-bearing limestone about ten feet from the base. It is well exposed at the west end of Lake Pawhuska Dam in sec. 13, T. 25 N., R. 8 E., where it is a total of 1.7 feet thick, consisting of 0.5 foot of purple, fine-grained, fusulinid-bearing limestone streaked with light green, silty limestone,

overlain by 1.0 foot of almost solid fusulinids in a shaly matrix, and topped by 0.2 foot of dense, fine-grained, fusulinid-bearing limestone. This is the lowest limestone in the Lecompton at this locality. Elsewhere in the area the bed is poorly exposed due to its crumbly nature, but even where the bed is covered, the slope below is, at numerous places, littered with fusulinid-bearing limestone fragments, and the soil has a reddish hue both from this bed and from the shales immediately above and below it.

This fusulinid bed has been found by the author in outcrops from the northern boundary of the area to the southernmost exposure in the N. W. ¼ of sec. 6, T. 24 N., R. 9 E., where it is one foot thick. It probably pinches out north of Little Hominy Creek.

A bed in the Pawhuska area correlated by Carter with the base of the Lecompton of Kansas is exposed in the western half of sec. 1, T. 26 N., R. 8 E. It lies about five feet above the highest sandstone of the Elgin and consists of 0.7 foot of light brown, fusulinid-bearing limestone which weathers bright orange. This weathering color makes the bed fairly easy to trace. However, it does not crop out south of Township 26 North. In Township 25 North, the approximate stratigraphic position of this bed is occupied by about three feet of light brown, calcareous, silty sandstone weathering bright orange-brown.

There are two algal limestones in the Lecompton limestone, one being exposed at the locality just mentioned, in sec. 1, T. 26 N., R. 8 E., about five feet above the basal bed. It is about one foot thick, light grey, and appears sandy due to the small algal structures. The other crops out in the N. W. corner of sec. 28, T. 24 N., R. 8 E., near

the base of a small hill capped by a Plummer limestone outlier. It is about 25 feet below the top of the member and consists of about one foot of light gray, fusulinid-bearing limestone containing numerous small algal structures giving it a sandy appearance.

At two localities in T. 26 N., R. 8 E., a conglomerate bed 0.5 foot thick crops out in the upper part of the member about ten feet below the top of the Plummer limestone and consists of rounded limestone pebbles in a fine-grained sandstone matrix.

A thin fusulinid-bearing limestone is poorly exposed in the eastern part of T. 25 N., R. 9 E., about ten feet above the Elgin sandstone. It grades laterally to orange-brown, calcareous sandstone along the outcrop. It crops out only in sections 20, 21, 28, and 29, and may be the same bed as the one described by Heald [31] as the Okay limestone. The Okay limestone was described from exposures in section 31 and named for the nearby Okay Ranch; however, the author did not find exposures answering Heald's description or the location of the old Okay Ranch.

The shales in the Lecompton are well exposed at the Lake Pawhuska locality previously mentioned and are mostly greenish gray to maroon and unfossiliferous. The only fossiliferous shale in the Lecompton crops out in the N. E. ¼ of sec. 13, T. 24 N., R. 8 E., near the base of a small hill capped by a Plummer limestone outlier. The top of the shale is 33 feet below the top of the Plummer and is 13 feet thick. It is green and maroon and is overlain by a one foot bed of fusulinid limestone.

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[31] K. C. Heald, U. S. Geol. Survey Bull. 668-E (1922), p. 29.

Paleontology. Fossils found in this member include:

Protozoa

Triticites sp.

Coelenterata

Lophophyllidium asarcum Jeffords

Bryozoa

Rhombopora lepidodendroides Meek

Brachiopoda

Chonetes granulifer Owen
Composita subtilita (Hall)
Cruirithyris planoconvexa (Shumard)
Marginifera splendens (Norwood and Pratten)
Neospirifer texanus (Meek)
Punctospirifer kentuckiensis (Shumard)
Rhynchopora cf. taylori Girty
Wellerella sp.

Pelecypoda

Astartella vera Hall

Gastropoda

Amphiscapha catilloides (Conrad)
Euphemites vittatus (McChesney)
Murchisonia terebra White
Trepospira discoidalis (Newell)
Worthenia sp.

Cephalopoda

Pseudorthoceras knoxense (McChesney)

Plummer Limestone Member

History of nomenclature. Winchester [32] in 1922 described the member from exposures near the Plummer ranch house in the N. W. ¼ of sec. 8, T. 26 N., R. 9 E.

Correlation. An exposure of the Plummer limestone on the north side of Highway 60 in the ravine just west of the Pawhuska Municipal

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[32] Winchester, op. cit., 1922, pp. 11-12.

Airport has been correlated by Moore [33] with the Rock Bluff member of the Deer Creek limestone of Kansas.

As previously mentioned, the Plummer has been correlated with the top of the Lecompton limestone south of the Pawhuska area.

Description and areal extent. Winchester described the member as consisting of two limestone beds separated by six to eight feet of shale; however, the author has found only one bed answering the description.

This bed is continuous across the area from north to south, though in the northern part the outcrop is at most places partially covered by float from the overlying Deer Creek limestone. South of Township 25 North the interval between the two members is greater, and the Plummer forms prominent terraces, as well as capping numerous outliers.

The thickness is about two feet at the type locality, and the bed thins gradually southward to 0.8 foot at the exposure north of Highway 60. The thinnest exposure recorded is 0.7 foot in Township 25 North. At the southern edge of this township the thickness increases southward, reaching a maximum of five feet at the southern edge of the area.

Accompanying the thickness variations is an accompanying variation in character. Throughout Townships 26 and 25 North the Plummer is a dark gray, fine-grained, dense, brittle limestone which breaks with a subconchoidal fracture. It contains many fossils, mostly brachiopods, which show as traces on the weathered surface and do not weather out separately. The bedding is massive and is cut by vertical joints. The weathered

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[33] R.C. Moore, Kansas Geol. Soc. Eleventh Annual Field Conference Guidebook, 1937, pp. 67, 75.

Figure 6. Plumer limestone, in the ravine just west of the Pawhuska airport, on the north side of Highway 60, in the southeast quarter of sec. 2, T. 25 N., R. 8 E.

surface is dull orange-brown to light gray, and the slope below is at most places littered with large (six to eight feet) rectangular slabs.

As the thickness increases, the weathered color becomes bright orange-brown and the fossil content increases both in number and variety. At an exposure in the road cut just south of Little Hominy Creek in the N. E. ¼ of sec. 9, T. 24 N., R. 8 E., it is a 2.7 foot massive bed weathering bright orange-brown and contains numerous corals and algal structures resembling "Cryptozoon". On an outlier in the S. W. ¼ of sec. 19, T. 24 N., R. 9 E., fossils weather out of the top part of the bed, littering the outcrop with numerous Composita subtilita, corals, and other fossils. At the exposure in the N. W. ¼ of sec. 34, T. 24 N., R. 8 E., it contains fusulinids, and the lower part is sandy.

The general picture of the Plummer limestone outcrop from north to south is an increase in thickness, fossil content, and stratigraphic distance below the Deer Creek limestone member.

Paleontology. Fossils found in this member include:

Coelenterata

Caninia torquia (Owen)
Lophophyllidium acarcum Jeffords

Brachiopods

Condrathyris perplexa (McChesney)
Cruarithyris planoconvexa (Shumard)
Composita subtilita (Hall)
Hustedia mormoni (Marcou)
Marginifera wabashensis (Norwood and Pratten)
Meekella striatocostata (Cox)
Neospirifer sp.
Punctospirifer kentuckiensis (Shumard)
Wellerella osagensis (Swallow)

Fossil collecting localities. Good collecting localities include: Outlier in the S. W. ¼ of sec. 18, T. 24 N., R. 9 E.

Figure 7. Plummer limestone, thinnest exposure in the Pawhuska area, in the northeast quarter of sec. 27, T. 25 N., R. 8 E.

Figure 8. Plummer limestone, exposure showing southward thickening, in the northeast quarter of sec. 16, T. 24 N., R. 8 E.

Site of old rock crusher in the New England oil field in the N. W. ¼ of sec. 29, T. 25 N., R. 9 E.

Shale Above Plummer Limestone

The shale between the Plummer and Deer Creek limestone members is well exposed in few places in the area. At the previously mentioned exposure just north of Highway 60, it is about 11 feet thick and consists of black, fissile, fossiliferous shale grading upward to buff, fossiliferous shale.

The basal part of the shale is exposed in a gully in the N. E. ¼ of sec. 27, T. 25 N., R. 8 E., and consists of two feet of gray-brown shale with ferrous streaks, overlain by two feet of black, fissile shale, topped by about eight feet of fossiliferous, buff shale. The black fissile shale disappears in the southern part of the area.

The thickness is 10 feet at the northern boundary, about 11 feet at the locality north of Highway 60, and increases to a maximum of about 80 feet near the southern boundary. This thickening in Township 24 North is accompanied by the appearance of sand in the upper part of the section, which occurs as a massive, cross-bedded sandstone bed about 15 feet thick, about ten feet below the Deer Creek limestone.

Paleontology. Fossils found in this shale include:

Coelenterata

Lophophyllidium asarcum Jeffords

Brachiopoda

Chonetes granulifer Owen
Chonetinella sp.
Composita subtilita (Hall)
Cruirithyris planoconvexa (Shumard)
Hustedia mormoni (Marcou)
Martinifera sp.
Wellerella osagensis (Swallow)

Pelecypoda

Astartella vera Hall
Nuculana bellistriata (Stevens)
Nuculopsis ventricosa (Hall)
Yoldia sp.

Gastropoda

Amphiscapha catilloide (Conrad)
Euphemites vittatus (McChesney)
Glabrocingulum wannense (Newell)
Pharkidonotus sp.
Strobeus sp.
Trepospira discoidalis (Newell)
Worthenia tabulata Conrad

Cephalopoda

Pseudorthoceras knoxense (McChesney)

Fossil collecting localities. Good collecting localities include: North of Highway 60, in the S. E. ¼ of sec. 2, T. 25 N., R. 8 E.

Lake Pawhuska Dam, sec. 13, T. 25 N., R. 8 E.

Deer Creek Limestone Member

History of nomenclature. This is probably the "Pawhuska limestone" described by Smith in 1894, as has already been discussed.

The Deer Creek limestone of Kansas was named by Bennett [34] for exposures on Deer Creek, near Topeka.

Correlation. If the underlying Plummer limestone is equivalent to the Rock Bluff member of the Deer Creek limestone of Kansas, then the Deer Creek limestone of the Pawhuska area is the equivalent of the Ervine Creek limestone member of Kansas.

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[34] John Bennett, "A Geologic Section Along the Kansas River from Kansas City to McFarland", Kansas Univ. Geol. Survey, vol. 1 (1896), p. 152.

Figure 9. Typical Plummer limestone terrace (foreground) below prominent Deer Creek limestone outcrop, in the northeast quarter of sec. 23, T. 26 N., R. 8 E.

South of the Pawhuska area the Deer Creek limestone thins rapidly in the Hominy area and is not found south of the Arkansas River, according to Russell [35].

Description and areal extent. The Deer Creek limestone is the thickest limestone in the Pawhuska formation and crops out in a prominent escarpment which is rapidly traceable either on the ground or on aerial photographs. Further facilitating the study of the bed are three excellent exposures in abandoned quarries west and southwest of Pawhuska. Two of these quarries are on the east side of the main ravine draining into Lake Pawhuska just west of the Pawhuska airport, one north of Highway 60 in the S. E. ¼ of sec. 2, T. 25 N., R. 8 E., and the larger of the two south of the highway and the airport in the N. E. corner of sec. 11, T. 25 N., R. 8 E. The largest of the three quarries is just north of the A. T. & S. F. railroad on the Atlantic Field Road, in the S. W. corner of sec. 14, T. 25 N., R. 8 E.

The thickness varies from about 15 feet at the northern part of the area to over 20 feet at the quarry exposures. A maximum thickness of 34 feet is exposed east of a sharp bend in Clear Creek in the N. E. ¼ of sec. 21, T. 25 N., R. 8 E. Southward the member thins to about five feet in the S. W. ¼ of sec. 30, T. 24 N., R. 8 E.

The height of the outcrop escarpment is, at most places, considerably less than the total thickness of the limestone. The base of the escarpment marks the approximate base of the limestone, but the upper part weathers back from the escarpment, the top being from 5 to 15 feet above it, depending on the variation in resistance of the beds along

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[35] O. R. Russell, personal communication, 1954.

Figure 10. Deer Creek limestone, in the abandoned quarry just north of the A. T. & S. F. railroad, in the southwest quarter of sec. 14, T. 25 N., R. 8 E.

Figure 11. Deer Creek limestone in the northwest quarter of sec. 35, T. 25 N., R. 8 E. This figure illustrates the southward thinning of the member when compared with Figure 10.

the outcrop. This results in a wide outcrop belt (up to one fourth mile) readily distinguished on aerial photographs or on the ground.

The member consists mostly of light gray, fine-grained, dense limestone in thin, irregularly curving beds. The lower four feet is dark gray and massively bedded. It weathers to light gray or white flags, which cover the slopes below the outcrop. It is fossiliferous, with the most fossils occurring in a 2.5 foot interval in the approximate middle of the member. Numerous fusulinids, brachiopods, corals, and mollusks occur throughout the member, with the fusulinids being concentrated in thin beds or in thin shaley partings between some of the thin beds. The southward thinning is probably at the expense of the basal beds. The thick sandstone below the limestone in the southern part of the area is separated from it by about five feet of shale; therefore the thinning of the limestone is probably not due to "sanding up".

The vertical joints cutting most of the limestone beds of the Pawhuska area are especially prominent in the Deer Creek limestone due to its greater thickness. This results in an angularity of outcrop pattern, and it determines stream patterns to a great extent, especially in the smaller tributaries.

Paleontology. Fossils found in this member include:

"Cryptozoon"

Protozoa

Triticites sp.

Coelenterata

Aulopora prosseri Beede

Brachiopoda

Composita subtilita (Hall)

Dictyoclostus americanus (Dunbar and Condra)

Linoproductus prattenianus (Norwood and Pratten)
Neospirifer dunbari King

Cephalopoda

Moorecceras tuba (Girty)

Fossil collecting localities. Good fossil collecting localities include the two abandoned quarries south and west of the Pawhuska airport.

Shale Above the Deer Creek Limestone

The shale between the Deer Creek limestone and the Little Hominy limestone has been correlated by Moore [36] with the Calhoun shale of Kansas.

This shale is buff, nodular, and fossiliferous. Grass covers the shale slope across most of the area; however, where exposed, the shale makes excellent fossil-collecting localities.

The thickness is 20 to 25 feet across Townships 25 and 26 North, decreasing to about 10 feet in Township 24 North.

Paleontology. Fossils found in this member include:

Protozoa

Tritieites sp.

Coelenterata

Lophophyllidium easarcum Jeffords

Bryozoa

Fenestella sp.
Rhombopora snideri Mather
Rhombopora lepidodendroides Meek

Brachiopoda

Chonetes granulifer Owen
Chonetinella flemingi (Norwood and Pratten)
Composita subtilita (Hall)

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[36] R. C. Moore, Kansas Geol. Soc. Eleventh Annual Field Conference Guidebook, 1937, p. 67.

Composita elongata Dunbar and Condra
Crurithyris planoconvexa (Shumard)
Derbya crassa (Meek and Hayden)
Dictyoclostus americanus (Dunbar and Condra)
Hustedia mormoni (Marcou)
Juresania nebrascensis (Owen)
Juresania symetrica (McChesney)
Marginifera wabashensis (Norwood and Pratten)
Neospirifer dunbari King
Neospirifer sp.
Punctospirifer kentuckiensis (Shumard)
Wellerella osagensis (Swallow)

Pelecypoda

Astartella vera Hall
Myalina sp.
Nuculana bellistriata (Stevens)
Nuculopsis ventricosa (Hall)
Schizodus sp.

Gastropoda

Amphiscapha catilloide (Conrad)
Cymatospira montfortiana (Norwood and Pratten)
Euphemites vittatus (McChesney)
Glabrocingulum wewokense (Newell)
Meekospira peracuta (Meek and Worthen)
Pharkidonotus tricarinatus (Shumard)
Strobeus naludinaeformis (Hall)
Trepospira discoidalis (Newell)

Cephalopoda

Pseudorthoceras knoxense (McChesney)

Fossil collecting localities. Good fossil collecting localities include: Bluff northeast of bend in M. V. railroad in the N. W. ¼ of sec. 1, T. 26 N., R. 8 E.

Gully northeast of bend in road at top of hill in the N. E. ¼ of sec. 14, T. 26 N., R. 8 E.

Below small hill east of road in the S. E. ¼ of sec. 35, T. 26 N., R. 8 E.

A. T. & S. F. railroad cut in the S. W. ¼ of sec. 16, T. 25 N., R. 8 E.

Little Hominy Limestone Member

History of nomenclature. Heald and Mather [37] named this member from exposures on Little Hominy Creek in the southwestern part of T. 25 N., R. 8 E.

Correlation. In the same publication they also correlated it tentatively with either the Howard or Topeka limestones of Kansas.

Moore [38] correlated it with the lower part of the Topeka limestone of Kansas.

The Little Hominy limestone disappears in the southern part of the Pawhuska area and has not been reported south of the area.

Description and areal extent. The best exposures near the type locality are on the sides of a small tributary valley of Little Hominy Creek in the N. W. ¼ of sec. 35, T. 25 N., R. 8 E. At this locality the Little Hominy escarpment closely resembles that of the Deer Creek limestone 35 feet below. (See Figure 12.)

Here the Little Hominy consists of ten feet of light gray to white, algal, slightly sandy limestone. The lower two feet is thin-bedded and contains abundant fusulinids; this is overlain by a four foot massive bed, which is the escarpment former and has numerous algal structures concentrated at the top in small channels. The upper four feet is also thin-bedded, and contains such a large percentage of

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[37] K. C. Heald and K. F. Mather, U. S. Geol. Survey Bull. 686-H (1922), p. 152.

[38] R. C. Moore, Kansas Geol. Soc. Fifth Annual Field Conference Guidebook, 1931, Correlation Chart.

Figure 12. Little Hominy limestone escarpment above Deer Creek limestone escarpment, in the northwest quarter of sec. 35, T. 25 N., R. 8 E.

Figure 13. Little Hominy limestone, closeup of Figure 12. The maximum thickness of the member in the Pawhuska area is exposed at this locality.

algal structures that it appears sandy. Immediately overlying the limestone is about four feet of sandstone.

Southwestward the bed thins rapidly and converges toward the Deer Creek limestone; in the S. W. ¼ of sec. 30, T. 24 N., R. 8 E., it is a one foot bed of limestone conglomerate, six feet above the Deer Creek limestone; and it disappears completely about one mile north of the southern boundary.

Northward it thins rapidly, and in the outlier mapped in the S. E. ¼ of sec. 22, T. 25 N., R. 8 E., only the overlying sandstone is exposed. Throughout the rest of the area to the northern boundary the limestone varies in thickness from four feet to zero, and where it is not present, its stratigraphic position can be mapped on the overlying sandstone.

This local thinning is probably due to erosional hiatus at the top of the limestone, since at several localities conglomerates occur in the top of the bed. However, just north of the Pawhuska area in the bank of North Bird Creek in the S. E. ¼ of sec. 34, T. 27 N., R. 8 E., the lower part of the limestone is conglomeratic and truncates the underlying shale at a small angle. The conglomerates in the upper part of the bed are well exposed in two cuts of the A. T. & S. F. railroad about one fourth mile apart, one in the N. E. ¼ of sec. 17, and the other in the S. W. ¼ of sec. 16, T. 25 N., R. 8 E.

At other exposures no conglomerate appears in the limestone, and it contains fusulinids and/or small algal structures. In the north central part of sec. 14, T. 26 N., R. 8 E., it consists of four feet of algal limestone topped by several thin fusulinid-bearing layers. At some

Figure 14. Little Rocky limestone, in the west central part of sec. 6, T. 26 N., R. 9 E. This figure illustrates the northward thinning of the bed when compared with figure 13.

exposures it contains neither, as in sec. 1, T. 26 N., R. 8 E., where it consists of 1.5 feet of light gray, fine-grained, dense limestone containing a few brachiopods and other fossils.

Paleontology. Fossils found in this member include:

Algae
Triticites sp.
Linoproductus prattenianus (Norwood and Pratten)

Shale Above the Little Hominy Limestone

The Little Hominy limestone is from 20 to 35 feet below the top of the Pearsonia limestone and about 65 feet below the Turkey Run limestone in Township 26 North. The Pearsonia limestone disappears southward, the southernmost exposure being in sec. 28, T. 26 N., R. 8 E. In Townships 24 and 25 North the interval is less, the Turkey Run limestone being 40 to 50 feet above the Little Hominy limestone.

The rocks of this interval are poorly exposed throughout the area, the most complete exposure being in the north central part of sec. 14, T. 26 N., R. 8 E., where they consist mostly of buff, silty shale alternating with thin sandstone beds. Immediately above the Little Hominy limestone is a two foot sandstone bed topped by about eight feet of maroon and gray shale. Above this shale is a five foot covered interval littered with fusulinids, which probably weather out of a thin limestone. A thin fusulinid-bearing limestone bed which may be equivalent to that just mentioned crops out ten feet above the Little Hominy limestone in the S. W. ¼ of sec. 30, T. 24 N., R. 8 E.

Locally a thick, cross-bedded, spring-forming sandstone crops out immediately above the Pearsonia limestone, and in the S. E. ¼ of sec. 16, T. 26 N., R. 8 E., it is about 18 feet thick. At other places the

sandstone is less than five feet thick.

A limestone conglomerate bed approximately two feet thick crops out 11 feet below the top of the Turkey Run limestone on the outlier hill in the S. W. ¼ of sec. 22, T. 26 N., R. 8 E.

The only fossiliferous bed found is a 0.25 to 0.5 foot bed of light brown sandstone, which contains numerous limonite fillings of pelecypods, about one foot below the Turkey Run limestone.

Pearsonia Limestone Member

History of nomenclature. Carter [39] named this bed from exposures in the Pearsonia area, which is just north of the Pawhuska area.

It was known previously as the "red lime", a field designation used by Heald [40], who mapped it as the top of the Pawhuska formation.

Description and areal extent. In the southern part of the Pearsonia area, in the N. E. ¼ of sec. 34, T. 27 N., R. 8 E., the Pearsonia limestone is 3.6 feet thick. It consists of a massive bed 2.75 feet thick of dark blue-gray, fine-grained, dense, brittle limestone which weathers brownish gray and forms large rectangular blocks with rounded edges, topped by 0.6 foot of fusulinid-bearing limestone weathering thin-bedded.

Southward in the Pawhuska area the bed thins rapidly, consisting of one foot of massive limestone overlain by 0.5 foot of fusulinid-bearing limestone in the north central part of sec. 14, T. 26 N., R. 8 E.

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[39] J.A. Carter, personal communication, 1954.

[40] K. C. Heald, U. S. Geol. Survey Bull. 691-C, (1918), p. 67.

The thinning is at the expense of the lower part of the bed, since at the southernmost exposures the fusulinid-bearing limestone makes up the complete member.

Paleontology. The only fossils found in the member are Triticites sp.

Turkey Run Limestone Member

History of nomenclature. Heald and Mather [41] named the member in 1922 from exposures near the head of Turkey Run in sections 9, 16, and 17, T. 24 N., R. 8 E. (See Figure 15.)

Correlation. The Turkey Run limestone is the topmost member of the Pawhuska formation and was correlated by Moore [42] with the top of the Topeka limestone of Kansas.

Southward it has been traced across the Hominy area by Russell [43] and across Pawnee County by Greig [44].

Description and areal extent. Southward from the type locality it extends past the southern boundary. Northward it extends to within one half mile of the northern boundary, the northernmost outcrops being found in the S. E. ¼ of sec. 3, T. 26 N., R. 8 E.

Throughout the area the lithologic character of the bed remains practically the same, and the thickness varies only slightly. It may be

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[41] Heald and Mather, op. cit., 1922, p. 153.

[42] R. C. Moore, Kansas Geol. Soc. Fifth Annual Field Conference Guidebook, 1931, Correlation Chart.

[43] O. R. Russell, personal communication, 1954.

[44] P. B. Greig, personal communication, 1954.

observed in several excellent exposures in the area.

In a small, wooded gully in the S. E. ¼ of sec. 16, T. 26 N., R. 8 E., it is 2.8 feet thick, the top 2.35 feet being a massive bed of gray, fine-grained, dense, fossiliferous limestone, and the bottom 0.6 foot consisting of reddish gray, medium grained, crumbly, fossiliferous limestone. The fossils include corals, small brachiopods, mollusks, bryozoans, and crinoid stems.

Just below a pond dam in the center of sec. 33, T. 26 N., R. 8 E., it crops out as a 3.2 foot massive bed.

In an A. T. & S. F. railroad cut about 1½ miles southeast of the McInnis stockyard siding, in the N. W. ¼ of sec. 17, T. 25 N., R. 8 E., it is also a 3.2 foot massive bed. (See Figure 16.)

At the southern edge of the area the limestone is slightly sandy, as exposed in the S. W. ¼ of sec. 30, T. 24 N., R. 8 E.

Distinguishing characteristics are the typical blue-gray color, the tendency to break with a sub-conchoidal fracture, and the "ring" when struck with a hammer. It is cut by numerous vertical joints, which not only influence the formation of weathered flags but also influence stream patterns.

Wabaunsee Group

The Wabaunsee formation was described by Prosser [45] in 1895 as those beds underlying the base of the Cottonwood limestone and overlying

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[45] Charles S. Prosser, "The Classification of the Upper Palaeozoic Rocks of Central Kansas", Journal of Geology, vol. III (1895), no. VI, pp. 688-690.

Figure 15. Turkey Run limestone, type locality, near the head of Turkey Run, in the northwest quarter of sec. 16, T. 24 N., R. 6 E.

Figure 16. Turkey Run limestone and underlying fossiliferous sandstone, in an A. T. & S. F. railroad cut in the northwest quarter of sec. 17, T. 25 N., R. 8 E.

the Osage coal (now known as the Hodawey coal) and named for exposures in Wabaunsee County, Kansas.

It has since been raised to group rank in Kansas and has been redefined several times. The latest definition, according to Moore and others [46], places it as the uppermost group in the Virgil series, with the upper limit being the unconformity separating the Permian from the Pennsylvanian in Kansas and the base being at the top of the Topeka limestone.

Only beds of the lower and middle parts of the group crop out in the Pawhuska area. They consist primarily of thick sandstone and shale beds interspersed in the middle part with several thin limestone beds.

The lowest formation in the group has been called the Severy shale in Kansas, and that name is also retained by the author in the Pawhuska area. The beds above the Severy shale have not been grouped into formations and are, in ascending order, the Bird Creek limestone, unnamed shales, sandstones, and thin limestones, the Elmo coal, the Rulo limestone, unnamed shales, limestones, and sandstones, and the Wakarusa limestone.

The total thickness of the rocks of this interval is about 100 feet greater at the northern boundary than it is at the southern, being approximately 220 feet in Township 26 North and about 120 feet in Township 24 North.

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[46] Moore and others, op. cit., 1951, pp. 55-58.

Lower Wabaunsee

Severy Shale Member

History of nomenclature. This member was named by Haworth[47] in 1898, for Severy, Kansas.

Correlation. The top of the Turkey Run limestone is the base, and the base of the Bird Creek limestone is the top of the interval. Therefore, it can be recognized at least as far south as the south edge of Pawnee County, since the two limestones have been traced that far.

Description and areal extent. The Severy shale is poorly exposed in the area but, where exposed, consists mostly of buff, nodular, silty shale and sandstone, the sandstone being more predominant in the south. In the S. E. ¼ of sec. 15, T. 24 N., R. 7 E., a 15 foot bed of massively cross-bedded sandstone crops out 15 feet below the Bird Creek limestone.

The most distinctive part of the interval is the upper ten feet, which consists of green, nodular, fossiliferous shale interspersed with streaks of maroon shale. Irregular nodules of green, indurated shale with yellow-brown limestone centers occur in a maroon shale streak nine feet below the base of the Bird Creek limestone in the bed of Middle Bird Creek in the S. E. ¼ of sec. 6, T. 26 N., R. 8 E.

Another fossiliferous zone is about 25 feet from the top, in the bed of Middle Bird Creek in the N. W. ¼ of Sec. 8, T. 26 N., R. 8 E. It consists of black, fissile, indurated shale containing numerous brachiopods and bryozoans.

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[47] E. Haworth, "Stratigraphy of the Kansas Coal Measures", Kansas Univ. Geol. Survey, vol. III, Pt. I (1898), p. 67.

A fossiliferous sandstone bed one foot thick and containing limonite molds of pelecypod shells crops out 15 feet above the Turkey Run limestone in the north central part of sec. 14, T. 26 N., R. 8 E.

The thickness of the complete interval in the northern part of the area, as measured in the N. E. ¼ of sec. 16, T. 26 N., R. 8 E., is about 95 feet. In the southern part it is about 30 feet, as measured in the N. ½ of sec. 18, T. 25 N., R. 8 E.

Paleontology. Fossils found in the member include:

Fenestella sp.
Chonetes granulifer Owen
Punhenites vittatus (McChesney)
Nuculana sp.

Bird Creek Limestone Member

History of nomenclature. Heald named the limestone in 1919 "from its exposure on the valley sides of Bird Creek and its tributaries" [48] in T. 27 N., R. 8 E. However, the name was first published in 1918 by Bowen [49], who obtained it from Heald's unpublished work.

Correlation. Moore [50] has correlated the bed with the Church limestone member of the Howard limestone formation of Kansas.

Southward the bed has been traced to the south edge of Pawnee County.

Description and areal extent. The best exposure of the bed found by the author in the Bird Creek tributaries is on the north bank of Middle

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[48] K. C. Heald, U. S. Geol. Survey Bull. 686-Q (1922), p. 216.

[49] G. F. Bowen, U. S. Geol. Survey Bull. 686-L (1922), p. 137.

[50] R. C. Moore, "Divisions of the Pennsylvanian System in Kansas", Kansas Geol. Survey Bull. 83, (1949), p. 174.

Bird Creek about 200 yards east of the Drummond Ranch road in the S. E. ¼ of sec. 6, T. 26 N., R. 8 E. It is a 2.5 foot thick massive bed of light brownish-gray, fine-grained, dense, brittle limestone breaking with a sub-conchoidal fracture. It is fossiliferous throughout, although the fossils do not weather out, and the top of the bed is covered with Cruirithyris planoconvexa. (See Figure 17.)

Another excellent exposure is in the A. T. & S. F. railroad cut about one half mile southeast of the McInnis stockyard siding, in the N. E. ¼ of sec. 18, T. 25 N., R. 8 E., where it is a 1.8 foot thick, massive bed of blue-gray, fine-grained, dense, brittle, fossiliferous limestone breaking with a subconchoidal fracture. (See Figure 18.)

The bed is continuous across the area with essentially the same character, though thinning to the south, the thinnest exposure being in the road cut just south of the small creek in the S. E. ¼ of sec. 13, T. 24 N., R. 7 E., where it is 1.4 feet thick. The fossils are difficult to identify since they do not weather out and show only as traces on the weathered surface. It is cut by vertical joints at most places and weathers gray to light brown, forming irregular flags.

The Bird Creek limestone may be quickly traced across the area by observing outcrops along the Drummond Ranch road north of Highway 60 and along the Naval Reserve road south of the highway, since the outcrop crosses these roads at numerous places.

Middle Wabaunsee

The outcrop belt of these beds is poorly exposed across the Pawhuska area. The belt is marked by rolling prairie rising gently

Figure 17. Bird Creek limestone, on the bank of Middle Bird Creek, in the southeast quarter of sec. 6, T. 26 N., R. 8 E.

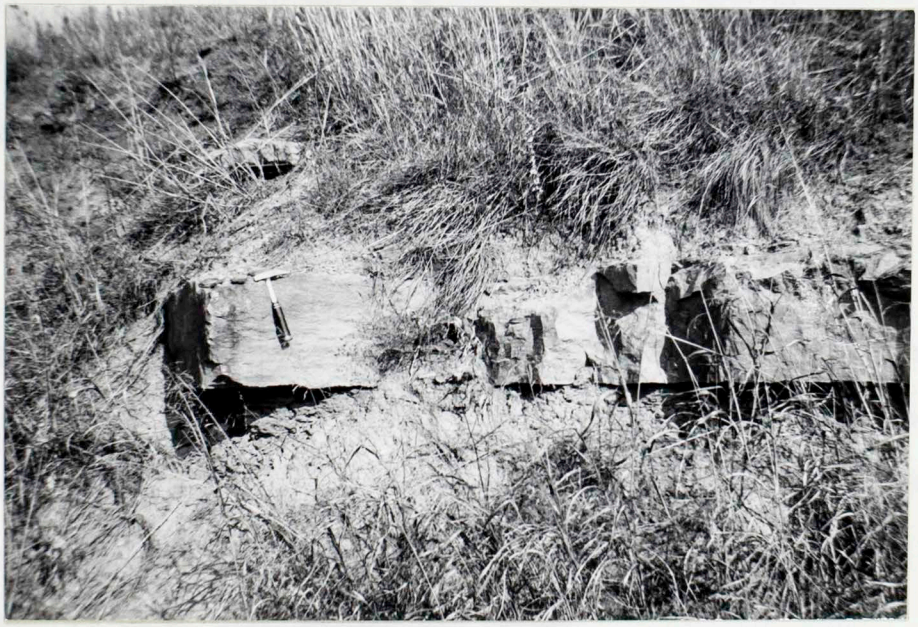

Figure 18. Bird Creek limestone, in the A. T. & S. F. railroad cut near the McInnis stockyard siding, in the northeast ¼ of sec. 18, T. 25 N., R. 8 E.

westward to the base of the Flint Hills, with thin soil supporting a thick grass cover. The position of the limestone beds beneath the cover is typically marked by gentle terraces.

The total stratigraphic thickness is 125 feet at the northern edge of the area and about 95 feet in the southern part.

The top of the interval is the Wakarusa limestone, which has been traced across the area. At about the middle of the interval the Rulo limestone and the underlying Elmo coal are well exposed in the northern part of the area. Due to the poor exposures, the disappearance of the Elmo coal southward, and the presence of several other similar limestone beds short distances above and below the Rulo limestone, the author was unable to trace it definitely across the area. However, a limestone similar in lithology and stratigraphic position crops out in the southern part of the area and can be tentatively correlated with it.

In this thesis four divisions are used: the basal shale, the Rulo limestone, the upper shale, and the Wakarusa limestone.

Basal Shale Member

This interval contains a lower buff to black, fossiliferous shale section, a middle sandy interval, and an upper greenish gray to olive drab, maroon streaked shale. Several thin, fossiliferous limestone beds appear throughout the interval in the southern exposures. The thickness varies from 50 to 65 feet across the area.

The complete section is exposed at three localities: along the sides of the small tributary north from Middle Bird Creek in the eastern half of sec. 6, T. 26 N., R. 8 E., in the railroad cut southeast of McInnis in the northern half of sec. 6, T. 25 N., R. 8 E., and in the

road cut on the Naval Reserve road just south of the small creek crossing in the S. E. ¼ of sec. 15, T. 24 N., R. 7 E.

The middle sandstone interval is greatest in the northern part of the area, consisting of 30 feet of massively cross-bedded, cliff-forming sandstone, topped by 10 feet of thick-bedded sandstone, along the bluff east of Middle Bird Creek in sec. 8, T. 26 N., R. 8 E.

The top of the shale is marked by the Elmo coal in the northern half of T. 26 N., where it lies immediately below the Rulo limestone. The coal is exposed below a wet weather falls formed on the Rulo limestone in Middle Bird Creek in the N. E. ¼ of sec. 12, T. 26 N., R. 7 E., where it is a 0.33 foot seam of bituminous coal. At the eastern point of the bluff formed on the Rulo limestone south of the creek in the S. E. ¼ of sec. 8, T. 26 N., R. 8 E., it consists of three seams 0.04 to 0.02 foot thick in one foot of shale. The southernmost exposure is in the road cut along the north line of the N. W. ¼ of sec. 17, T. 26 N., R. 8 E., where it consists of one foot of bituminous shale, separated from the Rulo limestone by three feet of buff and gray shale.

Paleontology. Fossils found in the member include:

Bryozoa

Rhombopora snideri Mather

Brachiopoda

Chonetes granulifer Owen
Chonetina flemingi (Norwood and Pratten)
Crurithyris planoconvexa (Shumard)
Hustedia mormoni (Marcou)
Juresania nebrascensis (Owen)
Juresania swallowi (McChesney)
Marginifera wabashensis (Norwood and Pratten)
Neospirifer dunbari King
Orbiculoidea missouriensis (Shumard)
Wellerella osagensis (Swallow)

Figure 19. Basal shale member of the Middle Wabaunsee, in the A. T. & S. F. railroad cut southeast of McInnis, in the Northwest quarter of sec. 18, T. 25 N., R. 6 E.

Pelecypoda

Myalina sp.

Gastropoda

Euphemites vittatus (McChesney)

Cephalopoda

Gastrioceras sp.

Fossil collecting localities. Good fossil collecting localities include: South bank of South Bird Creek just west of junction with tributary, southeast of dry weather bridge on Drummond Ranch road, in the N. W. ¼ of sec. 29, T. 26 N., R. 8 E.

Railroad cut on A. T. & S. F., southeast of McInnis stockyard siding, in the N. E. ¼ of sec. 18, T. 25 N., R. 8 E.

Road cut on Naval Reserve road, south of creek crossing, in the S. E. ¼ of sec. 15, T. 24 N., R. 7 E.

Rulo Limestone Member

History of nomenclature. The bed was named by Condra and Bengston [51] in 1915 from exposures near Rulo, Nebraska.

Correlation. Moore [52] has traced the bed across Kansas from Nebraska to Oklahoma.

Carter [53] has traced the bed from Kansas across the Pearsonia area, Oklahoma, to the northern edge of the Pawhuska area.

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[51] G. E. Condra and N. A. Bengston, "The Pennsylvanian Formations of Southeastern Nebraska", Nebraska Academy of Science Publ., vol. 9, no. 2 (1915), p. 14.

[52] R. C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas", Univ. of Kansas Bull. 22, (1936), p. 213.

[53] J. A. Carter, personal communication, 1954

Description and areal extent. Other than the presence of the underlying Elmo coal, the most notable characteristic of the Rulo limestone is its variation in thickness, with an accompanying variation in lithology, in the northern half of Township 26 North.

At the wet weather falls previously mentioned in Middle Bird Creek, in the N. E. ¼ of sec. 12, T. 26 N., R. 7 E., it is a massive bed 1.7 feet thick, of dark gray, fine-grained, dense, brittle limestone containing few fossils.

About 1.5 miles east by south from this exposure, in the S. W. ¼ of sec. 8, T. 26 N., R. 8 E., it forms a bluff on the south bank of Middle Bird Creek. It consists of 19 feet of thin-bedded, fossiliferous limestone containing numerous limonite "pebbles" with the upper eight feet being sandy.

One half mile south of this exposure, in the road cut in the N. W. ¼ of sec. 17, T. 26 N., R. 8 E., it consists of 3.75 feet of light brown to gray, medium-grained, fossiliferous limestone containing sand-size particles of limonite.

In the southern part of the area the bed which has been tentatively correlated with the Rulo limestone is about 80 feet above the Bird Creek limestone, and is exposed in the road cut on the Naval Reserve road south of the creek crossing in the S. E. ¼ of sec. 15, T. 24 N., R. 7 E. It is a massive bed 0.75 foot thick of dark gray, fine-grained, dense limestone containing few fossils except for a thin fossiliferous layer capping the bed.

Upper Shale Member

The shale above the Rulo limestone is poorly exposed above the wet weather falls previously mentioned in the bed of Middle Bird Creek in the S. E. ¼ of sec. 12, T. 26 N., R. 7 E., where it is 30 feet of gray shale. In the basal five feet are two thin limestone beds which are probably equivalent to the upper part of the Rulo limestone where it is thickest.

The thickness varies from 60 to 30 feet across the area, with no general trend toward thickening or thinning being observed.

An algal limestone about one foot thick occurs in the upper part, about 10 feet below the base of the Wakarusa limestone, and is consistent across the area, although poorly exposed at most places because of its "crumbly" nature.

Wakarusa Limestone Member

History of nomenclature and correlation. This bed was originally known in the Pawhuska Quadrangle as the "Cryptozoon bearing limestone" by Heald [54].

It has since been correlated by Moore [55] and Carter [56] with the Wakarusa limestone of Kansas.

The Wakarusa was named by Beede [57] in 1898, from exposures on

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[54] F. C. Heald, U. S. Geol. Survey Bull. 691-C (1918), pp. 64-66.

[55] R. C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas", Univ. of Kansas Bull. 22 (1936), p. 221

[56] J. A. Carter, personal communication, 1954.

[57] J.W. Beede, Kansas Acad. Sci. Trans, Vol. 15, (1898),p. 30.

Wakarusa Creek near Auburn, Kansas.

Description and areal extent. The distinguishing feature of the Wakarusa limestone is the presence of numerous algal organisms known as "Cryptozoon". These fossils are readily observed on the weathered surface of the bed as irregular, concentrically laminated, dark gray masses with bryozoan colonies or fossil fragments as centers, up to 0.5 foot in long dimension, though most are about 0.25 foot in diameter.

These structures are numerous in the northern part of the area, and the surface of the limestone has a spotted appearance due to their numbers. (See Figure 20.) Southward the number decreases until in the southern part of the area they are rare. The decrease in "Cryptozoon" is marked by an increase in the number of colonial bryozoans.

The Wakarusa limestone is, as previously stated, poorly exposed across most of the area. Its outcrop is marked by large rectangular blocks weathering to small chips, bright orange to light tan in color. It is about one foot thick and consists of gray, fine-grained, dense, brittle limestone which is difficult to break and has a sub-conchoidal fracture. It is fossiliferous, containing small brachiopods, crinoid stems, and numerous other unidentifiable fragments besides the "Cryptozoons" in Township 26 North.

The poor exposures are due partly to the presence of an overlying limestone bed one to three feet thick which slumps over the Wakarusa limestone at numerous places.

It is exposed in the road cut in the northwest corner of sec. 17, T. 26 N., R. 8 E., where it forms an outlying hill.

The southward decrease in numbers of "Cryptozoon" can be seen

Figure 20. Wakarusa limestone, showing appearance of "Cryptozoon" (dark blotches) on weathered surface, northwest quarter of sec. 5, T. 26 N., R. 8 E.

Figure 21. Wakarusa limestone in bed of wash at ranch road crossing, in the southeast quarter of sec. 11, T. 25 N., R. 7 E.

in an excellent outcrop on the west bank of Hominy Creek due west of the old St. John's School, along the line between the S. E. ¼ of sec. 33 and the S. W. ¼ of sec. 34, T. 25 N., R. 7 E. It is a two foot massive bed of blue-gray, fine-grained, dense, fossiliferous limestone containing large colonial bryozoans, rare "Cryptozoon", fusulinids, small brachiopods, crinoid stems, and a few corals.

Paleontology. Fossils found in this member include:

"Cryptozoon"
Tritieites sp.
Composita subtilita (Hall)

Alluvium

The valleys of the permanent streams throughout the area are filled with alluvium in the lower reaches and for some distance upstream in many cases.

The streams have, since the deposition of the alluvium, cut down through it and are now flowing on bedrock. This down cutting has exposed thicknesses up to 45 feet observed by the author.

The most distinctive feature of the alluvium is its ability to support nearly vertical bluffs where the streams have cut through it. Just east of the dry weather bridge on North Bird Creek, one fourth mile southeast of Bird Creek School (S. W. corner of sec. 29, T. 26 N., R. 9 E.) a nearly vertical bluff 45 feet thick is cut in the alluvium. About one fourth mile downstream from Hominy Falls (in the S. E. ¼ of sec. 20, T. 24 N., R. 8 E.), a 43 foot bluff has been cut by Hominy Creek.

The alluvium is made up of light brown, silt to fine sand size

Figure 22. Alluvium in the south bank of North Bird Creek just east of the dry weather bridge in the southwest corner of sec. 29, T. 26 N., R. 9 E.

Figure 23. Alluvium in the bank of Hominy Creek about one fourth mile downstream from Hominy Falls in the southeast quarter of sec. 29, T. 24 N., R. 8 E.

material. It is poorly stratified at most places, with some layers showing poorly developed cross-bedding at a few localities. In a 20 foot thick exposure on Middle Bird Creek in the N. W. ¼ of sec. 26, T. 26 N., R. 8 E., the lower eight feet is a gravel bed of angular limestone and sandstone pebbles and cobbles.

The origin of the alluvial material is probably a combination of eolian and fluvial deposition. The fine grain size and the weathering to steep bluffs indicate a large per cent of loess. However, the bedding and presence of gravel indicate river deposition.

Poorly defined terrace gravels occur along the sides of Middle Bird Creek about 20 feet above the creek bed, west of the Drummond Ranch road in the N. W. corner of T. 26 N., R. 8 E., and the N. E. corner of T. 26 N., R. 8 E. The gravel consists mostly of sub-angular, fusulinid-bearing flint cobbles. The flint probably was transported to its present position from the Foraker chert outcrop in the Flint Hills to the west.

An interesting non-geological sidelight is the presence in the area of artifacts made from this flint. The author found two such artifacts on the banks of Middle Bird Creek. They are an arrow point and a flint knife, tentatively identified by H. C. Skinner [58] as Foraker flint and Wreford flint respectively.

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[58] Hubert C. Skinner, A Petrographic Study of Some Artifact Flints of the Central United States, 1954, unpublished manus.

Figure 24. Arrowhead made from fusulinid-bearing flint, found on bluff above North Bird Creek in the southeast quarter of sec. 30, T. 26 N., R. 9 E.

Figure 25. Flint knife found in the bank of a Middle Bird Creek tributary, in the Northeast quarter of sec. 12, T. 26 N., R. 7 E. Note the excellent preservation of the fusulinids.

CHAPTER III

REGIONAL GEOLOGY

Historical Geology

The Virgil rocks of the central part of the Mid-Continent region crop out in nearly parallel belts striking a little east of north and extending from the northern edge of the Arbuckle Uplift area across Oklahoma and Kansas.

The sediments vary from near shore coarse clastic and red-bed facies in central Oklahoma to predominantly marine limestone in northern Kansas, with those in northern Oklahoma being transitional between the two. This facies change does not indicate an appreciable change in depth of deposition but indicates distance from the source of sediments, which lay to the south in upper Pennsylvanian time.

The series is characterized by cyclical alternation of marine and non-marine sediments deposited on a relatively stable interior platform area. At no time in the Pennsylvanian was this area covered to any great depth by the seas nor uplifted high above them. Rather, numerous fluctuations in sea level (or land level) resulted in a more or less rhythmic series of transgressions and regressions of shallow epicontinental seas. Rather than being local, these fluctuations in level were contemporaneous over the whole region, with the result that numerous thin

limestones and coal seams in the series are continuous for hundreds of miles along the outcrop. Individual sedimentary cycles, each marking a single transgression and regression of the sea, can also be correlated across large areas, although individual beds in the cycles are not necessarily continuous.

In Kansas the cycles are marked by a predominance of shale, alternating with limestone, the beginning of each cycle being marked by non-marine sandstone and shale. Numerous coal seams occur, marking the termination of each non-marine phase of the cycles.

Southward into northern Oklahoma the coal seams disappear, the percentage of limestone decreases, and the percentage of sandstone increases. Thus in the Pawhuska area cyclic sedimentation is evident, but not so well defined as in Kansas. The sandstones increase southward across the area, accompanied by a decrease in the number and thickness of the limestone beds. However, several of the thin, continuous limestones present in Kansas have been traced into and across the area.

Farther south the series is made up predominantly of thick beds of coarse sandstone and chert conglomerate, which are not continuous over large areas and are difficult to correlate.

The present drainage system of the area is the result of several stages of erosion. The oldest erosion surface is known as the Pawhuska Rock Plain [59] and is an upland erosion surface preserved on the hilltops. It is approximately Pleistocene in age. The terraces found on Middle Bird Creek represent a younger stage of erosion probably similar to the present drainage system, and are possibly late Pleistocene in age.

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[59] Ham, op. cit., 1939.

The valley alluvial fills were probably formed in Recent time and represent a period of greater deposition than at present. The fact that the present drainage cuts through the alluvium does not mean that the region has been rejuvenated, since the streams have not cut down into the bedrock.

Structural Geology

The Pennsylvanian and overlying Permian rocks of the Mid-Continent region have a low angle regional dip westward from the Ozark dome, this structure being known as the Prairie Plains homocline. The dip in central Oklahoma is from 60 to 100 feet per mile and decreases in the northern part of the state to 20 to 40 feet per mile.

The outcrop lines of these beds converge southward toward the Arbuckle Mountains due to the southward steepening of dip, truncations by unconformities and thinning of individual beds, and onlap on the Hunton Arch.

Locally the regional dip is interrupted by small structures which are particularly numerous in Osage County. In the western part of the county (west of the longitude of the Pawhuska area) there are a few folds, which are mostly noses. The average dip is about 38 feet per mile to the west, and the strike varies from due north to N. 5° E. In the eastern part there are numerous faults and folds, which make regional dip and strike determinations difficult. The general strike varies from N. 10° E. to N. 35° E., and the dip averages about 36 feet per mile to the west.

The characteristic feature of the faults is the alignment. With few exceptions, they trend northwest-southeast and occur in belts *en echelon*. Most of the faults fall into two groups, those striking N.

26° - 35° W. and those striking N. 11° - 20° W. They are all normal, those having the downthrown side on the southwest being about equal in number to those downthrown of the northeast. They are of small magnitude, the throw being less than 30 feet and the length being less than one mile in most cases, though a few are several miles long. The faults are believed to die out downward in the shales lower in the Pennsylvanian.

The en echelon faults in Osage County are part of a wide belt of faults extending from Pontotoc County, Oklahoma, northward to the Kansas line. This belt follows generally the "swing" of the outcrop belt of the Pennsylvanian rocks. In Osage County this wide belt is made up of two smaller well-defined belts, both of which pass through the Pawhuska area, in which area the greatest concentration is found. In the area the author mapped 37 faults.

The folds are mostly of three types, domes, anticlines, and noses, the most numerous being the anticlines. They are of small magnitude, with most having a closure of from 10 to 40 feet, the maximum in the Pawhuska area being 70 to 90 feet on the Myer's dome. The area of the lowest closing contour is in most cases about one fourth square mile, the maximum rarely exceeding one square mile. The steepness of the flanks of the folds generally increase with depth, as has been revealed by drilling.

According to Milliken [60], most of the folds in Osage County are elongate, and 84% of the elongate folds have a northeast-southwest trend,

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[60] C. V. Milliken, "Inter-Relations of the Folds of Osage County, Oklahoma", American Assoc. Petroleum Geol. Bull., vol. 4, (1920), pp 151-158.

the most frequent direction being N. 15° to 35° E. However, he noted no alignment of individual folds, nor any area in which any one direction of elongation is prominent, but most of the larger folds lie in three well-defined north-south belts across the area.

Numerous theories have been proposed for the origin of the en echelon faults and alignment of the folds in Oklahoma. Although he has not made extensive studies or experiments on the problem, the author believes, on the basis of field observation, and a consideration of the mechanics of earth movements, that the faults and folds are the result of the same deforming force, and that the theory proposed by Ickes [61] furnishes the best explanation for the origin of the forces.

He theorized that northwestward forces from the Choctaw fault zone of the Ouachita Uplift were opposed by a southeastward buttressing effect of the Nemaha Ridge of Kansas. The northwestward force was then resolved into two horizontal components, one a little east of north and one a little north of west. The buttressing force was also resolved into two components, parallel and opposite to these two. The resulting two pairs of shear forces resulted in a northeast-southwest tensional stress causing the faults, and a northwest-southeast compressional force forming the folds.

Other similar theories involving shearing couples as origin of

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[61] S. L. Ickes, "Discussion: Origin of the Faults in Creek and Osage Counties, Oklahoma", American Association of Petroleum Geologists, Bulletin, vol. 10 (1926), pp. 727-729.

the stresses were advanced by Fath [62], Foley [63], and Kramer [64]. Link [65] and Powers [66] theorized that the surface structure was influenced by pre-Pennsylvanian topography due to differential compaction, and that later horizontal compressive forces may have accented the original folds. Brown [67] suggested horizontal compressive forces acting with equal intensity in all directions as the origin of the folds. Nevin and Sherrill [68] thought that the folds were the result of vertical forces due to regional uplift, with the alignment corresponding to north-northeastward trending zones of weakness in the basement rocks. A torsional stress combined with regional uplift in the Osage County area was suggested by Sherrill [69] as the cause of tensional stresses developing the faults.

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[62] A. W. Fath, "The Origin of the Faults, Anticlines, and Buried 'Granite Ridge' of the Northern Part of the Mid-Continent Oil and Gas Field", U. S. Geol. Survey, Professional Paper 128 (1920), pp. 75-84.

[63] L. L. Foley, "The Origin of the Faults in Creek and Osage Counties, Oklahoma", American Association of Petroleum Geologists, Bull. vol. 10 (1926), pp. 293-303.

[64] William Kramer, "En Echelon Faults in Oklahoma", Amer. Assoc. Petroleum Geologists, Bull., vol. 18 (1934), pp. 249-268.

[65] T. A. Link, "En Echelon Tension Fissures and Faults", Amer. Assoc. Petroleum Geologists, Bull., vol. 13 (1929), pp. 627-637.

[66] Sidney Powers, "Structural Geology of Northeastern Oklahoma", Journal of Geology, vol. XXXIX (1931), pp. 117-132.

[67] R. W. Brown, "Origins of the Folds of Osage County, Oklahoma", Amer. Assoc. Petroleum Geologists, Bull., vol. 12 (1928), pp. 501-513.

[68] C. M. Nevin and R. E. Sherrill, "The Nature of Uplifts in North-Central Oklahoma and Their Local Expression", Amer. Association Petroleum Geologists, Bull., vol. 13 (1929), pp. 23-30.

[69] R.E. Sherrill, "Origin of the En Echelon Faults in North-Central Oklahoma", Amer. Assoc. Pet. Geol., Bull., vol. 13 (1929) pp.31-37.

Economic Geology

Road ballast material has been obtained in the past from quarries (now abandoned) in the Deer Creek limestone. This limestone makes an excellent source for such material, due to its thickness, but its thin-bedding and irregularities make it of little value for building material.

Brick clay has been quarried from the Kanwaka shale at the now abandoned Pawhuska Vitrified Brick and Tile Company plant. According to Sheerar [70] this shale is suitable for making common and face brick, hollow block, and sewer pipe.

The Elgin sandstone and some of the other thick sandstone beds throughout the section are spring-formers along the outcrops, and should make good sources for well water a few miles west of the outcrops.

Oil production in the Pawhuska area is mostly from shallow pumping wells, there being a total of 562 producing wells, with a total average daily production of approximately 2,700 barrels in December, 1953. There are 19 fields, of which the Atlantic (S. W. corner of T. 25 N., R. 8 E.), New England (S. W. part of T. 25 N., R. 9 E., and S. E. part of T. 25 N., R. 8 E.), and Osage-Hominy (S. sec. T. 24 N., R. 8 E.) fields are the major producers. [71]

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[70] Leonard F. Sheerar, "The Clays and Shales of Oklahoma", Oklahoma A. and M. College, Division of Engineering Publication, vol. 3 (1932), p. 195.

[71] Vance Kong Reports, "Osage District", December, 1953.

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APPENDIX

MEASURED STRATIGRAPHIC SECTIONS

I. Sec. 34, T. 27 N., R. 8 E. Measured from exposures along northeast bank of North Bird Creek and southwest side of Midland Valley Railroad in east half of section.

PEARSONIA limestone.

Limestone, dark bluish gray, weathering brownish gray. Fine grained, dense, brittle, breaking with sub-conchoidal fracture. Massive bed weathering to large rectangular blocks with rounded edges. Top 0.8 foot is fusulinid-bearing and weathers thin-bedded..... 3.6

Covered interval, probably shale 5.4

Sandstone, weathering light brown 1.0

Covered interval, probably shale 11.0

LITTLE HOMINY limestone.

Limestone, light gray, weathering "dirty gray". Thin, irregular bedding, weathering to thin, irregular flags. Upper part is fusulinid-bearing. Lower part is algal and conglomeratic. Thickness varies locally up to ... 4.3

Shale, light greenish gray, indurated, fissile, cut by numerous vertical joints 6.0

Limestone, light gray. Grades locally to light gray to bluish gray, shaly limestone and to dark bluish gray shale. Thin, irregular-curving bedding. Fossiliferous, abundance of brachiopods and fusulinids..... 4.0

II. Sec. 36, T. 27 N., R. 9 E. Measured from exposures at base of hill west of Highway 99, in northeast part of section.

ORSAD limestone.

Limestone, light gray, fine-grained, dense. Fossiliferous, abundant fusulinids and small brachiopods. Weathers flaggy 0.2

Shale 0.1

Limestone, "pebbly" 1.5

III. Sec. 12, T. 26 N., R. 7 E. Measured at wet weather falls in Middle Bird Creek and south bank of creek in northeast part of section.

WAKARUSA limestone:
Limestone, dark bluish gray, fine-grained, dense, brittle, breaking with sub-conchoidal fracture. Weathers orange-brown to gray with numerous "Cryptozoons" showing as gray splotches on surface. Few other fossils 1.0
Shale, gray, poorly exposed 25.0
Limestone, light brown, fine-grained, "crumbly".
Weathers light tan with maroon streaks 1.0
Shale, green 2.0
Limestone, light gray, weathering orange to tan. Dense, fine-grained. Fossiliferous, abundant productid-type brachiopods 0.5
Shale, buff 3.0
RULO limestone:
Limestone, gray, fine-grained, dense, brittle.
Weathers to dark gray, irregularly curving flags, showing numerous crinoid stems on surface. Massive bed, forming low falls 1.7
ELMO coal:
Coal, bituminous 0.3
Shale, gray, fissile, underclay showing ferrous stains on partings . 5.0

IV. Sec. 6, T. 26 N., R. 8 E. Measured along east side of tributary of Middle Bird Creek in east part of section.

WAKARUSA limestone:
Limestone, cut by vertical joints and weathers to large rectangular blocks with rounded edges. Weathers bright orange-brown to light tan, surface spotted with outlines of "Cryptozoons".
Not measured.
Covered interval 11.0
Limestone, light gray, algal. Appears sandy due presence of small algal structures. Weathers "crumbly" 1.0
Covered interval 25.0
RULO limestone:
Limestone, dark gray, fine-grained, dense, brittle.
"Rings" with hammer blow and breaks with sub-conchoidal fracture. Weathers to bright orange-brown to light grayish brown, large rectangular blocks with rounded edges. Fossiliferous, abundant Myalina, small brachiopods, and crinoid stems 1.4
Covered interval 18.0
Limestone, light gray; weathers light gray, flaggy to "crumbly". Algal, thin-bedded at top, grading down to unfossiliferous, massive at base 3.1
Shale 0.5
Limestone, light gray, weathers orange. Fine-grained, sandy, limonitic, dense. Fossiliferous, bryozoans, brachiopods, crinoid stems 1.5
Shale, greenish gray 3.5
Limestone, light gray, weathers reddish brown. Coarse-grained, fossiliferous 1.0

Shale, alternating maroon and greenish gray 4.0
Sandstone 1.0
Shale, alternating maroon and greenish gray 9.0
Sandstone, massive, irregular cross-bedding. Medium-grained, sub-rounded, clean. Thickness varies up to 18.0
Covered interval, probably shale. Pinches out locally, up to 5.0
Sandstone, massive, irregular cross-bedding. Medium-grained, sub-rounded, friable. Weathers brown 9.5
Covered interval, probably buff, fossiliferous shale 13.5
BIRD CREEK limestone:
Limestone, light brownish gray, fine-grained, dense, brittle, sub-conchoidal fracture. Massive bed, cut by vertical joints. Fossiliferous throughout, thin lamina of Cruirithyris planoconvexa at top. Forms prominent ledge in bank of creek. Weathers dark bluish gray 2.5
SEVEY shale:
Shale, greenish gray, nodular, fossiliferous 7.0
Shale, dark maroon. Contains numerous irregular nodules of green, indurated shale with yellowish brown limestone centers, which are resistant to erosion 4.0

V. Sec. 17, T. 26 N., R. 8 E. Road cut along north side of northwest quarter.

WAKARUSA limestone:
Limestone, gray, fine-grained, dense, brittle, sub-conchoidal fracture. Weathers light gray to orange-brown with numerous "Cryptozoons" showing on surface. Fossiliferous, small brachiopods and crinoid stems 0.8
Covered interval, probably shale 15.0
Sandstone, poor exposure 3.0
Limestone, gray, fine-grained, dense. Fossiliferous, approximately 50% fossils, and small algal structures. Weathers to light gray, "crumbly" cobbles 1.0
Covered interval 22.0
Limestone, light brown, fine-grained, dense. Contains disseminated limonite grains, which give brown to orange-brown weathered surface. Sandy in lower part 3.0
Covered interval 6.5
RULO limestone:
Limestone, light brown to gray, dense, medium-grained, massive bed. Weathers to light gray to orange-brown flags, contains disseminated limonite grains. Fossiliferous, bryozoans, brachiopods, clams showing on surface 2.8
Shale, buff and gray 3.7
ELMO coal:
Shale, bituminous 1.0
Shale, bluish gray to yellow 4.0
Covered interval 16.0

Limestone, light tan, poorly exposed, about 0.5
Covered interval 4.5
Sandstone, poorly exposed, about 6.0
Covered interval 31.0
BIRD CREEK limestone:
Not measured.

VI. Secs. 29 and 30, T. 26 N., R. 8 E. Measured on hill on south side of South Bird Creek in northwest corner of sec. 29 and northeast part of sec. 30.

Limestone, light gray, fine-grained, dense, sandy. Contains disseminated limonite grains. Weathers gray. Not measured.
Covered interval 10.0
Limestone, light gray to tan, algal. Weathers to dirty white, "crumbly" cobbles 1.0
Limestone, orange-brown, shaley, weathers bright orange-brown..... 0.5
Shale, buff, fissile. Contains numerous "paper thin" sandstone laminae 13.5
Covered interval 15.0
RULO limestone:
Limestone, dark gray, fine-grained, dense. Fossiliferous, abundant brachiopods, crinoid stems, and Mvalina. Weathers to bright orange to gray flags and boulders. About 1.0
Covered interval 23.0
Sandstone, cross-bedded; current ripple marks on top. Medium-grained, friable. Weathers brown and locally pink 10.0
Shale, buff, nodular, fossiliferous. Contains several limestone "stringers" in lower part 17.0
BIRD CREEK limestone:
Limestone, dark gray, fine-grained, dense, brittle. Massive bed cut by vertical joints. Weathers to tan to gray rectangular blocks 2.1
SEVENY shale:
Shale, green, nodular, indurated. Maroon streaks 6.9
Sandstone, fine-grained, light green. Not measured.

VII. Sec. 8, T. 26 N., R. 8 E. Measured on bluff on south side of Middle Bird Creek in southwest quarter of section.

RULO limestone:
Limestone, red to gray, coarse-grained. Contains rounded pebbles of limonite which are outlined on weathered surfaces but do not stain rock. Particles of gypsum and a few bright red spots on surface. Thin-bedded. In upper half interspersed with thin (about 2" thick) beds of gray, fine-grained, "sparkly", dense, brittle, arenaceous limestone. Weathers brown to gray, flaggy 19.0

ELMO coal:
Shale, bituminous, containing several thin laminae of coal. About 1.0
Limestone, light gray, fine-grained, dense. Weathers to light gray, irregular chunks 1.0
Limestone, light brown, fine-grained, dense, fossiliferous. Weathers light orange-brown..... 1.0
Covered interval, probably shale 4.0
Limestone, light gray, sandy, fossiliferous. Not measured.
Shale, buff with silty layers. Contains three streaks of maroon shale 16.0
Sandstone, massive bed with oscillation ripple marks on top. Not measured.

VIII. Sec. 8, T. 26 N., R. 8 E. Measured on hill east of Middle Bird Creek in southeast quarter of section.

HULO limestone:
Limestone, dirty white, medium-grained, fossiliferous. Contains numerous limonite pebbles. Weathers dark gray with surface dotted with outlines of limonite pebbles. Not measured.
Covered interval, probably shale 23.0
Sandstone, massive bed, cross-bedded, medium-grained, light tan, friable. Forms prominent cliff. Spring-former locally 40.0
BIRD CREEK limestone:
Poor exposure. Not measured.

IX. Sec. 16, T. 26 N., R. 8 E. Measured in densely wooded ravine in east-central part of section.

BIRD CREEK limestone:
Limestone, dark gray, fine-grained, dense, brittle. Fossiliferous, abundant small brachiopods. Weathers gray with limonite stains and traces of fossils on surface. Forms large rectangular blocks. Not measured.
SKIATOOK shale:
Covered interval 34.0
Sandstone, light tan, medium grained, massive bed. Forms prominent terrace. About 5.0
Covered interval 39.0
Sandstone terrace. Not measured.
Covered interval 17.0
TURNEY RUN limestone:
Limestone, gray, fine-grained, dense, fossiliferous. Contains corals, small brachiopods, clams and bryozoans. Weathers gray with limonite stains. Massive bed 2.3
Limestone, reddish gray, medium-grained, "crumbly," fossiliferous, thin-bedded. Weathers orange-green 0.6
Sandstone terrace. About 2.0

X. Sec. 22, T. 26 N., R. 8 E. Measured on north side of outlier in southwest quarter of section.

TURKEY RUN limestone:
Not measured.
Covered interval 5.0
Sandstone, terrace. Not measured.
Covered interval 6.0
Conglomerate, well rounded limestone and limonite pebbles in gray limestone matrix. Weathers light gray to orange-brown, irregular slabs. About 2.0

XI. Sec. 16, T. 26 N., R. 8 E. Measured on bluff north of Middle Bird Creek in southeast quarter of section.

TURKEY RUN limestone:
Not measured.
Covered interval 7.0
Sandstone, terrace 6.0
Covered interval 19.0
Sandstone, massive bed, irregularly cross-bedded, light tan, medium-grained, friable. Weathers orange-brown. Forms prominent bluff. Forms springs locally 18.0
Covered interval 5.0
PEARSONIA limestone:
Limestone, sandy, gray, medium-grained, dense, fossiliferous, algal, Weathers gray-brown, flaggy. About.... 1.0

XII. Secs. 11 and 14, T. 26 N., R. 8 E. Measured in ravine in southeast quarter of sec. 11 and on large hill along road in southeast quarter of sec. 11 and north central part of sec. 14.

SKIVEY shale:
Shale, buff, alternating with thin sandstone beds 5.0
Sandstone, fossiliferous. Abundant limonite replacements of clam and brachiopod shells. Yellowish brown, fine-grained, friable 1.0
Shale, buff, alternating with thin sandstone beds 6.0
Limestone, gray, soft, fossiliferous. Weathers orange-brown 1.0
Covered interval 6.0
TURKEY RUN limestone:
Limestone, dark gray, fine-grained, dense, brittle, sub-conchoidal fracture. Massive bed, weathers to orange-brown, large, rectangular slabs with small limonite spots on surface 2.0
Covered interval 10.0
Sandstone, terrace. About 2.0
Shale, buff to light, silty, fissile. Contains numerous thin sandstone beds 13.0

PEARSONIA limestone:
Limestone, dark gray, coarse-grained, dense, fossiliferous. Topped by thin layer of fusulinid limestone. Weathers gray to orange-brown 1.5
Shale, buff, silty, alternating with thin sandstone beds 15.5
Sandstone, terrace. About 2.0
Covered interval, probably shale with thin fusulinid-bearing limestone layer 6.0
Shale, alternating maroon and gray 7.5
Sandstone, poor exposure, About 2.5
LITTLE HOSKINI limestone:
Limestone, light gray, dense, algal. Fusulinids in thin layers at top of bed. Weathers dirty white with numerous solution cavities. Consists of three massive beds interspersed with thin beds 4.0
Shale, buff, nodular, fossiliferous 21.0
DEER CREEK limestone:
Limestone, thin, wavy bedding with thin shale partings, some of which are fusulinid-bearing. Light tan to light gray, medium-grained, fossiliferous with abundant limonite grains in lower part to gray, slightly sandy, with few fossils in upper part. Weathers gray, flaggy, with limonite stains 14.0
Covered interval, probably shale 11.0
PLUMMER limestone:
Limestone, dark gray, fine-grained, dense, fossiliferous. Brittle. "rings" with hammer blow and "shatters" like glass. Cut by numerous vertical joints. Weathers to light gray with orange-brown spots, large rectangular blocks, which slide down slope below 1.1
LECOMPTON limestone:
Covered interval, probably shale 9.0
Conglomerate, gray, dense, fine-grained, rounded limestone pebbles (1" - 2" diameter) in fine-grained sandstone matrix. Weathers dirty brown with numerous solution pits and gray spots marking pebbles. About ... 0.5
Sandstone. About 1.0
Covered interval, probably maroon shale with thin, fusulinid-bearing limestone layer 21.4
Limestone, terrace. Not measured.
KANWAKA shale:
Covered interval 18.7
ELMO sandstone:
Limestone, light brown, sandy, grading up to light gray, course-grained, algal, fusulinid-bearing at top. Weathers dirty gray to brown, crumbly 2.3
Sandstone, massive bed, cross-bedded. Not measured.

XIII. Sec. 1, T. 26 N., R. 8 E. Measured in ravine and on large hill east of bend in M. V. railroad in western half of section.

Sandstone, medium-grained, well cemented 8.5
LITTLE HORNY limestone:
Limestone, light gray, fine-grained, dense, few fossils, mostly productids. Weathers light gray and flaggy 1.5
Shale, buff, nodular, fossiliferous 26.0
DEER CREEK limestone:
Limestone, light gray, fine-grained, dense, irregularly curving bedding. Fossiliferous, abundant fusulinids in lower part; not found in upper 4 feet. Weathers grey to white, flaggy. About 13.0
Covered interval. About 10.0
PLUMMER limestone:
Limestone, dark gray, fine-grained, dense, brittle, sub-conchoidal fracture, fossiliferous (show as traces on surface). Cut by numerous vertical joints. Weathers to large rectangular blocks, light tan to light gray .. 1.0
LECOMPTON limestone:
Covered interval 9.0
Conglomerate, rounded limestone pebbles in fine-grained sandstone matrix 0.5
Sandstone, fine-grained. About 1.0
Covered interval. About 11.0
Limestone, maroon, shaly, fusulinid-bearing 0.5
Covered interval, probably maroon shale 6.5
Limestone, light gray to tan, medium-grained, dense. Contains small algal structures 1.0
Covered interval 4.5
Limestone, light brown, fusulinid-bearing. Weathers bright orange-brown 0.7
KANWAKA shale:
Covered interval 4.3
ELGIN sandstone:
Sandstone, thin-beds alternating with shale. Poorly exposed 30.0
Sandstone, massive, even-bedded. Forms bluff..... 21.0

XIV. Sec. 8, T. 26 N., R. 9 E. Measured in ravine below pond north of old Plummer ranch house, in north central part of section.

DEER CREEK limestone:
Limestone. Not measured.
Shale, buff, fossiliferous. Poorly exposed 4.5
PLUMMER limestone:
Limestone, dark gray, fine-grained, dense, brittle. Curving traces of fossils show on weathered surface. Cut by vertical joints. Weathers to large rectangular slabs, light gray. About 2.0
LECOMPTON limestone:
Covered interval. About 20.5

Sandstone, massive bed, light gray, calcareous 6.0
Covered interval. About 8.5
Limestone, gray to maroon, almost solid fusulinids.
Weathers gray with maroon stains. Poorly exposed 0.3
Covered interval. About 4.7
Limestone, light brown, medium-grained, dense, conglomeratic. Weathers orange-brown with gray limestone pebbles standing in relief 2.0

KANWAKA shale:
Not measured.

XV. Secs. 19 and 30, T. 26 N., R. 9 E. Measured in ravine east of M. V. railroad in southeast quarter of sec. 19 and on bluff east of railroad in eastern half of sec. 30.

Shale, gray with black streaks. Not measured.
FLORENA limestone:
Limestone, poor exposure. About 1.0
LECOMPTON limestone:
Shale, gray with maroon streaks 16.5
Sandstone, brown, calcareous, ripple marks on top of bed.. 1.0
Covered interval 16.5
Limestone, light tan, algal, fusulinid-bearing.
Weathers gray to orange-brown 0.8
Covered interval 3.7
Limestone, orange-brown, fusulinid-bearing, fine-grained.
Weathers bright orange 0.5
KANWAKA shale:
Covered interval. About 7.5
EMAN sandstone:
Sandstone, massive, irregular cross-bedding. Light tan, medium-grained, sub-rounded grains, friable. Forms prominent bluff 29.5
Covered interval, probably shale 14.2
Limestone, gray, coarse-grained, fossiliferous. Weathers gray with fossils standing in relief on surface and bleached white. Massive bed..... 1.8
Sandstone, brown, cross-bedded 3.5
Shale, buff, alternating with occasional thin sandstone beds 21.5
Sandstone, irregularly cross-bedded. Thick beds at top and bottom, thin-bedded in middle third. Locally varies in thickness at expense of shales above and below from 5.0 to 25.0
Shale, gray, silty. Not measured.

XVI. Sec. 24, T. 26 N., R. 9 E. Measured in pond excavation in southwest quarter of section.

KANWAKA shale:
Not measured.

ORKAD limestone:
Limestone, gray, dense, fusulinid-bearing, fossiliferous. Abundant brachiopods, gastropods. Weathers orange-brown, flaggy 0.8
Shale, greenish gray, grading downward to buff 5.0
Shale, maroon, Not measured.

XVII. Sec. 33, T. 25 N., R. 7 E. Measured on west bank of Hominy Creek due west of St. John's School in southeast quarter of section.

WAKARUSA limestone:
Limestone, gray, fine-grained, dense, fossiliferous. Massive bed 0.8
Shale, buff 0.5
Limestone, blue-gray, fine-grained, dense, fossiliferous. Abundant small brachiopods. Few corals, fusulinids, large colonial bryozoans, "Cryptozoon". Cut by vertical joints. Weathers light gray to tan 2.0
Shale, light bluish gray, fissile. Carbonaceous streaks and limonite stains on bedding planes 4.0

XVIII. Sec. 12, T. 25 N., R. 7 E. Measured on outlier in southeast quarter of section.

WAKARUSA limestone:
Limestone, light gray, fine-grained, dense, fossiliferous. Abundant fusulinids, brachiopods, and "Cryptozoon". Cut by vertical joints. Weathers to thin, irregular flags, gray with orange spots 1.2
Covered interval 17.0
Limestone, light brownish gray, fossiliferous, slightly sandy. Weathers buff. Not measured.

XIX. Secs. 17 and 18, T. 25 N., R. 8 E. Measured in A. T. & S. F. railroad cut southeast of McInnis stockyard siding, in northwest quarter of sec. 17 and northern half of sec. 18.

Limestone, light brownish gray, almost solid fusulinids, thin-bedded. Contains small algal structures and disseminated limonite grains. Weathers buff 1.9
Shale, alternating buff and maroon, fissile. Contains irregular, greenish gray limestone nodules which weather maroon 5.0
Limestone, light gray, almost solid fusulinids 0.5
Shale, buff and maroon, fissile 3.5
Sandstone, calcareous, fossiliferous, light gray, fine-grained, dense. Weathers thin 3.0
Shale, greenish gray and maroon 1.0
Shale, black, fissile 2.0
Sandstone, medium-grained, tan 1.0

Shale, buff, fossiliferous in bottom half; bluish gray to black, no fossils in top half. Weathers buff with black streaks. Alternates with thin sandstone beds in top 2 feet 16.0
Limestone, gray, fine-grained, wavey-bedded 0.6
Shale, buff, nodular, fossiliferous 3.0
BIRD CREEK limestone:
Limestone, blue-gray, fine-grained, dense, brittle, sub-conchoidal fracture, fossiliferous. Weathers tan to gray with brown stains and fossils traces showing on surface..... 1.7
SEVERY shale:
Shale, buff, nodular, silty, blue-gray at top..... 3.3
Sandstone, cross-bedded, light tan, friable 5.0
Covered interval, probably buff shale 20.0
TURKEY RUN limestone:
Limestone, blue-gray, fine-grained, dense, sub-conchoidal fracture. "Rings" with hammer blow. Fossiliferous, traces show on surface. Weathers gray with brown band in middle. Forms prominent ledge 3.2
Shale, gray, calcareous 1.0
Sandstone, fossiliferous, fine-grained, dense, white to light brown 0.5

XX. Sec. 17, T. 25 N., R. 8 E. Measured in A. T. & S. F. railroad cut in northeast quarter of section.

Sandstone, light tan, fine-grained, friable, even-bedded. Limonite stains near top. Weathers maroon to tan 10.0
Shale, fissile. Thin laminae of dark gray alternating with light gray shale and thin sandstone laminae 2.8
LITTLE HOMINY limestone:
Limestone, gray, medium-grained, dense, brittle, fossiliferous, conglomeratic (pebbles of limonite). Weathers brown with fossils standing in relief on surface 1.0
Limestone, algal, gray, fine-grained, dense, brittle, Weathers tan 2.3
Shale. Not measured.

XXI. Sec. 16, T. 25 N., R. 8 E. Measured in A. T. & S. F. railroad cut in southwest quarter of section. About one fourth mile southeast of Section XX.

Sandstone, thick-bedded, light tan, fine-grained, friable. Weathers orange-brown to red 4.0
Shale, thinly laminated, alternating with thin sandstone laminae. 3.0
LITTLE HOMINY limestone:
Limestone, gray, dense, algal, conglomeratic. Weathers gray to tan, rounded edges 2.0
Shale, fossiliferous, variegated, green, maroon, buff, weathers maroon 11.5

Shale, fossiliferous, gray with buff streaks. Weathers tan to gray. 16.5

XXII. Sec. 35, T. 25 N., R. 8 E. Measured in valley of Hominy Creek tributary in northwest quarter of section.

LITTLE HOMINY limestone:
Limestone, light gray to white, medium-grained. Algal structures, abundant throughout, concentrated at top of massive bed in middle portion in cross-bedded channels. Disseminated limonite particles, sandy. Weathers gray, solution pitted, cinnamon brown at top 10.0
Covered interval 22.0
DEER CREEK limestone:
Limestone, medium-grained, light gray, dense, fusulinid at bottom to fine-grained, white, dense at top. Weathers to irregular boulders covered with solution pits, light gray and streaked with limonite stains. About 11.0

XXIII. Sec. 13, T. 25 N., R. 8 E. Measured in excavation at west end of Lake Pawhuska dam.

DEER CREEK limestone:
Not measured.
Covered interval 10.0
Shale, buff, fossiliferous. About 4.0
PLUMMER limestone (?):
Limestone, light gray, fine-grained, dense, brittle. Weathers gray, flaggy with fossil traces showing on surface 0.5
LECOMPTON limestone:
Shale, greenish gray 3.5
Limestone, purplish brown, fusulinid-bearing, fine-grained. Weathers light tan, with fusulinids appearing to be solid mass 0.6
Shale, greenish gray with maroon streaks in lower half 15.7
Sandstone, fine-grained, yellow 1.0
Limestone, maroon, shaly, almost solid fusulinids in lower part. Streaked with light green, silty limestone. Top of bed is dense, and contains no fusulinids. Weathers light tan to maroon, littering slope with fusulinids 1.7
Shale, greenish gray 5.0
Sandstone, light tan, calcareous, silty. Thin-bedded alternating with shale partings 3.5
KANWAKA shale:
Shale, maroon, poorly exposed 6.5
ELGIN sandstone:

Sandstone, thin cross-bedded, medium-grained, sub-rounded grains, friable. Contains ferrous mineral which gives pink color to weathered surface 20.0
Shale, poorly exposed, probably maroon. About ... 10.0
Sandstone, massive bed, even cross-bedding resulting in irregular upper surface. Current ripple marks on surface. Same description as lower bed. Forms prominent cliffs 42.5

XXIV. Sec. 19, T. 25 N., R. 9 E. Measured on outlying hill in southeast quarter of section.

DEER CREEK limestone:
Not measured.
Covered interval 10.5
PLUMMER limestone:
Not measured.
LECOMPTON limestone:
Covered interval 19.0
Limestone, light gray, fossiliferous, medium-grained. Weathers gray, flaggy 1.0
Covered interval, probably shale and sandstone .. 14.5
Limestone, sandy, light tan, fossiliferous. Abundant brachiopods and large corals. About 1.5
Covered interval 4.0
Limestone, white, medium crystalline. Weathers gray, "Crumbly" 1.0
KANWAKA shale:
Covered interval 12.5
Sandstone, thick cross-bedded, alternating with thin shale beds 22.5
ELGIN sandstone:
Sandstone, massive cross-bedded. Forms prominent ledge 22.0

XXV. Sec. 11, T. 25 N., R. 8 E. Measured in abandoned quarry south of Highway 60 in northeast corner of section.

DEER CREEK limestone:
Limestone, thin-bedded, light gray, dense, brittle, grading to conglomerate at top. Contains brown, softer fusulinid-bearing layers 8.0
Limestone, brownish gray, fine-grained, dense, fossiliferous. Occasional channels cutting through bed, filled with fusulinids and fragments of other fossils in black, shaly matrix. Even-bedded..... 4.0
Limestone, thin, irregular bedding, light brownish

gray, fine-grained, dense. Most fossiliferous layer in member. Some layers are almost solid fusulinids, also brachiopods, corals, and others 2.5

Limestone, light gray, fine-grained, dense, brittle, fossiliferous, fusulinid. Topped by bituminous, light brown layer 1.0

Limestone, massive bed, dark gray, medium-grained, dense, few fossils. Main escarpment former in member 4.0

XXVI. Sec. 2, T. 25 N., R. 8 E. Measured in abandoned quarry north of Highway 60, just west of airport, and in ditch north of road.

DEER CREEK limestone:

Limestone, not described 14.5

Covered interval 11.5

Shale, black, fissile, fossiliferous. Abundant corals, clams, gastropods, cephalopods. Numerous small, dark blue concretions. 4.7

PLUMMER limestone:

Limestone, gray, fine-grained, dense, massive bed cut by vertical joints. Fossiliferous, traces show on surface. Weathers brown to orange. Very difficult to break 0.8

LECOMPTON limestone:

Shale, buff, nodular 1.2

Limestone, brown, coarse-grained, soft. Topped by layer of fusulinids. Doubtful position. Not measured.

XXVII. Sec. 27, T. 25 N., R. 8 E. Measured in gully in northeast quarter of section.

DEER CREEK limestone:

Not measured.

Covered interval, probably buff, fossiliferous shale 28.0

Shale, black, fissile 2.0

Shale, gray-brown, contains ferrous limestone streak 2.0

PLUMMER limestone (?):

Limestone, dark gray, medium-grained, fusulinid-bearing, brittle. Weathers tan with the fusulinids standing in relief on surface 0.7

LECOMPTON limestone:

Shale, black, bituminous 4.0

XXVIII. Sec. 35, T. 25 N., R. 8 E. Measured in bank of gully in southwest quarter of section.

DEER CREEK limestone:

Not measured.

Covered interval 8.5
Shale, dark yellowish brown, fossiliferous 11.0
PLUMMER limestone:
Limestone, dark gray, fine-grained, dense. Contains "Cryptozoon". Weathers tan 0.7
LECOMPTON limestone:
Shale, dark olive drab 4.8
Sandstone, thin, calcareous. Not measured.

XXIX. Sec. 4, T. 25 N., R. 9 E. Measured on massive bluff known locally as "Lovers' Leap", in northwest corner of section.

KANWAKA shale:
ELGIN sandstone:
Sandstone, massive, even cross-bedding. Forms prominent cliff. Light tan, calcareous, clean, sub-rounded grains. Fine-grained at top grading to medium-grained at base 60.0

XXX. Sec. 5, T. 25 N., R. 9E. Measured in abandoned shale quarry of old Pawhuska Vitrified Brick and Tile Co., in east central part of section.

KANWAKA shale:
ELGIN sandstone:
Sandstone, poorly exposed. Covered interval. About 50.0
Sandstone, calcareous, dense, fine-grained..... 0.5
Shale, olive drab with dark gray streaks..... 24.0
Sandstone, calcareous. Not measured.
Shale, dark greenish gray 7.5
Sandstone, calcareous, fine-grained, thin bed. Not measured.
Shale, olive drab at top, grading downward to dark gray at base. Contains occasional thin sandstone beds 47.5

XXXI. Sec. 15, T. 24 N., R. 7 E. Measured along main road in central part and southeast quarter of section.

WAKARUSA limestone:
Limestone, poor exposure. Not measured.
Covered interval 4.2
Sandstone, terrace. Not measured. 6.0
Covered interval 1.0
Limestone, algal, light gray, medium-grained. Weathers light gray, flaggy. About 25.0
Covered interval 0.8
RULO limestone (?):
Limestone, dark gray, fine-grained, dense. Few fossils except at very top of bed..... 8.7
Covered interval .....

Sandstone, calcareous, fine-grained 0.5
Covered interval 5.0
Limestone, purple and brown, algal, fossiliferous, medium-grained 0.5
Shale, green and maroon, containing several fossiliferous limestone layers and a few thin sandstone layers 5.0
Limestone, purple, thin bed. Not measured.
Shale, green and maroon, nodular 5.5
Sandstone, light brown, friable, medium-grained..... 3.0
Covered interval 2.0
Limestone, sandy, fossiliferous, light gray, algal. Contains numerous disseminated limonite grains..... 1.0
Sandstone, fossiliferous, medium-grained, friable. Contains numerous channels filled with fossils in calcareous matrix. Abundant Hyalina sp. Bottom of bed is thin layer of greenish gray and maroon, fossiliferous li estone 2.3
Shale, olive drab, fissile, indurated, grading upward to maroon. Numerous thin siltstone laminae in lower part and thin limestone layer in middle 11.5
Shale, buff, nodular, fossiliferous. Contains several thin fossiliferous limestone layers 3.0
Limestone, gray, fine-grained, dense, fossiliferous. Weathers gray to light tan 0.5
Shale, buff, nodular, fossiliferous. Thin calcareous sandstone layer near base 8.0
BIRD CREEK limestone:
Limestone, dark gray, fine-grained, dense, brittle, sub-conchoidal fracture. Cut by vertical joints. Few fossils. Weathers gray to light brown, irregular flags..... 1.4
SKIATOOK shale:
Shale, green and maroon, indurated, nodular, sandy 10.0
Shale, silty, buff. Alternating with thin sandstone layers 5.5
Sandstone, massive, cross-bedded, medium-grained, friable, sub-rounded grains 15.0

XXXII. Secs. 4 and 5, T. 24 N., R. 6 E. Measured on sides of ravine cut by Little Hominy Creek in the northeast quarter of sec. 5 and northwest quarter of sec. 4.

TURKEY RUN limestone:
Limestone, poor exposure. About 2.5
Covered interval, probably shale and thin sandstone beds 22.5
Sandstone, cross-bedded, fine-grained, friable 7.5
Covered interval 7.5
LITTLE HOMINY limestone:
Limestone, gray, medium-grained, dense. Weathers to dark gray, irregular boulders 1.0
Covered interval, probably fossiliferous shale 12.0
DEER CREEK limestone:
Limestone, light gray, fine-grained, dense.

Few fusulinids. Fossiliferous, some fossils occur as limonite molds. Topped by thin fusulinid-bearing limestone grading upward to fossil conglomerate. Weathers dark gray, thin-bedded, littering slope below with white flags 19.0

XXXIII. Sec. 30, T. 24 N., R. 8 E. Measured on large hill in southwest quarter of section.

TURKEY RUN limestone:
Limestone, blue-gray, fine-grained, dense, slightly sandy. Cut by numerous vertical joints. Weathers to flags cut vertically through bed, light gray to tan. Not measured.
Covered interval 5.0
Sandstone, terrace. Not measured.
Covered interval 32.0
Limestone, light green and maroon, fusulinid-bearing 0.5
Covered interval 5.0
Sandstone, calcareous, thin-bedded. Limonite stains 5.0
LITTLE HOMINY limestone:
Conglomerate, limestone pebbles. Weathers gray 1.0
Covered interval 6.0
DEER CREEK limestone:
Limestone, light tan, coarse-grained, fossiliferous, containing veins of limonite. Weathers dirty gray, "rotten" and litters slope with white to gray, irregular flags showing fossil traces on surface. About 5.0
Covered interval 5.0
Sandstone, massive, even-bedded. Forms prominent ledge 19.0

XXXIV. Sec. 6, T. 24 N., R. 9 E. Measured near head of intermittent stream in northwest quarter of section.

DEER CREEK limestone:
Not measured.
Covered interval. About 8.0
Sandstone, gray, calcareous. About 1.0
Covered interval, probably shale 31.0
PLUMMER limestone:
Limestone, gray, fine-grained, dense, fossiliferous. Abundant corals and occasional algal structures resembling "Cryptozoon". Weathers bright orange-brown and forms large rectangular blocks. Wide terrace but not prominent escarpment. About 2.5
LECOMPTON limestone:
Shale, maroon and greenish gray 20.7
Limestone, gray with purple streaks, fine-grained, dense. Weathers light tan to gray 0.7
Limestone, light greenish gray and maroon streaked, fine-grained, dense, slightly sandy, fusulinid-bearing. Weathers tan with fusulinids standing in relief 0.3

KANWAKA shale:
Shale, green and maroon 14.2
ELGIN sandstone:
Not measured.

XXXV. Sec. 9, T. 24 N., R. 8 E. Measured in road cut just south of Little Hominy Creek, in the northeast quarter of section.

DEER CREEK limestone:
Limestone, fine-grained, dense, thin-bedded with shale partings in bottom part to medium-grained, medium-bedded at top. Weathers flaggy at bottom to irregular boulders with numerous solution pits at top. Contains disseminated limonite particles which stain weathered surface 15.0
Shale, buff to blue-gray, nodular 8.0
Sandstone, even-bedded, alternating with shale partings 7.5
Covered interval 9.5
Sandstone, terrace. About 3.0
Covered interval. About 52.0
PLUMMER limestone:
Limestone, gray, fine-grained, dense, massive bed. Contains abundant corals and algal structures resembling "Cryptozoon". Weathers bright orange-brown, rectangular blocks. Cut by vertical joints.. 2.7
LECOMPTON limestone:
Covered Interval 4.3
Shale, black, flesile 3.0
Shale, buff 15.0
Sandstone, calcareous, light gray, fine-grained, dense. Weathers light brown 3.5
Shale, green and maroon 8.5
Limestone, sandy, light tan, medium-grained, dense. Weathers brown 1.5
KANWAKA shale:
Covered interval. About 5.0
ELGIN sandstone:
Not measured.

XXXVI. Sec. 32, T. 24 N., R. 8 E. Measured in wooded gully in southwest quarter of section.

DEER CREEK limestone:
Limestone, light gray, medium-grained, thin-bedded. Contains numerous limonite veinlets. Weathers gray with numerous solution pits..... 4.0
Covered interval 75.0
PLUMMER limestone:
Limestone, light gray, dense at top to sandy, fine-grained in bottom part. Weathers orange-brown.

Abundant Composita subtilita. Thin-bedded 4.0

XXXVII. Sec. 34, T. 24 N., R. 8 E. Measured at south end of large Plummer outlier, in northwest quarter of section.

Sandstone, cross-bedded, medium to fine-grained, sub-rounded grains. 3.6
Covered interval 11.4
Sandstone, cross-bedded, medium-grained, friable, sub-rounded grains. Forms prominent ledge 14.0
Covered interval 46.0
PLUMMER limestone:
Limestone, light gray, medium to fine-grained, dense, fossiliferous. Abundant brachiopods and few fusulinids. Disseminated limonite grains, sandy in lower part. Thin, irregular bedding. Weathers orange-brown. About 5.0
LECOMPTON limestone:
Covered interval 25.0
Sandstone, calcareous, fossiliferous, fine-grained, Weathers orange-brown. Topped by thin bed of sandy, fusulinid-bearing limestone, light gray, medium-grained, fossiliferous, which weathers gray with crinoid stems standing in relief. About 1.3
KANWAKA shale (?):
Covered interval 38.5
KLEIN sandstone:
Not measured.

XXXVIII. Secs. 20,21,28, and 29, T. 24 N., R. 9 E. Measured on outlying hill at corner of four sections.

PLUMMER limestone:
Limestone, light gray, fine-grained, dense, fossiliferous. Abundant large corals. Weathers gray with orange streaks, flaggy, showing fossil traces on surface. Not measured.
LECOMPTON limestone:
Covered interval . About 25.0
Limestone, algal, fusulinid-bearing, light gray. Contains disseminated limonite grains. Weathers gray. Covered by slump from Plummer limestone at most places. About 1.0
Covered interval 24.0
Limestone, fusulinid-bearing, brownish gray, fine-grained, dense. Contains about 50% disseminated limonite grains. Weathers orange-brown, irregular cobbles. About 1.0

XXXIX. Sec. 7, T. 24 N., R. 9 E. Measured on north side of outlying hill in northwest quarter of section.

PLUMMER limestone:
Not measured.
LECOMPTON limestone:
Covered interval 24.0
Limestone, finely crystalline, underlain by "crumbly", fossiliferous limestone. About 1.0
Covered interval 20.0
Limestone, gray, fine-grained, dense, brittle, sub-concholdal fracture, cherty, fossiliferous. Weathers light brown, irregular cobbles 0.5
Covered interval 7.5
Limestone, sandy, brown, fusulinid-bearing. About 0.5
KANWAKA shale:
Covered interval 12.0
ELGIN sandstone:
Not measured .

XL. Sec. 16, T. 24 N., R. 8 E. Measured in road cut in north-east quarter of section.

PLUMMER limestone:
Limestone, massive bed, gray, fine-grained, dense, fossiliferous. Abundant small brachiopods, corals, bryozoans at base. Weathers to large rectangular blocks, prominent ledge, orange-grown 2.4
LECOMPTON limestone:
Covered interval 15.0
KANWAKA shale:
Shale, red at top, grading downward to light gray..... 15.0
ELGIN sandstone:
Sandstone, cross-bedded, friable, medium sub-rounded grains. Forms massive ledge..... 25.0
Shale, buff, streaked with blue-gray, nodular. Contains numerous ferrous concretions in upper half .. 25.0
Siltstone, light brown, cross-bedded, shaly..... 15.0
Shale, olive drab, nodular 14.5
Shale, blue-gray, nodular 23.0

XLI. Sec. 18, T. 24 N., R. 9 E. and sec. 13, T. 24 N., R. 8 E. Measured on outlying hill along line between the two sections.

PLUMMER limestone:
Limestone, gray, fine-grained, dense, medium crystallinity, thin-bedded, fossiliferous. Top of bed covered with fossils eroded out of bed. Weathers bright orange-brown, and litters slope with flags. About 2.0
LECOMPTON limestone:
Covered interval 27.0
Limestone, light gray, fine-grained, dense, fusulinid-bearing. Weathers gray, irregular boulders..... 1.0

Shale, green and maroon, fossiliferous. Occasional thin calcareous sandstone layer 20.0
Limestone, light grayish tan, dense, sandy. Numerous limonite-lined cavities. Weathers orange-brown to white, rectangular blocks with rounded edges and numerous solution pits 0.8
KANWAKA shale (?):
Shale, greenish gray 8.2
Sandstone, white, fine-grained 1.0
Shale, maroon, alternating with thin siltstone layers ... 5.0
Covered interval 40.0
ELGIN sandstone:
Sandstone, massive cross-bedded, medium-grained, sub-rounded grains. Forms prominent bluffs and locally waterfalls 33.0

XLII. Sec. 32, T. 24 N., R. 9 E. Measured in old excavation just north of private road, north of old race track, in north-east quarter of section.

KANWAKA shale:
ELGIN sandstone:
Sandstone, massive cross-bedding. Caps prominent hills. Poorly exposed. About 20.0
Covered interval 47.0
Shale, olive drab to buff, nodular, fossiliferous (few fossils found). Contains numerous ferrous concretions and thin sandstone layers in botton part 50.0
Shale, dark gray to black, fissile to nodular, with orange-brown and blue-gray streaks. Contains numerous ferrous concretions and thin, dark gray, silty limestone layers which weather orange-brown. Fossiliferous, sloper literally covered with fossils, which probably weather out of concretions and limestone layers; most have brown stains. Abundant Trepospira and Worthenia..... 22.0
Approximate base of Kanwaka shale.