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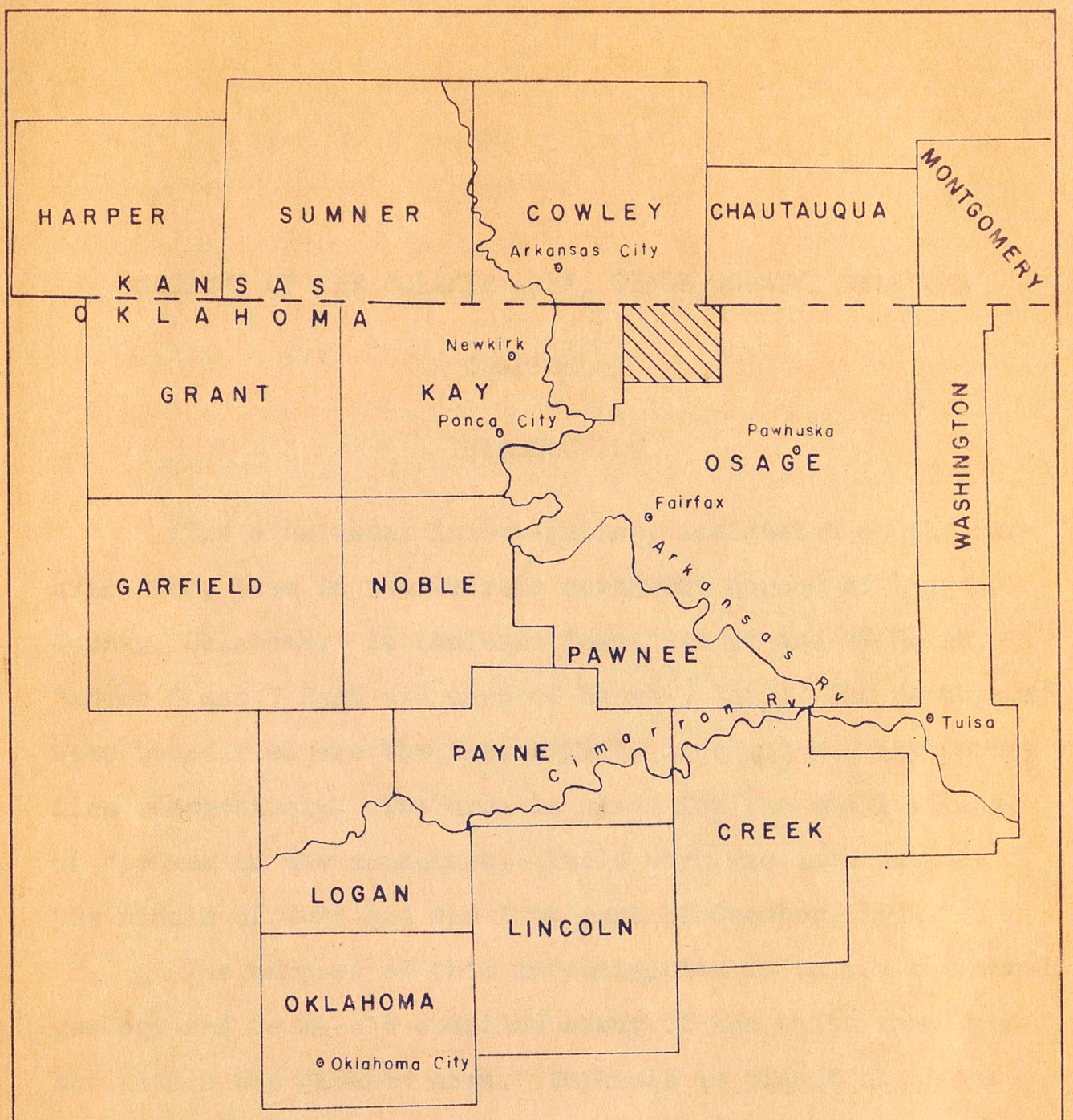

LOCATION MAP
of
FORAKER AREA

FIGURE 1

GEOLOGY OF THE FORAKER AREA, OSAGE COUNTY, OKLAHOMA

CHAPTER I

INTRODUCTION

The area under investigation, designated as the Foraker Area, lies in the extreme northwest corner of Osage County, Oklahoma. It includes Townships 28 and 29 North, Ranges 6 and 7 East and part of Range 5 East. The north and west boundaries are the Kansas State Line and the Kay County Line respectively. The area is named for the small village of Foraker in the southeast. Field work was done between the middle of June and the last part of October, 1952.

The purpose of this investigation is to map the areal geology and to make a detailed study of the units that crop out within the Foraker area. Emphasis is placed on the aspect of the units along the strike, progressing from north to south. Outcropping units within the area consist of rocks of the Wolfcampian Series (Lower Permian) and of the upper Virgilian Series (Upper Pennsylvanian).

The most striking topographic features in the area are the east-facing escarpments west of Beaver Creek in the northwest corner and similar escarpments (see Fig. 2) in the

eastern part roughly paralleling the eastern border. The western escarpment is rimmed by the Wreford limestone, while the Foraker limestone forms the top bench of the eastern escarpment. Both of these limestone formations contain considerable chert, making them more resistant to erosion than the softer strata which lie both above and below them. In contrast to these sharp, eastward facing escarpments, the area between is composed of what appears to be a broad, flat area. This area, in reality, is a series of low, step-like benches with a few outliers of Cottonwood and Neva limestones which support a gently sloping, grass-covered surface. These surface features are attributable to the diversity in composition and to the variety of types of rock that crop out in the area. With few exceptions, the entire columnar section is an alternation of limestone and shale. The limestone beds form the benches and the shales form the slopes of the eastward-facing escarpments. Where there is an influx of chert, as in the Wreford and Foraker limestones, there is also equal increase in resistance of the limestone, consequently making sharper escarpments.

This area is the southern extension of a series of hills known as the Flint Hills of Kansas. In central Kansas the Florence limestone is the capping rock layer. Farther south, throughout much of Cowley County, Kansas, the Wreford limestone forms the principal rim of the Flint Hills. In southern Cowley County and northern Oklahoma, the chief

Figure 2. Eastward facing escarpment capped by Foraker limestone in SW/4 sec. 23, T. 29 N. R. 7 E.

bench is lower at the top of the Foraker limestone.

In years of slight rainfall, all streams in the area are intermittent. The central area, which is the largest watershed, is drained by Salt Creek. It heads a little south of the Kansas-Oklahoma line, and flows southward through the center of the area a few degrees west of south. Elm Creek, a tributary of Salt Creek, drains the eastern portion of this central area. Subordinate streams are: Beaver Creek, draining the western area; Buck Creek, Sand Creek, and the headwaters of numerous other small streams, draining the eastern margin of the area. The streams flow in a general southerly direction.

The regional dip of 40 to 45 feet per mile to the northwest was determined by the three-point method. Outcrop points and estimated elevations from the U. S. Geological Survey topographic map of the Foraker Quadrangle, edition of 1916, reprinted in 1945, were used in applying this method.

Stratigraphic sections were measured by a rule graduated to tenths of a foot, and the hand level and tape method. Sections that were impractical to measure by these methods were estimated by using elevations taken from the topographic map, making allowance for the dip if the horizontal distances were over a mile. When the hand level and tape method was used in measuring thicknesses, the dip was disregarded.

Previous work in this area was done by Heald,[1] who mapped the structure of the Foraker Quadrangle in the period of 1915 to 1916. This bulletin was published with the specific purpose of recommending the most ideal locations for oil prospecting. A few key beds, used for mapping structure, were described. Heald named the Foraker limestone for the village of Foraker, and the Red Eagle limestone was named from exposures near Red Eagle School. This school was located southwest of Foraker, but since 1916 has been destroyed. Heald described the Foraker limestone as being 74 feet thick. This thickness probably included the interval down to the base of the Brownville limestone, which is now accepted as the topmost bed in the Virgil series of the Pennsylvanian system of the northern Mid-Continent area. A type section is designated for the Foraker limestone and correlative names applied to those beds which lie below it. This will be dealt with in other parts of this thesis.

In 1929, Bass[2] mapped and described in detail the key beds of Cowley County, Kansas, which borders the Foraker area on the north. This work deals principally with oil and gas fields of the county. Subsequent work by R. C. Moore,[3]

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[1]K. C. Heald, "The Oil and Gas Geology of the Foraker Quadrangle, Osage County, Oklahoma," United States Geological Survey, Bulletin 641-B, 1916.

[2]N. W. Bass, "The Geology of Cowley County, Kansas," Kansas Geological Survey, Bulletin 12, 1929.

[3]R. C. Moore, et al, "The Kansas Rock Column," Kansas Geological Survey, Bulletin 89, 1951.

and others has revised and added much to the nomenclature used by Bass.

Soil Conservation photo-index sheets and topographic maps were used in mapping formational contacts. The contacts were transferred to a base map drawn on a scale of 2.1 inches to the mile. Roads are good, but few transverse the large ranches.

CHAPTER II

STRATIGRAPHY AND LITHOLOGY

Virgilian Series

The Virgilian series includes those Upper Pennsylvanian formations from the unconformity at the top of the Missourian series to the unconformity at the base of the overlying Wolfcampian. It includes beds from the base of the Tonganoxie sandstone to the base of the channel-filling Indian Cave sandstone. The Pennsylvanian-Permian boundary is distinguished principally by this locally prominent channel sandstone. Although reported to be well developed in southeastern Cowley County, Kansas, evidence of its presence in the Foraker area is lacking. The youngest Pennsylvanian unit, well developed in the designated area, is the Brownville limestone, and all beds overlying it will be treated as Permian or transitional in age.

The Virgilian series is divided into, in descending order: Wabaunsee, Shawnee, and Douglas groups. Only beds of the upper Wabaunsee group crop out within the Foraker area. It is divided into Richardson, Nemaha, and Sacfox subgroups, of which only beds of the upper two (Richardson, Nemaha)

crop out within the area.

The stratigraphical units of the Virgilian series, as a whole, are consistent units transversing the region from Oklahoma across Kansas into Nebraska. These units are mainly alternations of limestone and shale, and marine and non-marine deposits. Evidence of cyclical sedimentation is present in this area but has been obscured by poor exposures and missing units. Northward in Kansas, the evidence of sedimentation is much clearer, especially in the Wabaunsee and Shawnee groups. Sandstone is present in all of the Virgilian groups, but is not so prominent in the Wabaunsee and Shawnee groups as it is in the Douglas group. Sandstone beds increase from the Kansas-Nebraska line into Oklahoma.

Wabaunsee Group

The Wabaunsee group was originally described by Prosser[4] in 1895 as the interval from the base of the Cottonwood limestone down to the Osage coal. This was redefined in 1932[5] by moving the lower boundary down to the top of the Topeka formation and the upper boundary down to the base of the Americus limestone. By eliminating beds that are now

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[4]C. S. Prosser, "The Classification of the Upper Palezoic Rocks of Central Kansas," Journal of Geology, Vol. 3, 1895, p. 689.

[5]R. C. Moore,"A Reclassification of the Pennsylvanian System in the Northern MidContinent Region," Kansas Geological Society, Guidebook, 6th Annual Field Conference (1932), p. 94.

considered Permian, Condra[6] restricted the Wabaunsee group to beds lying below the top of the Brownville limestone and above the Topeka formation. This classification was followed by Moore[7] in 1936, and the usage, as defined, has been accepted by most geologists for the last 18 years.

As previously stated, the Wabaunsee consists of three subgroups. These divisions are based primarily on their contrasting topographic expressions. The Nemaha subgroup is composed of beds that make good escarpments, while the other two, which lie above and below, are predominately easily eroded beds that have poor outcrops. In Kansas and Nebraska, the Richardson subgroup includes beds from the Brownville limestone down to the top of the Tarkio limestone. The Tarkio limestone is the upper unit of the Nemaha subgroup, while the base is drawn at the bottom of the Burlingame limestone. However, the Tarkio limestone has not been recognized south of northern Lyon County, Kansas, and the question arises as to where the line should be drawn in Oklahoma for the Richardson and Nemaha subgroups. Since the divisions are based primarily on the nature of their outcrops, it seems logical to lower the base of the Richardson subgroup to the

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[6] G. E. Condra, "Geologic Cross Section, Forest City, Missouri to Dubois, Nebraska," Nebraska Geological Survey, Paper 8, 1935, pp. 9-11.

[7] R. C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," Kansas Geological Survey, Bulletin 22, 1936, p. 224.

top (Elmont limestone member) of the Stonebreaker formation. In this thesis, the Richardson subgroup of Oklahoma will be recognized as the interval between the Brownville limestone down to the top of the Stonebreaker limestone, and the Nemaha from the top of the Stonebreaker down to the base of the Burlingame limestone.

Auburn Shale: The Auburn shale includes the interval between the Cryptozoon limestone, which is equivalent in part to the Wakarusa limestone of Kansas, and Stonebreaker limestone. Exposures are poor and are restricted to the banks of Buck Creek in sec. 25, T. 29 N., R. 7 E. of the designated area.

Along Buck Creek it is composed of two relatively thin limestone units, cross-bedded and platy sandstone, and intervening shale which is sandy in the upper part (see Measured Section V, Appendix). The lowest unit of the Auburn shale exposed in the area is a bluish-gray, fine to coarse grained limestone. This bed contains a thin shale break which divides it into a lower bed of 1.2 feet thickness and an upper bed which is 0.4 foot thick. The lower bed contains a few fusulinids, Cryptozoa, and crinoid and brachiopod fragments. It is fine grained and weathers to rectangular blocks. Probably as the result of the presence of algal remains, the upper surface is uneven. The upper bed is coarser grained than the lower, has thin shale partings, is ferruginous, and has few fossils other than crinoid

fragments. A dark blue shale, containing pelecypods, underlies this unit. This limestone unit is exposed in the bed of Buck Creek on the township line and lies approximately 57 feet below the Reading limestone.

The overlying shale section, although poorly exposed, is composed of blue shale which contains brachiopods, crinoids, and mollusks. It grades upward into a greenish-yellow shale which is non-fossiliferous. This exposure comprises about half of a 28 foot interval of which the upper half is covered by soil. It is probably a continuation of the yellow shale, since immediately below the upper limestone unit of the Auburn shale a small exposure of fossiliferous yellow shale is present.

The upper limestone unit is 1.1 feet thick and is a massive, fossiliferous bed. The lower part is shaly and contains an abundance of pelecypods and fragments of brachiopods. The upper part is clean, fine grained and only sparsely fossiliferous. This bed is characterized by its yellow weathered surface, its crumbly nature on weathering, and by the clean, blue-gray color of the upper part. It lies about 30 feet below the Reading limestone.

The upper part of the Auburn shale is made up of 25 feet of gray and yellow, calcareous, sandy shale with a cross-bedded, channel-filling sandstone occurring near the middle. Above the cross-bedded sandstone, the shale is gray, sandy and slightly calcareous, grading upward into a

yellow shale which in turn becomes gray, calcareous and fossiliferous near the base of the overlying Stonebreaker formation.

Stonebreaker Formation: The Stonebreaker limestone was named by Heald[8] from exposures on the Stonebreaker ranch in T. 29 N., R. 8 E. Early reports by Kansas geologists referred to equivalent beds found in Kansas as the Emporia limestone.[9] The name Emporia has been discarded and replaced by Elmont limestone, Harveyville shale, and Reading limestone, in descending order. These beds are traceable into the Stonebreaker limestone of Oklahoma, and are clearly defined in T. 29 N., R. 8 E., east of the Foraker area.

Outcrops of the Stonebreaker formation are restricted to sections 24, 25, and 36, T. 29 N., R. 7 E. in the area of investigation. Outcrops are few and poor in this area and much of the material gathered for this thesis was obtained from the western part of T. 29 N., R. 8 E., east of the designated area.

The Reading limestone member can be divided into three limestone units and two shale units (see Measured Section III, Appendix). The middle limestone unit (see Fig. 3) is by far the most easily recognized, due principally to

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[8]K. C. Heald, "Geologic Structure of the Northwestern Part of the Pawhuska Quadrangle, Oklahoma," U.S. Geological Survey, Bulletin 691, 1918, pp. 63-64.

[9]Bass, op. cit., pp. 42-45.

Figure 3. Middle unit of Reading limestone member in NW/4 sec. 18, T. 28 N., R. 8 E. Note thin coal bed at position of pick.

its excellent outcrops and its general overall character. This middle unit occurs as three limestone beds with intervening thin, fossiliferous shales. The oldest bed is 3.2 feet thick, is fine to medium grained, and consists of blue-gray colored limestone. It is easily recognizable by the abundance of fusulinids. In most outcrops the fusulinids weather white in contrast to the yellowish-brown color of the weathered bed. The bottom part of this bed is fine grained, and has a weak conchoidal fracture, the upper part is medium-grained and contains more limonite and fusulinids than the lower part. The middle limestone is thinner but its lithology closely resembles that of the lower bed. Fusulinids are present but do not occur in quantity as they do in the lower bed. Cryptozoa are found in this bed but not in such abundance as in the overlying, thin limestone bed. This upper thin limestone bed, characterized by Cryptozoon remains, but lacking fusulinids, is rarely found. The Cryptozoa are usually formed around bryozoan or crinoid fragments. The complete thickness of this unit is 5.6 feet, and it has a distinctive rhombohedral jointing pattern which is evident at all outcrops. It is brown in color, stained by yellow blotches caused by the limonite. Due probably to algal remains, the bed weathers at places to small thin slabs.

Underlying the middle fusulinid-bearing limestone and overlying the Auburn shale, is a limestone containing a few pelecypods and brachiopods, but consisting principally

of well rounded crinoid plates. The upper surface is wavy, probably resulting from algal remains. Below this bed, in sec. 25, T. 29 N., R. 7 E., is a mound-like accumulation of algal and crinoid remains which is suggestive of a biohermal limestone (see Fig. 4). The limestone bed appears to be distorted upward across this accumulation. No other occurrence was found in this or the adjacent area.

Gray, sparsely fossiliferous, calcareous shale occupies the position between the lower and middle units. A thin but persistent coal bed occurs near the middle of the shale at all exposures.

A seven foot greenish-gray shale with thin lenses of maroon shale lies above the middle unit. Fossils are not plentiful. The uppermost limestone member (see Fig. 5) is characterized by its crumbly nature and by algal remains which are found strewn along the ground as fine grained, yellow limestone boulders. This bed averages 1.3 feet thick and is excellently exposed along one of the tributaries of Buck Creek in sec. 25, T. 29 N., R. 7 E.

The thickness of the Reading limestone member averages about 20 feet in this general area. It is a continuous limestone unit cropping out from Oklahoma northward into Nebraska.

The Harveyville shale member includes the beds between the Reading and Elmont limestones. The description and thickness of this shale were taken from the excellent exposure along the north bank of Sand Creek in sec. 30, T.

Figure 4. Lowest bed of Stonebreaker formation showing biohermal limestone accumulation, NW/4 sec. 25, T. 29 N., R. 7 E.

Figure 5. Upper bed of Reading limestone member overlain by Harveyville shale member as seen in SW/4 sec. 30, T. 28 N., R. 8 E.

28 N., R. 8 E.

The Harveyville shale is best described by dividing it into three zones (see Measured Section I, Appendix). The lower zone overlies the upper bed of the Reading limestone and is a gray, calcareous shale. It is 2.5 feet thick and has at its top a thin coal bed and a poorly developed underclay. The middle zone is dark-gray, almost black, calcareous shale with thin, platy limestone beds near the middle. An abundance of the brachiopod Chonetes, was found in this zone. At the top of this zone there appears to be a thin and poorly developed underclay (see Fig. 3). (A definite conclusion was not reached as to whether it is an underclay.) The upper zone is predominately black shale and carries a few brachiopods.

The upper unit of the Stonebreaker formation is the Elmont limestone, which has two limestone beds and an intervening shale (see Measured Section I, Appendix). Although the Elmont limestone is poorly represented within the area of investigation, it is well exposed (see Fig. 6) in the adjacent area to the east, Tps. 28 and 29 N., R. 8 E. The two limestones have distinctive characteristics and are readily recognized where exposed. The lower bed is thin and closely resembles the upper layer of the middle Reading limestone unit. They both carry a profusion of Cryptozoon, but the lower Elmont bed is fusulinid-bearing while the other limestone is not.

The shale between these two limestone beds is predominately black and is barren of fossils except in the upper part. The lower part is carbonaceous, grading upward into the top part which is gray and calcareous. The upper part contains an abundance of Crurithyris planoconvexa. Limestone concretions are present in the upper part about 1.5 feet below the upper limestone bed. The break between the shale and the upper limestone bed is gradual, resulting in little faunal change in the lower part of the limestone. In the upper part, however, bryozoans, crinoids, and several species of brachiopods are present. Some are fragmental and all are tightly embedded in the matrix, making it impractical to obtain specimens for laboratory identification. The bed is gray, weathers yellow, and is somewhat arenaceous. The Elmont limestone is well exposed on the east side of the creek which runs through the western half of sec. 18, T. 28 N., R. 8 E. (see Fig. 4).

The Stonebreaker formation has an aggregate thickness of 31 feet.

Willard-Langdon Shale: In southern Kansas and northern Oklahoma, this shale and sandstone section consists of beds that lie between the Elmont and Dover limestones and represents a combination of three shales. In northern

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[10] R. C. Moore, "Divisions of the Pennsylvanian System in Kansas," State Geological Survey of Kansas, Bulletin 83, 1949, pp. 186-7.

Kansas these shales are recognizable as distinct beds separated by the Tarkio and Maple Hill limestones. In northern Kansas, the Langdon shale overlies the Maple Hill limestone; the Willard shale occupies a position subjacent to the Tarkio limestone, and the Pierson Point shale lies between the Willard and Tarkio limestones.

South of a point in Lyon County, Kansas, the Tarkio limestone disappears, resulting in a merging of the two shales and the unit is called the Willard-Pierson Point shale. South of Emporia, Kansas, the Maple Hill limestone has not been positively identified, and the three shales coalesce into one and this unit is recognized in the Foraker area as such. This shale and sandstone interval is the Willard-Langdon shale.

The Willard-Langdon shale is poorly exposed in the general area of Osage County (see Measured Sections VII and XI, Appendix). It is predominately shale and sandstone with two thin limestones near the top. The lower limestone is thin and exists only as float along the grass covered slope. The Willard-Langdon shale is exposed at the base and top with the middle consistently covered throughout the area. The lower part is composed of yellow, sandy shale with a coal bed lying 4 feet above the Elmont limestone. This is the thickest and best developed coal in the columnar section that crops out within the Foraker area (see Fig. 7). This coal was not found in the designated area but good exposures

Figure 6. Upper limestone and shale beds of Elmont limestone member, NW/4 sec. 19, T. 28 N., R. 8 E.

Figure 7. Coal bed at base of Willard-Langdon shale, NW/4 sec. 19, T. 28 N., R. 8 E.

are found in sec. 18, T. 28 N., R. 8 E. (see Fig. 5). The top part of this shale is made up of maroon and gray sandy shale. A good exposure is found in sec. 13, T. 28 N., R. 7 E. The upper limestone of the Willard-Langdon shale is also exposed at this same location in the bed of the small creek that runs through the section. This limestone is gray, compact, and weathers buff with red blotches caused by the overlying maroon shale. Its most distinguishing characteristics are fossil content and algal remains. Myalina of the Myalina subquadrata type outnumber other pelecypods, brachiopods, bryozoans and crinoids that are present.

The middle part, although covered at most places, consists of three sandstone ledges. The average thickness for each of these beds is two feet. Some are probably channel-filling, but proof of this is lacking. The sandstone lying about 20 feet above the Elmont limestone has oscillation ripple-marks and plant remains. The other sandstone beds are smooth and evenly bedded with the exception of the bed that lies near the top, which is locally cross-bedded. These beds are fine grained, poorly indurated, and weather to rectangular blocks that lie strewn along the grass-covered slopes. Silicified wood was found along the ravines and creeks that drain this sandstone zone.

The thickness of the Willard-Langdon shale is about 120 feet and is remarkably constant. The only noticeable

variation in the section was a definite increase in the amount of sandstone in the southern part of the area.

Dover Limestone: The Dover Limestone consists of two limestone beds and an intervening sandy shale (see Measured Section XVI, Appendix). Although the Dover limestone averages about 18 feet, it consists mostly of sandy micaceous shale and soft, sandy limestone. Outcrops of this limestone were not found south of secs. 13 and 24, T. 28 N., R. 7 E. in the Foraker area. In sec. 13, T. 28 N., R. 7 E. the outcrops are good, with the lower member resting on the Willard-Langdon shale. The lower bed (see Fig. 8) is blue-gray, arenaceous, fossiliferous, and has a thin inconcistent shale break near the middle. Large well-preserved specimens of Dictyoclostus americanus are dispersed throughout the 3.5 foot bed. Other brachiopods and bryozoans are also present but not in a good state of preservation; a few fusulinids are found at the top. Upon weathering this bed takes on a buff color and looks like a fine grained sandstone.

The upper limestone bed is 1.3 feet thick, brownish-gray weathering to brown. This bed is characterized by the fusulinids it carries, which, at places, are plentiful. Fragments of brachiopods and pelecypods are also present, the latter being more prevalent. This bed grades downward into a micaceous sandstone which makes up almost half of the entire thickness of this bed. The shale lying between the upper and lower beds is yellow and sandy, with thin,

platy sandstone beds occurring near the top.

It is doubtful that the Dover limestone is exposed or present south of the Foraker area. A quick reconnaissance south of the Foraker area near Shidler and Fairfax, Oklahoma, revealed that the stratigraphical position of the Dover limestone is occupied by sandstone, indicating that it might grade laterally southward into sandstone. Future detailed mapping of these areas will disclose whether the Dover is present.

Dry Shale: The inverval between the top of the Dover limestone and the base of Grandhaven limestone is known as the Dry shale.[11] In the Foraker area this interval exists only as a grass-covered slope near the base of the steep escarpment caused by the Foraker limestone. The measured thickness, when the Dover limestone is present, is about 20 feet.

In the southern part of the area, where the Dover limestone is not recognizable, this shale is indistinguishable from the underlying Willard-Langdon shale. Following R. C. Moore's method of naming beds, the sandstone and shale interval between the Elmont and Grandhaven limestones should be referred to as the Willard-Dry shale.

Grandhaven Limestone: The Grandhaven limestone comprises two beds in Kansas,[12] but in Oklahoma only the upper

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[11] Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," op. cit., p. 236.

[12] Ibid., p. 237-238.

is recognizable. In the northern part of the area, sec. 25, T. 29 N., R. 7 E., where it reaches its maximum thickness, it is an easily recognized bed (see Measured Section VIII, Appendix). In this section it is a cross-bedded calcarenite with a maximum thickness of 2 feet. Its color is tan to gray, mottled by the various colored limestone pebbles it contains. In certain places in this section, it is strongly ferruginous, giving the bed a bright red color. Fossils are mostly fragmental, but a few large pelecypods are found that are well preserved.

Progressing southward along the strike, the Grandhaven thins rapidly to about 0.5 foot in sec. 24, T. 28 N., R. 7 E. where it is exposed in a creek bed. At this exposure it is evenly bedded, red in color and has retained its calcarenitic texture. Rarely a large pelecypod is found. This bed, with the exception of its northern exposures, is inconspicuous and is located by reference to its stratigraphical position, which is between 14 and 20 feet below the overlying Jim Creek limestone.

Friedrich Shale: The Friedrich shale is well exposed on the east bank of the small creek running through sec. 24, T. 28 N., R. 7 E. It includes the beds from the base of the overlying Jim Creek limestone down to the Grandhaven limestone. Its thickness is consistent in the Foraker area, varying only a few feet from the average thickness of 16 feet (see Measured section XIII, Appendix).

The Friedrich shale consists of gray, arenaceous, micaceous shale with thin laminated beds of calcareous sandstone. The lower 5 feet is dark gray and not so sandy, and is overlain by an interbedded series of shales and thin calcareous sandstones. Four feet below the overlying Jim Creek limestone is a thin coal bed. Above the coal and below the Jim Creek is a gray, calcareous, fossiliferous shale.

Jim Creek Limestone: The Jim Creek limestone is the best Pennsylvanian marker bed that crops out within the area of investigation. It is very persistent and can be recognized by its own characteristics alone, but its value as a marker is further enhanced by a thin consistent coal bed that lies about 4 feet below it (see Fig. 9). It has a bluish-gray to tan color on fresh surface and weathers to a yellowish-brown color. It is fusulinid-bearing and carries fragments of brachiopods, crinoids and bryozoa. In the southern part of the area, sec. 26, T. 28 N., R. 7 E., it is slightly more arenaceous and contains more limonite than it does in the northern part.

In Kansas, the Jim Creek is a single massive bed, attaining a thickness of not over 2 feet; there it is classed as a formation.[13] In the northern part of the Foraker area, near the Kansas line, the Jim Creek appears as a single bed 2 feet thick. However, the bed increases slightly in thick-

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[13] Ibid., p. 240-241.

ness in the southern area, where its maximum thickness is 2.8 feet (see Measured Section XIX, Appendix). This increase is probably due to a thin shale break near the middle of the bed. At most outcrops it appears as a massive bed that weathers to small shelly fragments.

French Creek Shale: In the Foraker area, the French Creek shale[14] forms a grass-covered slope lying between the Nebraska City limestone and the Jim Creek limestone. It has an average thickness of 14 feet. Only in the southwestern part of sec. 25 and the northeastern part of sec. 26, T. 28 N., R. 7 E. is there any indication as to what types of rock make up the interval (see Measured Section XIII, Appendix). Here is it a gray, calcareous shale with limestone concretions occurring at about the middle. Elsewhere in the same vicinity there occurs a laterally discontinuous 1.5 foot thick bed that is made up of three zones. The upper zone is a yellow, sandy, 0.3 foot calcarenite which grades downward into a 0.7 foot clean, white, sandy limestone. This in turn grades into a 0.5 foot sandy, yellow limestone. It is a massive bed with no shale breaks or fossils. Evidence of the middle zone was not found north of sec. 13, T. 28 N., R. 7 E. Traveling southward along the strike from sec. 13, T. 28 N., R. 7 E., it is found above the Jim Creek as fragments intermixed with those of the upper and lower zones. In sec.

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[14] Ibid., p. 241.

26, T. 29 N., R. 7 E., this bed is exposed along the south bank of Sand Creek in the northwest part of the section.

Nebraska City Limestone: Named for Nebraska City, Nebraska, by Condra,[15] the Nebraska City limestone extends from Nebraska across Kansas into Oklahoma. It is not resistant and does not crop out prominently in the Foraker area. It is exposed in the road cut in the southwestern part of sec. 25, T. 28 N., R. 7 E. where its maximum thickness of 3.5 feet is represented by three limestone layers and intervening thin shales (see Fig. 10). This is the only place in the area where the lower beds are found in place (see Measured Section XX, Appendix). In other parts of the area they are found strewn along the grass-covered slopes.

The lower layers are calcarenites containing small limestone pebbles and possibly some shale pebbles. Apparently these calcarenite layers disintegrate on prolonged weathering because only a few fragments are found anywhere in the area. Where found they have a distinctive spotted, weathered surface and are valuable in identification of the Nebraska City limestone. The upper bed is an algal and molluscan bed that is more resistant and is found with less difficulty than the lower calcarenites. In sec. 25, T. 28 N., R. 7 E., this bed is a coquina made up almost entirely of small gastropods.

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[15] G. E. Condra, "The Stratigraphy of the Pennsylvanian System in Nebraska," Nebraska Geological Survey, Bulletin 1, 2nd Series, 1927, p. 116.

Figure 8. Lower bed of Dover limestone as seen in NW/4 sec. 13, T. 28 N., R. 7 E.

These two photos should be reversed
R.C.T.

Figure 9. Jim Creek limestone and coal bed in upper part of Friedrich shale, approximately 3 miles east of Foraker in SE/4 sec. 26, T. 28 N., R. 7 E.

In the northern part of the area it is a massive bed with a tan colored fresh surface weathering brown. It is ferruginous, contains nodules of limonite, and carries a small pelecypod that is generally composed of pink material. During summer months when vegetation is plentiful, the Nebraska City limestone is not easily found, but by referring to its stratigraphical position in regard to the Jim Creek limestone, some evidence of its presence is almost always evident.

In Kansas the Nebraska City limestone is treated as a molluscan bed belonging to the transgressive phase of the Caneyville limestone. The Caneyville limestone[16] is a cyclothem which includes the Nebraska City limestone, a fusulinid-bearing limestone, and the Grayhorse limestone, which is the regressive part of the Caneyville cyclothem. Neither the coal bed nor the fusulinid bed are found in the Foraker area, consequently it will not be treated as such in this thesis. The interval between the Nebraska City limestone and Grayhorse limestone has not been named and the need for naming it is negligible. It will be referred to as the shale interval between the Nebraska City limestone and Grayhorse limestone. This interval is covered throughout the area. A 0.3 foot limestone, composed of thin alternating layers of calcarenitic limestone and clean, dense, almost lithographic

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[16]Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," op. cit., pp. 241-243.

limestone occurs approximately 4 to 6 feet above the Nebraska City limestone. This bed weathers yellow and is easily recognized where found on the slopes of this interval. In the upper part, approximately 4 feet below the Grayhorse limestone, yellow sandy limestone boulders are found intermittently along the strike of the Grayhorse limestone. These are probably weathered remains of limestone concretions. In the southern area, thin, discontinuous, algal beds are present and the correct position of these beds is both impractical and impossible to ascertain except to say they occur somewhere near the middle of the interval.

Grayhorse Limestone: The Grayhorse limestone was originally named by Bowen[17] from its excellent exposures on the crest of the Little Grayhorse anticline in the northwest part of sec. 11, T. 24 N., R. 6 E. It first appeared in print in K. C. Heald's[18] report on an adjacent area.

In the Foraker area, the Grayhorse limestone is best exposed in the bed of a small creek in the southeast part of sec. 16, T. 29 N., R. 7 E (see Fig. 11). In this area it is made up of two limestone beds separated by one foot of greenish-gray shale with intercalated beds of limestone. The

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[17] C. F. Bowen, "Report on Tps. 24, 25, and 26 N. R. 6 and 7 E.; Tps. 25 and 26 N., R. 5 E.; T. 26 N., R. 4 E.," U. S. Geol. Survey, Bull. 686 L, 1918, p. 138.

[18] K. C. Heald, "Structure and Oil and Gas Resources of the Osage Reservation, Okla.; T. 27 N., R. 7 E.," U. S. Geol. Survey, Bull. 686 K, 1918, p. 130.

Figure 10. Exposures of Nebraska City limestone in road-cut in sec. 25, T. 28 N., R. 7 E.

Figure 11. Outcrop of Grayhorse limestone in sec. 16, T. 29 N., R. 7 E.

upper bed is 0.6 foot thick, and is a dark gray, ferruginous limestone with thin shale partings. On weathering it becomes slabby and takes on a grayish-brown color. At localized spots, it appears as a calcarenite filled with small yellow and white limestone pebbles that give the surface a spotted appearance. Well preserved fossils are few; of these, Myalina is the most common. Tiny fragments of brachiopods, crinoids and other fossils lie parallel to the bedding planes, and weather in relief to the bed.

The lower bed is 1.3 feet thick, fine-grained, gray limestone that weathers tan. Fossils have been replaced by dark coarsely crystalline calcite, and in some instances the fossils and fractures have been filled with limonite. Fossils are practically all fragmental at this exposure, but at other outcrops in the same general vicinity this lower bed is filled with pelecypods that are fairly well preserved.

South of sec. 16, T. 29 N., R. 7 E. the Grayhorse limestone is never completely exposed in the Foraker area. It lies approximately 15 feet above the more resistant Jim Creek limestone, and by referring to this marker bed, the Grayhorse can be traced across the entire area. With the exception of a few partial exposures in drainage ditches and along the road in sec. 13, T. 28 N., R. 7 E., the Grayhorse limestone appears as gray, fine-grained, dense, angular to rounded boulders near the middle of the eastward facing escarpment that transverses the eastern margin of the area

from north to south.

In Kansas the Grayhorse is considered the top member and regressive phase of the Caneyville cyclothem. At present the Caneyville formation is not recognized in Oklahoma.

Pony Creek Shale: The thickness of the Pony Creek shale[19] varies from a minimum of 42 feet near the Kansas-Oklahoma line to a maximum of 51 feet near the southern limits of the Foraker area, showing a slight thickening towards the south. It consists for the most part of yellow sandy shale, but contains a sandstone near the middle of the lower part and a thin coal bed near the top of the interval.

The Pony Creek shale is poorly exposed in the Foraker area. The only known exposure for the interval below the sandstone is in the SE/4 of sec. 16, T. 29 N., R. 7 E. (see Measured Section X, Appendix). The interval lying above the sandstone is exposed along road cuts in secs. 16 and 23, T. 29 N., R. 7 E. (see Measured Section VIII, Appendix) and sec. 13, T. 28 N., R. 7 E. The coal bed is exposed at the last two locations.

The interval below the sandstone averages 14 feet. It is a continuous gradation upward from yellow, slightly sandy shale to yellow, gray and green, sandy, micaceous sand-

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[19] Condra, "The Stratigraphy of the Pennsylvanian System in Nebraska," op. cit., p. 81.

stone near the top. The contact surface with the base of the overlying sandstone is irregular, with the maximum depth of channeling not over two feet.

The cross-bedded, channel-filling sandstone varies in color from buff to dark brown, weathering to a brown color. It averages 3.5 feet thick and is found along the strike across the entire area. It is poorly developed in the south but serves as a marker bed in the northern part of the area where at a few places it forms a small bench. It is the only prominent sandstone bed in the stratigraphical section between the Foraker limestone and the Jim Creek limestone. In a few outcrops it has a gray, micaceous and calcareous fresh surface. Probably its most distinctive characteristics are the cross-bedding and the abundance of tiny limonite spots found on the fresh surface.

The interval overlying the sandstone averages 34 feet, consisting predominately of shale. Near the top of this shale interval, a thin coal bed is found about 10 feet below the Brownville limestone. It is also found in southern Kansas. South of sec. 13, T. 28 N., R. 7 E., the Pony Creek shale is covered and the coal bed is not seen again in the Foraker area.

Brownville Limestone: The Brownville limestone, named by Condra and Bengston[20] from outcrops in southeastern

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[20] G. E. Condra, and N. A. Bengston, "The Pennsylvanian Formations of Southeastern Nebraska," Nebraska Academy of Science, Pub. vol. 9, 1915, p. 17.

Nebraska, is regarded as the uppermost stratigraphic unit of the Wabaunsee group and of the Pennsylvanian System in northern Oklahoma, Kansas, and Nebraska. In Kansas and Nebraska, the Brownville limestone is reported to consist of a fusulinid-bearing bed overlain at places by an algal and molluscan bed. The algal-molluscan bed is reported by Moore[21] to be found occasionally in Chautauqua County, Kansas, which lies adjacent to the northeast corner of the Foraker area. This was not found in the Foraker area, but a bed filled with pelecypod remains is found below the fusulinid-bearing bed of the Brownville and will be considered part of the Brownville limestone (see Measured Section X, Appendix). This bed is 1.9 feet thick, brittle, compact, and is found consistently below the fusulinid-bearing bed throughout the area. The only measurable exposure found for this lower coquinoid bed is along the west side of the road in SW/4 of sec. 16, T. 29 N., R. 7 E. It lies 2 to 3 feet below the overlying massive bed, separated by yellow-drab shale. This interval appears to be thinner in the southern part of the area.

The fusulinid-bed is 4 feet thick, including a thin shale break near the top (see Fig. 12). It is massive, fossiliferous, ferruginous, slightly arenaceous, and weathers

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[21]Moore, "Divisions of the Pennsylvanian System in Kansas," op. cit., p. 196.

to slabby or rounded fragments. An abundance of large fusulinids is found in the upper part of the bed, while the lower part contains only a few small fusulinids. The lower part is yellowish-tan in color, grading upward into a darker reddish-brown color near the top. It normally weathers brown, but it is grayish-brown in the southern part of the area. The fusulinids are very noticeable since they are white and usually weather in relief to the bed. Large crinoid plates and stems are also characteristic of the middle and upper zones.

The Brownville limestone is an excellent marker; however, its value as such is somewhat diminished in the Foraker area by the overlying Foraker formation. The Brownville limestone forms the most abrupt bench of all the Pennsylvanian rocks that crop out within the Foraker area. This bench can be traced with ease across the entire area, until it reaches the middle part of sec. 26, T. 28 N., R. 7 E., near the southern boundary, where the bench is not so pronounced. South from this point to the edge of the area, the Brownville limestone serves at its maximum as a marker bed. This is not due to better exposures of the bed, because contrary conditions exist. Near the center of the eastern part of T. 28 N., R. 7 E., there is a sudden divergence of the outcrop belt, probably caused by a flattening of the beds. Lateral widening of the surface contacts between the Foraker, Brownville, and Jim Creek limestones continues southward to

the southern limits of the Foraker area. Here the outcrop belt has more than tripled its former horizontal distance. Not only does the outcrop belt widen, but the sharp eastward facing escarpment disappears along with the excellent exposures and bench of the Foraker limestone. It is due to the disappearance of both the geological and topographical expressions of the Foraker limestone and the widening of the outcrop belt that the value of the Brownville as a marker bed is increased.

Wolfcampian Series

The Wolfcampian Series includes the older Permian or transitional rocks. It is made up mainly of limestones and shales in the northern MidContinent region. In the Foraker area most of the shales are maroon and some contain thin platy sandstones, while the limestone beds are predominately gray. The Wolfcampian limestone units differ from the underlying Virgilian limestone units in color, lithology, and thickness. The limestone beds of Wolfcampian age commonly contain discontinuous lenses or concretions of chert, are gray in color and some are as much as 20 feet thick. In contrast to this, Virgilian limestone beds are void of chert; weather to a brown or tan color and are thin, commonly not over 3 feet thick. These contrasting visible features found in the Foraker area help to differentiate Virgilian beds from Wolfcampian beds.

The Wolfcampian series, formerly called the Big Blue series of Kansas, is divided into three groups. In descending order, they are: Chase, Council Grove, and Admire groups. The Wreford limestone is the only member of the Chase group present in the Foraker area, while members of the Council Grove group cover over 75 percent of the area and form the broad featureless area between the Foraker and Wreford limestones. Beds of the Wolfcampian series play an important part in forming the Flint Hills of Kansas.

Admire Group

The Admire group was originally defined in 1903 by Adams[22] as the Admire shale. He defined it as a 40 foot interval lying below the Americus limestone and above the Emporia limestone (Stonebreaker). This constitutes an extremely erroneous measurement for the thickness between the Stonebreaker and Americus limestones. In the Foraker area, this thickness is about 256 feet, which closely corresponds with the thickness in Kansas. Condra[23] interpreted Adams' description as meaning the interval lying between the Americus and Brownville limestones, thus restricting the Admire shale

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[22]G. I. Adams, G. H. Girty, and David White, "Stratigraphy and Paleontology of the Upper Carboniferous Rocks of the Kansas Section," U. S. Geological Survey, Bulletin 211, 1903, p. 53.

[23]Condra, "The Stratigraphy of the Pennsylvanian System in Nebraska," op. cit., p. 72.

to this interval. Condra[24] in 1935 and Moore[25] in 1936 raised it to group status. Presumably this was done on the basis of lithology, differentiating Wolfcampian beds that are similar to Virgilian beds but differ from beds of the overlying Council Grove Group.

Condra and Moore have given names to nine units that make up the Admire group. Of these, only the three members of the Hamlin shale and the Five Point limestone can be identified in the Foraker area. The Houchen Creek limestone, member of the Hamlin shale, is the only unit found south of sec. 16, T. 29 N., R. 7 E. Along the road cut in the southwest part of sec. 16, T. 29 N., R. 7 E., less than one mile south of the Kansas line, all four units are present, but poorly exposed. The Admire group averages 50 feet in the Foraker area, of which well over half is occupied by the upper four units. The interval below the Five Point limestone is indivisible in the Foraker area and will be referred to as the lower shale division of the Admire group. It is approximately 20 feet thick.

When Condra[26] raised the Admire to group status, he

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[24]Condra, "Geological Cross Section, Forest City, Missouri, to DuBois, Nebraska," op. cit., p. 8.

[25]Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," op. cit., p. 246-248.

[26]Condra, "Geological Cross Section, Forest City, Missouri to DuBois, Nebraska," op. cit., p. 8.

also divided the Hamlin shale into three members. In descending order, they are: Oaks shale member, Houchen Creek limestone, and Stine shale. The Hamlin shale is the uppermost formation of the group underlying the Americus limestone. The Oaks shale member is 2.7 feet thick and is gray weathering to a drab yellow color. Black, carbonaceous shale streaks are present near the top. Fossils are either rare or absent.

The Houchen Creek limestone can be divided into an upper and lower part (see Measured Section X, Appendix). The upper part is a series of thin limestones, limestone nodules, and shales. The limestones average 0.5 foot thick and the shales 0.7 foot thick. A dirty, soft, porous, yellow limestone, 2.1 feet thick, makes up the lower part.

The limestones of the upper part are gray, clean, and fine grained, almost lithographic. The upper and lower beds of this division are fossiliferous and the shales are barren. The lowest layer is 0.9 foot thick and carries a few brachiopods and tiny helicoid gastrapods. These are evident only on the weathered surface. The topmost bed is 0.6 foot thick and is sparsely populated with tiny inarticulate brachiopods.

The yellow, dirty, porous limestone of the lower part is barren of fossils. It is the only complete bed of the Admire group that can be identified south of sec. 13, T. 28 N., R. 7 E. It and the upper three feet of the Stine

shale member are excellently exposed along the road-cut in sec. 13, T. 28 N., R. 7 E. This three feet of dark calcareous shale is the only exposed portion of the 20 foot interval that makes up the Stine shale. Elsewhere this shale is nothing more than a grass-covered slope lying near the top of the eastward facing escarpment rimmed by the Foraker limestone. In the southern portion of the area, where the underlying Five Point limestone is not found, the Stine shale can not be differentiated from the lower shale division of the Admire group. It is in this part of the area that the entire Admire group can be justifiably described as contained in a grass-covered slope overlying the Brownville limestone and underlying the Americus limestone.

The Five Point limestone is 2 feet thick, gray to reddish-brown, massive, dense, ferruginous and fossiliferous. The upper 0.5 foot is a coquinite made up almost entirely of small gastropods, loosely cemented by coarsely crystalline calcite. The Five Point limestone is in a younger stratigraphical position but at a few places slumps to about the position of the Brownville limestone. Because of this, and the close resemblance in color and lithology to the Brownville, attention should be placed on the main identifying features that characterize each bed. The Five Point is distinguished by a coquinite at the top, whereas the Brownville is characterized by an abundance of large fusulinids. Fusulinids are also found in the Five Point limestone, but

they are small and rare. The Five Point limestone is rarely found south of T. 29 N., R. 7 E. in the Foraker area, but is found with little difficulty in the northern part of the area.

The lower shale division of the Admire group is made up predominately of gray and yellow shale with a soft porous, silty, yellow limestone near the middle and 2.5 feet of thin calcareous sandstone interbedded with silty calcareous shale near the bottom. This shale division has a consistent thickness of about 16 feet. It overlies the Brownville limestone and underlies the Five Point limestone. Exposures are limited to the road-cut in sec. 16, T. 29 N., R. 7 E. These are spotty and partially covered by soil. South of this location, this interval is not exposed again in the Foraker area.

Council Grove Group

The three lowest formations of this group are thick and massively bedded while those lying above are thin but persistent. Generally beds of this group are well represented and can be traced across the entire area, having an outcrop belt that covers well over 75 percent of the Foraker area.

Prior to lowering the Pennsylvanian-Permian boundary from the base of the Cottonwood limestone to the top of the Brownville limestone, the Council Grove group included beds from the base of the Wreford limestone to the top of the

Eskridge shale. In 1932, Moore[27] expanded this group to include beds down to the Americus limestone.

The Council Grove group has an average thickness of 344 feet in the Foraker area.

Foraker Limestone Formation: The Foraker limestone was named by Heald[28] for the village of Foraker in the southeast corner of the area. Although poorly exposed in the vicinity of Foraker, it is excellently exposed in the roadcut in SW/4 of sec. 16, T. 29 N., R. 7 E. This outcrop is designated as the standard type section for the Foraker formation. In Heald's description of the Foraker limestone, he referred to it as being 74 feet thick. This thickness undoubtedly included all of the interval that is now recognized as the Admire group and Brownville limestone.

In 1935, Condra[29] carrier the Foraker name into northwest Missouri and southeast Nebraska and called it a limestone formation. He defined it as underlying the Johnson shale and overlying the Hamlin shale and divided it into, in descending order: Long Creek limestone, Hughes Creek shale, and Americus limestone. With the exception of

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[27]Moore, "A Reclassification of the Pennsylvanian System in the Northern MidContinent Region," op. cit., p. 95.

[28]Heald, "The Oil and Gas Geology of the Foraker Quadrangle, Osage County, Oklahoma," op. cit., p. 25.

[29]Condra, "Geologic Cross Section, Forest City, Missouri, to DuBois, Nebraska," op. cit., p. 8.

changing Hughes Creek shale member to Hughes Creek limestone member, all names and members designated by Condra will be used in this thesis (see Measured Section X, Appendix).

Because of its topographical expression (see Fig. 12), chert content, and abundance of fusulinids, it is the most easily recognized bed in the area. An 11 foot, massive, cherty limestone bed of the Hughes Creek member forms the ledge of the eastward facing escarpment that transverses the northeastern and eastern margins of the Foraker area.

The type locality for the Americus limestone is southwest of Americus, Lyon County, Kansas. In the Foraker area it occurs as two limestone beds separated by 6.5 feet of gray, fossiliferous shale that weathers to a yellow drab color. Numerous cylindrical objects, probably animal burrows, are found strewn along the partly covered surface of this shale. Underlying this shale is the lowest and most distinctive unit of the Americus limestone (see Fig. 13). It is a gray, massive, fusulinid-bearing limestone bed separated near the middle by a very thin but consistent shale. This thin shale break separates the bed into two distinct layers that differ from each other in color and texture. The upper layer is 1.4 feet thick, dense, fine grained, and has a blue-gray fresh surface that weathers gray. The contrasting white color of the fusulinids against the dense, blue-gray groundmass makes it easy to identify. The lower layer is 2.6 feet thick, coarse-grained, light gray and

fossiliferous. Fusulinids are abundant but are not prolific as in the upper layer. Crinoid stems and plates and fragments of brachiopods and other fossils are present but few in number. At the type section, in sec. 16, T. 29 N., R. 7 E., a thin, somewhat shaly zone containing an abundance of fusulinids occurs near the middle of this lower bed. South from this point, along the road-cut in sec. 20, T. 28 N., R. 7 E., where this bed is again exposed, a thin, poorly developed shale is found. Apparently this zone and the shaly fusulinid zone found at the type section are correlatives.

A dark gray, shaly, arenaceous, fossiliferous limestone is the uppermost unit of the Americus limestone member. Fossils are fragmentary and weather in relief to the bed. The maximum exposed thickness is 1.4 feet in the Foraker area. Disappearance of this bed southward is probably due to a lateral gradation into shale.

The lower massive bed of the Americus limestone crops out extensively along the strike below the overlying Hughes Creek member. At most places it breaks into large slabs that are either rectangular or rhombohedral in shape.

The Hughes Creek limestone member is 23.3 feet thick, equal to the combined thicknesses of the other two members. Over half of its thickness is made up of resistant, cherty limestone. As would be expected, the Hughes Creek plays the most important part in the topographical expression of the Foraker formation. Chert is found throughout the formation

Figure 12. Outcrop of Brownville limestone at road-cut in sec. 16, T. 29 N., R. 7 E. The Foraker limestone forms the overlying bench.

Figure 13. Exposure of Americus limestone, Oaks shale member and upper beds of Houchen Creek limestone member at road-cut in sec. 16, T. 29 N., R. 7 E.

but not in such quantity as is present in this member.

The lower unit of this member is covered by soil and grass. It is 5.5 feet thick and is presumably gray shale. Overlying this covered interval is 12.8 feet of massive, cherty, coarse-grained, fusulinid-bearing limestone (see Fig. 14). A thin shale break occurs 1.5 feet above the base and is the only shale in this bed. The lower 1.5 feet is soft, fusulinid-bearing and weathers under the overlying bed and is rarely seen. The overlying 11 feet is light bluish-gray, spotted white by the profusion of fusulinids, and forms the ledge that rims the eastward-facing escarpment. Near the base it is dark gray, ferruginous and porous. The concretions and lenticular beds of chert that characterize this bed are irregular and discontinuous. These chert beds lie parrallel to the bedding plane and are blue-gray, spotted white by fusulinids. These and the thin shale break near the base are the only breaks in an otherwise continuous limestone bed.

The uppermost unit of the Hughes Creek is a 2 foot, gray, massive, ferruginous, fusulinid-bearing limestone bed. It is separated from the underlying massive, cherty bed by a 0.5 foot shale break.

The Long Creek limestone member is the youngest member of the Foraker formation. Its aggregate thickness is 12 feet and is composed of soft, arenaceous, fossiliferous limestone beds alternating with thin fossiliferous shales. With

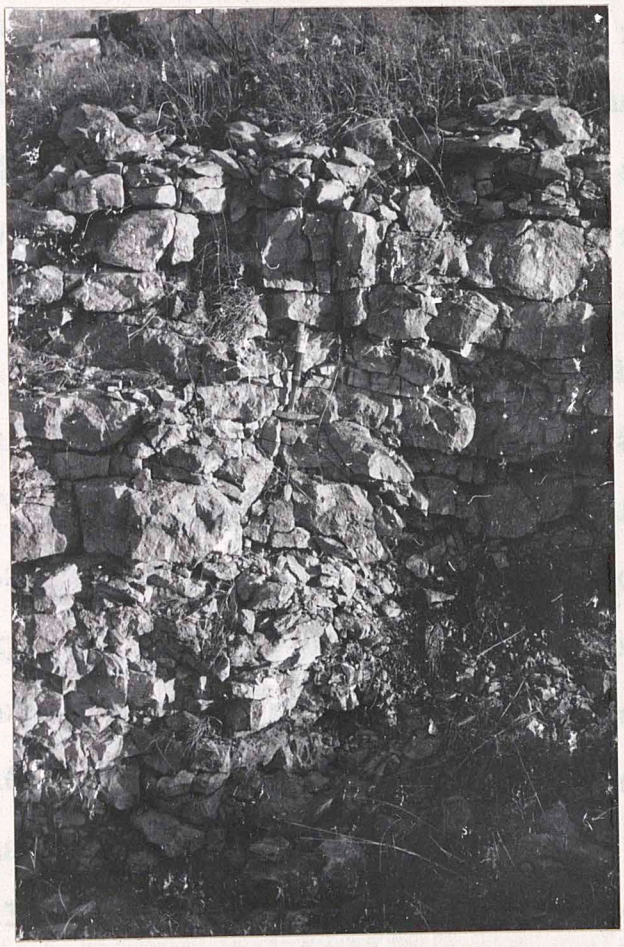

Figure 14. Road-cut through cherty bed at Hughes Creek limestone member in sec. 16, T. 29 N., R. 7 E.

the exception of exposures at the type section, this bed is rarely exposed (see Fig. 15).

Measurements were taken from exposures in the road-cut that cuts through the type section of the Foraker formation. Elsewhere in the area this member is rarely exposed, grading upward into the overlying Johnson shale, and with it forming a grass-covered slope. The beds are coarse-grained, somewhat porous, ferruginous, gray to buff on fresh surface weathering predominately to a light buff color. Large fusulinids are extremely prolific in these beds and occasionally are found concentrated in pockets.

Near Foraker in the southeast part of the area, the Foraker formation is nowhere prominently exposed nor topographically expressed as it is in the northern part. Northeast of Foraker, a small anticlinal structure was mapped by Heald[30] in 1916. It is probably the slight reversal of dip on the east flank and the general flattening of the beds over this small structure that has reduced the once prominent ridge to a low, rounded, grass-covered slope. South of the Foraker area, the Foraker formation once again resumes its position as a prominent ridge maker.

Johnson Shale: Beds that are now defined as Johnson shale, formerly were identified as the lower part of the

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[30]Heald, "The Oil and Gas Geology of the Foraker Quadrangle, Osage County, Oklahoma," op. cit., p. 39.

Elmdale shale. In 1935, Condra[31] discarded the name Elmdale and applied the present name to these beds lying between the Foraker and Red Eagle limestones.

Outcrops of the Johnson shale are similar to all other shale intervals present in the Foraker area. Similar, in that it is predominately covered throughout the area. In Kansas, just north of sec. 13, T. 29 N., R. 6 E. of Oklahoma, the Johnson shale is partially exposed (see Measured Section XXI, Appendix) along the bank of the small stream that heads in Oklahoma. It is predominately gray shale weathering to a yellow drab color. A thin consistent bed of maroon shale is found approximately 10 feet below the overlying Red Eagle limestone along outcrops in the northern edge of the area. A soft, yellowish-tan, marly limestone that becomes pitted and porous after weathering, is found a few feet below the maroon shale. Below this limestone bed, 8.5 feet of gray and greenish-gray shale intervening, is another limestone bed. It is a gray, soft and fine-grained limestone containing fusulinids, brachiopods, crinoid plates and fragments of these and other fossils. The lower part of the Johnson shale is an interbedded series of shales and thin platy limestone.

Along the northern edge of T. 29 N., R. 7 E., the

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[31]Condra, "Geologic Cross Section, Forest City, Missouri, to DuBois, Nebraska," op. cit., p. 8.

Johnson shale forms steep, grass-covered slopes along the banks of the numerous gulches. Southward, the topography flattens and the Johnson shale appears as a broad, gently sloping surface.

Red Eagle Limestone: The Red Eagle limestone was named by Heald[32] for its excellent exposures near Red Eagle School. At the time Heald did his work on the Foraker quadrangle, the Red Eagle School was located in the extreme west central part of sec. 26, T. 27 N., R. 6 E., but it has since been destroyed. In 1935, Condra[33] extended the name into northwest Missouri and southeast Nebraska. Here he defined it as underlying the Roca shale and overlying the Johnson shale and divided it into three members. These are, in descending order: Howe limestone, Bennett shale, and Glenrock limestone.

All but the Glenrock limestone member have been identified in the Foraker area (see Measured Section XXII, Appendix). It is possible that the Glenrock is present, but outcrops are such in this area that the basal part of the formation is never exposed.

The boundary between the Bennett limestone and the overlying Howe limestone is not well defined in the Foraker

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[32]Heald, "The Oil and Gas Geology of the Foraker Quadrangle, Osage County, Oklahoma," op. cit., p. 24.

[33]Condra, "Geologic Cross Section, Forest City, Missouri, to DuBois, Nebraska," op. cit., p. 8.

Figure 15. Exposure of Long Creek limestone member at road-cut in sec. 16, T. 29 N., R. 7 E.

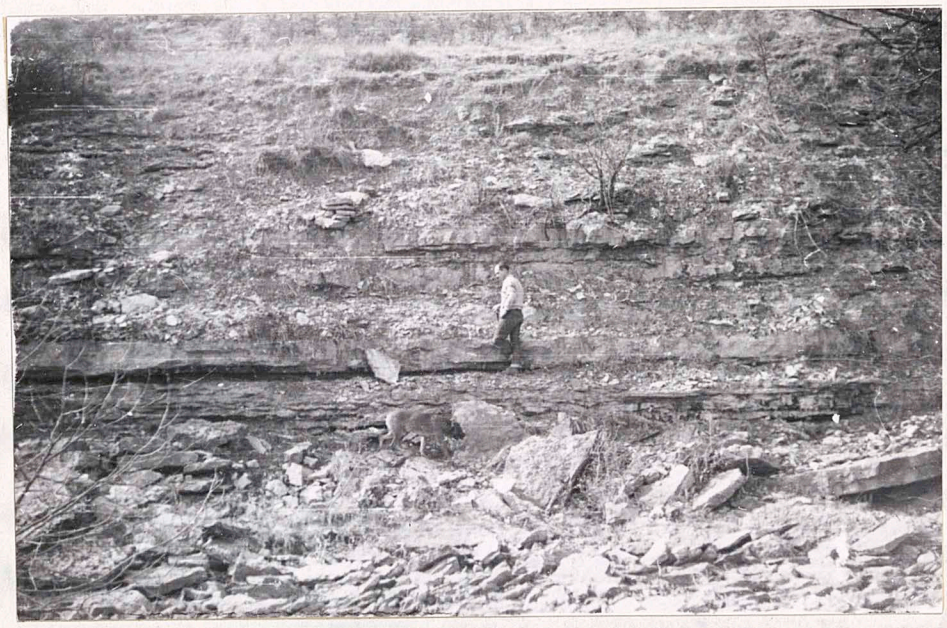

Figure 16. Exposure of Red Eagle limestone as seen in Kansas one mile north of sec. 13, T. 29 N., R. 6 E., Oklahoma.

area. For convenience in mapping and description the Bennett limestone, as used in this thesis, is restricted to beds that form the main outcrop ledge of the Red Eagle limestone. Beds lying above this are more closely related to each other, forming a more practical grouping than if an attempt was made to pick the boundary somewhere in these poorly exposed, locally absent beds. Due to this, the reported measurement for the Bennett is in all probability less than actual thickness. This, in turn, has resulted in a slightly greater thickness for the Howe.

In the type area, the Bennett is predominately shale. However, in southern Kansas and northern Oklahoma the Bennett changes facies to an almost complete limestone section, which is referred to as a limestone member instead of a shale member (see Fig. 16).

The Bennett limestone forms the main ledge of the Red Eagle outcrops (see Fig. 17). The upper 6.5 feet is somewhat thin bedded with beds averaging 1 to 2 feet in thickness. Fresh surface is light gray, slightly spotted tan by limonite and has a distinctive, finely crystalline appearance, containing numerous small voids that are partially filled by limonite. Upon weathering, the surface becomes crumbly and rough, turning to a dull powdery gray color. It contains a few brachiopods, crinoid stems and fragments of these and other fossils. It is this upper part of the Bennett that plays the important role in forming the characteristic ledge

of the Red Eagle formation.

Underlying the upper part of the Bennett is 1.5 feet of thin bedded limestone that is coarser grained than either of the upper or lower beds. This bed is lighter gray in color than the underlying bed, and has a characteristic tan weathered surface. Being softer than either the upper or lower beds, it weathers back in the rock ledge, separating the Bennett into three units. Along the northern boundary of the area, these three beds are easily recognizable. Southward along the strike, only the upper bed is prominently exposed.

The lower division of the Bennett is 4 feet thick. Fossils are mainly fragmentary and rare. This bed is similar to the upper bed.

The top member of the Red Eagle is the Howe limestone. The upper boundary for the Red Eagle can be drawn conclusively by referring to the distinctive arenaceous tan colored limestone bed found at the top of the Howe limestone. This bed is never found completely exposed in the Foraker area, but numerous smooth, slabby, rounded, tan colored fragments are commonly found at the top of the covered slope of the Howe limestone.

Outcrops of the Red Eagle are prominent in the northern part of the area where it is exposed near the top of the numerous gulches found along the state line in T. 29 N., R. 7 E. Near the middle of this township the distribution

Figure 17. Typical outcrop of Bennett limestone member, NE/4 sec. 13, T. 29 N., R. 6 E.

Figure 18. Exposures of Sallyards limestone and Roca shale, NE/4 sec. 14, T. 29 N., R. 6 E.

becomes erratic, disappearing completely in sec. 34, T. 29 N., R. 7 E. It reappears in sec. 3, T. 28 N., R. 7 E., and is continuous throughout the southern part of the area. There it is partially exposed along road-cuts and in low, rounded benches.

Roca Shale: The Roca shale is overlain by the Grenola formation and underlain by the Red Eagle formation. It was classified previously as the upper division of the now discarded Elmdale shale. It is excellently exposed in the NW/4 of sec. 14, T. 29 N., R. 6 E., just south of the state line (see Fig. 18). This is the only exposure of this shale found in the designated area. The Roca consists of 11.5 feet of non-fossiliferous maroon shale overlain by 6 feet of yellow-drab shale.

Grenola Limestone: Condra and Busby[34] named the Grenola formation for Grenola, Elk County, Kansas, and defined it as lying below the Eskridge shale and above the Roca shale. It was divided into, in descending order: Neva limestone, Salem Point shale, Burr limestone, Legion shale, and Sallyards limestone. This is now the accepted sequence of the Grenola formation.

Shale intervals below the prominent Neva limestone are poorly exposed throughout the area. The interval known

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[34] G. E. Condra, and C. E. Busby, "The Grenola Formation," Nebraska Geological Survey, Paper 1, 1933, pp. 9-10.

as the Salem Point shale is not exposed, while the Legion shale is only partially exposed. The Sallyards and Burr limestones are exposed in the northern and southern parts of the area. Elsewhere they are occasionally found in drainage ditches and as fragments along grass-covered slopes.

The Sallyards limestone (see Fig. 18) is approximately 3 feet thick, of which the lower foot is composed of gray massive limestone that weathers buff in color (see Measured Section XXIV, Appendix). This lower zone contains numerous small fossil fragments, fusulinids and tiny helicoid gastropods. Lying above this is a fine-grained, sandy limestone which grades upward into calcareous siltstone. It is unevenly bedded, contains no fossils, and weathers gray with thin, inconsistent streaks of tan.

Overlying the Sallyards limestone, is a series of thin shales and clean, fine-grained, gray limestone. The limestone beds are barren of fossils and weather white with yellowish-tan stains. Upon weathering, the shales are yellowish-gray. These limestones and yellow shales make up the Legion shale member.

The Burr limestone is 9 feet thick in the Foraker area (see Measured Section XXIII, Appendix). The lower part consists of a gray, massive, coarse-grained, fossiliferous limestone that weathers almost white (see Fig. 19). Fossils are mostly fragmentary and microscopic in size. The upper part, composed of thin limestones interbedded with shale, is

rarely exposed. The topmost layer is a coquinite of fragmentary fossils with an exposed thickness of 0.6 foot.

The overlying Salem Point shale member is never exposed, but the entire thickness is believed to be made up of shale.

The Neva limestone is the most prominent member of the Grenola formation. Differing from the underlying thick limestones found in the Council Grove group, the Neva has been subjected to erosion, leaving only remnants of the basal member exposed in the northern part. In the southern part it is excellently developed and exposed. In the northern part, it occurs as outliers with only the basal member present. Near Grainola, the Neva crops out along the west bank of Salt Creek. Southward the Neva outcrop and Salt Creek run parallel to each other with the Neva progressively increasing in thickness until it reaches the west central part of sec. 26, T. 28 N., R. 6 E. This increase in thickness is due merely to the presence of the upper members in the southern part. However, on the east side of Salt Creek, the upper beds of the Neva are absent, and, as in the northern part of the area, only scattered fragments of the basal unit are left to delineate a series of outliers.

Continuous outcrops of the Neva in the northern part of the area, as represented on the map compiled by Beckwith,[35]

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[35] H. T. Beckwith, "Geology of Osage County, Oklahoma," Oklahoma Geological Survey, Bulletin 40-T, Plate No. 1, 1928.

Figure 19. Outcrop of Burr limestone found just south of Kansas-Oklahoma line in NE/4 sec. 14, T. 29 N., R. 6 E.

Figure 20. Complete exposure of the soft, soluble upper bed of the Neva limestone member. Taken along the west bank of Salt Creek in sec. 28, T. 28 N., R. 6 E. Note thin cherty bed at the bottom of this bed.

more accurately follows the outcrop of the Burr limestone. This probably resulted from misinterpreting the basal Neva as upper Neva and the underlying Burr limestone member as basal Neva.

The maximum thickness of the Neva is 26 feet (see Measured Section, XXIV, Appendix). The upper bed (see Fig. 20) is gray, sparsely fossiliferous and soluble. It is rarely seen in its entirety. Where found, it is easily recognized by its characteristic jagged and porous surface (see Fig. 21). Underlying this bed is 2.5 feet of chert interbedded with dolomitic limestone. The chert is tan and is a valuable aid in mapping since the soft upper bed is absent throughout much of the area. Below the chert bed and above the lower bed is a series of gray to blue fossiliferous limestones interbedded with fossiliferous shales. Near the middle of the Neva is a shale zone containing the fusulinid Pseudoschwagerina. The basal bed of the Neva is 4.5 feet thick, gray, and somewhat dolomitic. After weathering, it becomes rough and porous, but never reaches the degree of irregularity that is shown by the upper bed. Irregular shaped masses of liminite are dispersed throughout the upper part of this bed.

Eskridge Shale: The name Eskridge was suggested by Prosser[36] and used by Beede[37] to include beds underlying the

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[36] C. S. Prosser, Unpublished Manuscript.

[37] J. W. Beede, "Coal Measures Faunal Studies, II," Kansas Univ. Science Bull., Vol. I, No. 7, Sept., 1902, p. 181.

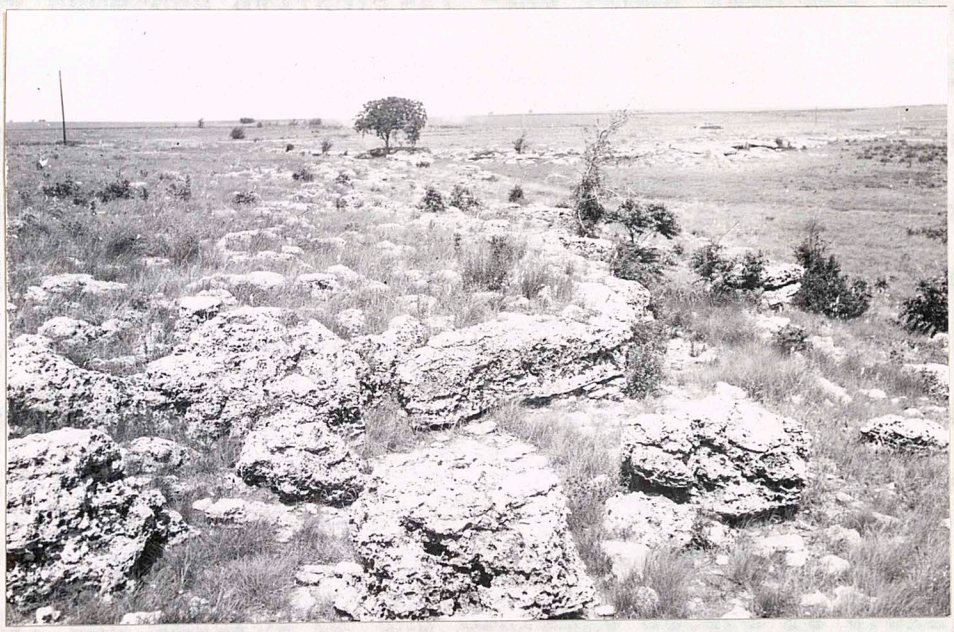

Figure 21. Exposure of top bed of Neva limestone showing jagged and porous nature of weathered surface, sec. 28, T. 28 N., R. 6 E.

Cottonwood limestone and overlying the Neva limestone. Named from exposures near Eskridge, Wabaunsee County, Kansas, the Eskridge shale was formerly considered the uppermost unit in the Wabaunsee group.

The Eskridge is approximately 67 feet thick and consists of four relatively thick, alternating beds of maroon and yellowish-gray shales (see Measured Section XXV, Appendix). The upper gray shale is calcareous, contains thin, irregular limestone beds, is fossiliferous and is characterized by numerous cylindrical rods found near the top. These rod-like objects are helpful in identifying the overlying Cottonwood limestone. A calcirudite, consisting of rounded limestone pebbles cemented by a coarse-grained matrix and carrying fragments of Myalina, brachiopods, gastropods, crinoids, and probably numerous other unidentifiable fossils, is approximately 20 feet below the overlying Cottonwood limestone. A few feet below this calcirudite is a cross-bedded calcareous sandstone. Progressing southward from T. 29 N., R. 6 E., the outcrop of the Eskridge occurs as broad, flat or rolling plains surrounding outliers of Cottonwood limestone. Occasionally the upper gray, calcareous shale is exposed below the Cottonwood limestone. In the SW/4 of sec. 26, T. 28 N., R. 5 E., the previously mentioned thin cross-bedded sandstone has increased in thickness to at least 10 feet (see Fig. 22). It is extremely cross-bedded and conglomeratic at its base. These are the only exposures of the

Eskridge found in the southern part of the area.

The beds lying below the upper gray, calcareous shale are seldom exposed. A few thin, platy sandstones are found near the middle of the section; otherwise it is made up of two maroon shale beds separated by a yellowish-gray shale.

Beattie Limestone: The Beattie limestone was named from the town of Beattie, Marshall County, Kansas. It includes two limestones and one shale member. In descending order, they are: Morrill limestone, Florena shale, and Cottonwood limestone.

The Cottonwood limestone is the most familiar member of the Beattie formation. At a relatively early date, this thin but remarkably persistent bed was traced from Nebraska across Kansas into Oklahoma. It was chosen by Prosser[38] in 1895 as the basal member of the Permian system. This was generally accepted until 1934 when Moore and Moss[39] found evidence of a stratigraphical break above the Brownville limestone.

The Cottonwood has thinned from a reported thickness of 10 feet in Cowley County, Kansas, to a maximum of 2.5 feet in northern Oklahoma (see Fig. 23). In the area of investigation, the outcrop pattern of the Cottonwood is similar to

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[38] C. S. Prosser, "The Classification of the Upper Paleozoic Rocks of Central Kansas," op. cit., pp. 764-766.

[39] R. C. Moore and R. G. Moss, "Permian-Pennsylvanian Boundary in the Northern MidContinent Area," Proc. Geol. Soc. America, 1933, p. 100.

Figure 22. Exposure of cross-bedded sandstone in Eskridge shale, sec. 26, T. 28 N., R. 5 E.

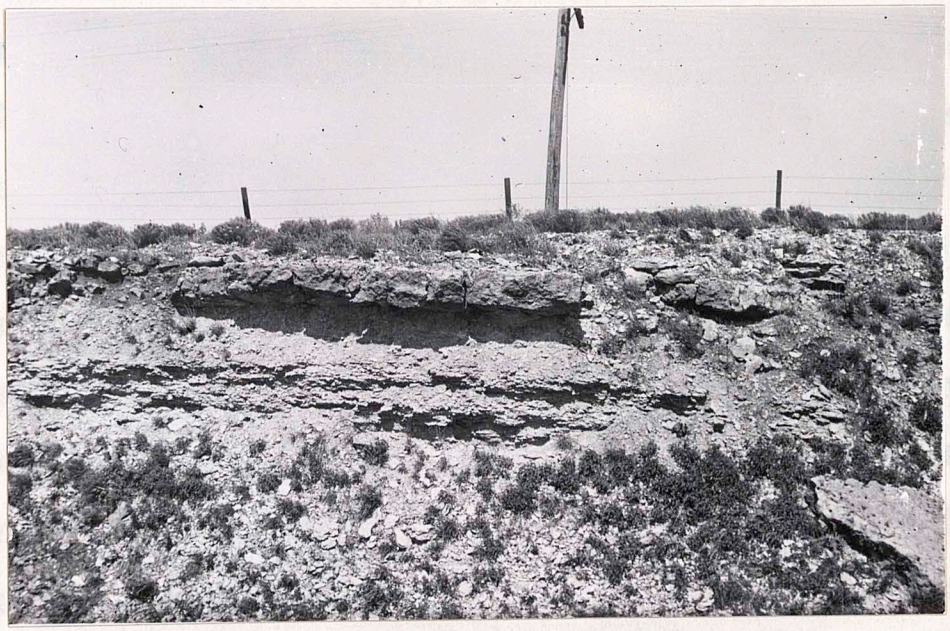

Figure 23. Railroad cut exposing the lower bed of the Cottonwood limestone and upper part of Eskridge shale. Located in SW/4 sec. 21, T. 29 N., R. 6 E.

that of the Neva limestone. In T. 29 N., R. 5 and 6 E., and southward along the west side of Beaver Creek, it crops out as a continuous bed. However, east of Beaver Creek and south of T. 29 N., Rs. 5 and 6 E., it occurs as a series of outliers. Although not forming a broad dip slope as does the Foraker, the Cottonwood limestone transverses the Foraker area in a belt that occasionally reaches a width of three miles. Much of this width is the result of the numerous outliers.

A one foot massive limestone containing thin maroon and greenish-gray shale breaks is found immediately above the Eskridge shale and persists throughout the area. Fresh surfaces are light gray, weathering gray to tan. Small fusulinids are found at some outcrops. The uppermost unit of the Cottonwood, a 1.5 foot thick gray limestone, is occasionally found in the northern part of the area. It weathers light gray to white, and into smooth rounded boulders that contain small cylindrical holes. Fusulinids are found abundantly at some localities in this bed. The thickness for this bed was approximated because it was never found completely exposed (see Measured Section XXVI, Appendix).

Near the state line, the Florena shale and Morril limestone are exposed along the creek in north central part of sec. 13, T. 29 N., R. 5 E. The Florena shale is made up of 21 feet of dark brownish-maroon shale and 6 feet of interbedded thin calcarenites and shale. The calcarenites

are composed of shale and rounded limestone pebbles with very little cementing material. The intervening shales are predominately maroon with streaks of gray and greenish-gray. This interval gradually becomes more calcareous towards the top, grading into the overlying Morrill limestone. Brachiopods, pelecypods, gastropods, and crinoid fragments are found in this zone.

The overlying Morrill limestone is gray with blotches of maroon stains. Smooth, well-rounded, tan to gray limestone pebbles are commonly found on the weathered surface. The Morrill limestone and the upper calcareous zone of the Florena shale produce a small, rounded bench near the Kansas line. Approximately one mile south of the state line, the bench disappears. From this point the Florena continues across the western part of the area as a grass-covered slope littered by fragments from the Morrill limestone and overlying limestones.

Interval Between the Beattie and Wreford Limestones: The interval, occupied predominately by poorly exposed shales separated by thin limestones, is topographically expressed as the eastward facing escarpment capped by the Wreford limestone (see Fig. 24). Beds occupying the interval represent the upper divisions of the Council Grove group. They are, in descending order: Speiser shale, Funston limestone, Blue Rapids shale, Crouse limestone, Easly Creek shale, Bader limestone and the Stearns shale (see Measured Sections XXVII

and XXVIII, Appendix). Of these, only the Crouse limestone is well exposed or topographically expressed.

The general northeast-southwest strike of the beds has resulted in a limitation of the outcrop for these beds, in the Foraker area. This, combined with poor exposures, has caused difficulty in obtaining complete and accurate descriptions and definitions of the exact limits for some of these units. The Bader limestone, consisting of two limestone units separated by a shale member, and the underlying (?) Speiser shale are especially noted for this condition. In the Foraker area, the positions of the Middleburg limestone, Hooser shale and Eiss limestone members of the Bader formation have been approximated as accurately as possible by referring to their correlative stratigraphic positions in Kansas.

The Stearns shale is covered but is believed to consist predominately of gray shale with thin gray limestone beds near the top. The overlying Eiss limestone member, reported in Kansas and Nebraska to consist of two limestone units separated by shale, is represented in the Foraker area by only one partially exposed gray, fine-grained fossiliferous bed. The Hooser shale, middle member of the Bader formation, is three feet thick, consisting of gray shale. The Middleburg limestone member, like the Eiss, is reported in Kansas to consist of two limestone units separated by shale, but is represented by one limestone unit in the area of investigation.

This bed is a fine-grained, greenish-gray limestone with voids filled by coarsely-crystalline calcite and limonite.

The Easly Creek shale, overlying the Bader formation and underlying the Crouse limestone, consists of gray shales in the lower part and maroon shale in the upper part. Thin beds of sandstone are found in this non-fossiliferous shale.

The Crouse limestone was named by Heald[40] from exposures on Crouse Hill, Foraker Quadrangle. This limestone lies approximately 60 feet below the base of the Wreford limestone and forms the only conspicuous bench below the Wreford limestone and above the Cottonwood limestone (see Fig. 26). At the base of the Wreford outlier in the NE/4 of sec. 23, T. 29 N., R. 5 E., the entire thickness of the Crouse, as it appears in the Foraker area, is excellently exposed. The lower part consists of four feet of gray, shaly, fossiliferous limestone. Fusulinids are abundant. Small, rounded, shaly limestone pebbles are observed on the weathered surface. The comparative softness of this lower part to the upper massive bed is evident by the under-cut notch found at other outcrops of the Crouse. The upper bed is 2.3 feet thick and is characterized by numerous distinctive, vertical, cylindrical holes (see Fig. 25). These smooth holes are conspicuously evident along the outcrop,

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[40]Heald, "The Oil and Gas Geology of the Foraker Quadrangle, Osage County," op. cit., 1916, p.22.

Figure 24. Eastward facing escarpment capped by Wreford limestone. Lower bench is formed by Crouse limestone, sec. 22, T. 29 N., R. 5 E.

making it a very easily recognizable bed. The fresh surface is speckled by tiny disseminated particles of limonite on a white, fine-grained ground mass. Fossils and fossil fragments are rare.

Overlying the Crouse is the Blue Rapids shale. Only the upper 2 or 3 feet of this 15 foot shale are exposed in the Foraker area. This exposure is found immediately below the Funston limestone along the northwest slope of the Wreford outlier in the NE/4 of sec. 23, T. 29 N., R. 5 E. This limited exposure consists of yellowish-gray shale.

The Funston limestone crops out as two thin limestones separated by shale. Outcrops occur as fragments strewn along the slopes of the outliers and eastward facing escarpment formed by the Wreford limestone. It is absent or covered at some localities. Neither bed is completely exposed. The lower bed has an exposed thickness of one foot and is gray, massive, and medium grained. The upper bed has an exposed thickness of 0.3 foot and is fossiliferous and gray in color.

The uppermost formation of the Council Grove group is the Speiser shale. As defined in 1927 by Condra,[41] this interval included beds between the Crouse and Wreford limestone, which is a practical classification for the beds

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[41]Condra, "The Stratigraphy of the Pennsylvanian System in Nebraska," op. cit., p. 239.

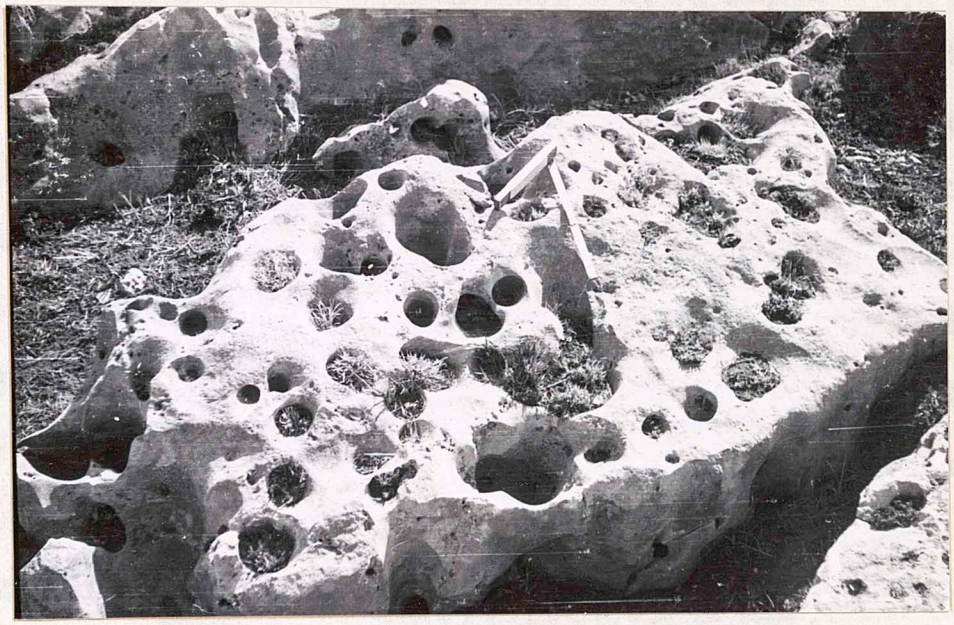

Figure 25. Crouse limestone showing vertical-cylindrical holes, NE/4 sec. 23, T. 29 N., R. 5 E.

Figure 26. Typical outcrop of Crouse limestone as seen in NE/4 sec. 23, T. 29 N., R. 5 E.

found in the Foraker area. However, in 1931, Condra and Upp[42] restricted the Speiser to beds lying between the Funston limestone and Wreford limestone. With the exception of a thick, massive sandstone exposed in the railroad-cut near the base of the Wreford outlier in SE/4 of sec. 23, T. 29 N., R. 5 E., the Speiser shale is completely covered by grass. This sandstone found in the shale has an exposed thickness of seven feet. It is a very fine grained, poorly indurated sandstone that is predominately light tan in color. It becomes darker brown toward the top, turning red at the top. Fresh surface is light tan, spotted by tiny grains of brown limonite. This bed is too soft to form a prominent bench, but it is occasionally found in large slabs along the grass-covered slopes.

Chase Group

The Chase group consists of alternating beds of limestone, in part cherty, and shale. In Cowley County, Kansas, Bass[43] gave a total thickness of approximately 275 feet. The two types of rock form about equal parts of the group. The abundant chert, found chiefly in the lowermost and middle limestone formations, is probably the most characteristic feature of the group. The Wreford limestone is

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[42] G. E. Condra and J. E. Upp, "Correlation of the Big Blue Series in Nebraska," Nebraska Geol. Survey, 2nd series, Bull. 6, 1931, pp. 23 and 24.

[43] Bass, op. cit., p. 67.

the lowest formation of the group and the Winfield limestone is the topmost formation. The Wreford limestone is the only formation of the Chase group that crops out in the Foraker area.

In Cowley County, Kansas, the Wreford limestone forms the backbone of the Flint Hills. It is mainly from the chert yielded by the Wreford formation that the Flint Hills are named. In the northwest part of the Foraker area, it rims the prominent eastward facing escarpment. The relief and steepness are less than those of the escarpment capped by the Foraker limestone.

Bass[44] reported that the Wreford varies little from 33 feet in thickness across Cowley County, Kansas. The 31 feet measured along the road cut southeast of Hardy in Kay County, Oklahoma, shows little change in thickness (see Measured Section XXIX, Appendix). It is never completely exposed in the Foraker area. Moore[45] has divided the Wreford into, in descending order: Schroyer limestone member, Havensville shale member, and Threemile limestone member. In northern and central Kansas, these three members are easily identifiable. However, in southern Kansas and northern Oklahoma the Wreford comprises a more or less continuous limestone section that is difficult to divide into units

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[44] Ibid., p. 70.

[45] Moore, "The Kansas Rock Column," op. cit., p. 45.

correlative to these found in northern Kansas.

The Wreford is distinguishable by the abundance of chert and silicified fossils, by its weathered buff color, and by its pronounced influence on surface features (see Fig. 24). East of the main outcrop, in the northwest corner of the area, the Wreford forms two outliers. The upper part of the Wreford limestone appears to consist of alternating beds of thin, light gray limestone and shales. This bed weathers back from the underlying resistant bed, forming a grass-covered slope littered by white to light-gray limestone fragments.

The upper boundary of the Wreford is rather poorly defined in the Foraker area. Limestone beds underlying the upper part average about 2.5 feet thick, are fine grained, gray, and weather to a buff color. Fossils found in these limestones are siliceous and being more resistant than the embedding limestone, weather in relief. Composita subtilita, Dictyoclostus americanus and a few other brachiopods, crinoids and corals are prominently displayed along the weathered surface.

Slightly below the middle of the Wreford, is a thick chert-bearing bed. The lower three feet are filled by chert in a random pattern, while the upper part contains two thin layers of small chert nodules (see Fig. 27). These are not continuous beds of chert, but merely individual nodules that seem to be laterally persistent. They are separated by 0.6

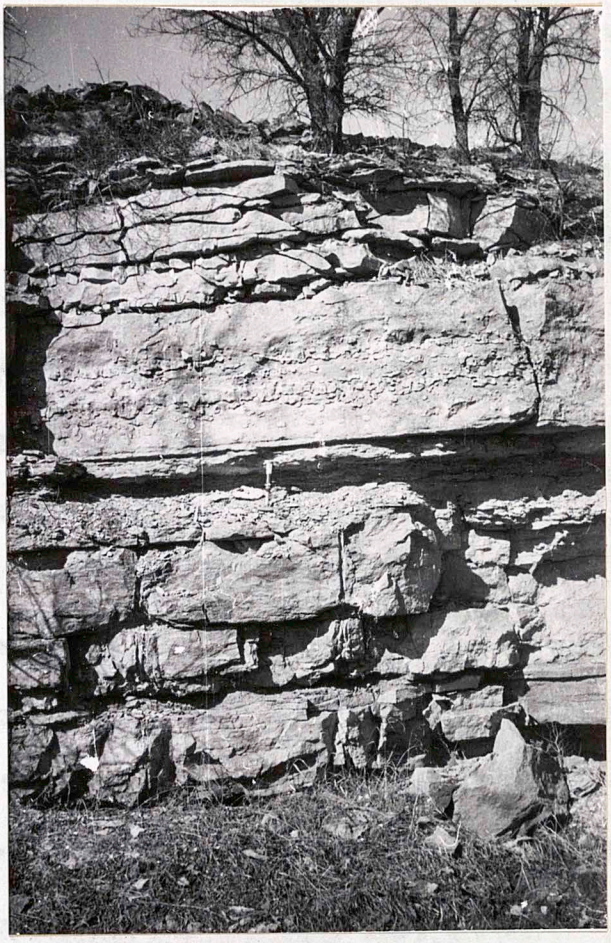

Figure 27. Exposure of Wreford limestone located 1/4 mile south of Hardy in Kay County, Oklahoma.

foot of limestone. This thick, cherty bed forms the main ledge of the Wreford outcrop. The lower boundary of the Wreford is sharply defined along the road-cut two miles southeast of Hardy, Oklahoma.

The abundance of chert found in the vicinity of the Foraker and Wreford outcrop areas rarely fails to arouse the inquisitiveness of the observer. Chert is especially abundant in all of the stream beds, making its use as road material practical and economical.

In 1919, Twenhofel[46] made a study of the origin of the cherts found in the Foraker and Wreford limestones along the Kansas and Oklahoma State Line. He described the chert as being quite porous, resulting from the removal of some organic remains. In relation to the limestone, the chert occurs as isolated nodules, commonly with the longest axis parallel to the bedding. The chert in the Wreford occurs in four or more zones, the chert in each zone differing from that of the others and being wide in horizontal distribution. He believes that it is possible that these cherts developed through direct precipitation of silica, although the facts do not support such an origin. Twenhofel concludes that the origin is best explained by the "replacement of unconsolidated limestone, the silica being derived

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[46] W. H. Twenhofel, "The Chert of the Wreford and Foraker Limestones Along the State Line of Kansas and Oklahoma," American Journal of Science, Vol. XLVII, Art. XXVII, 1919.

from silica in solution which was mingled with the sediments, from silica in solution in the sea water, and from solution of organic or other silica, or silicates deposited in some form with sediments."

CHAPTER III

REGIONAL GEOLOGY

Historical Geology

Regionally, the Foraker area is situated on the Prairie Plains homocline on the western flank of the Ozark uplift. Pennsylvanian and Permian rocks form long parallel belts of outcrop across this area. They extend without interruption from southeastern Nebraska across Kansas into south-central Oklahoma. In the northeastern part of this region, the direction of dip is to the northwest, and in the southeastern part, in which the Foraker area is located, the dip is toward the west-southwest.

Pennsylvanian deposits which occur in northern Oklahoma and Kansas are characterized by features of sedimentation on stable platform areas. Rock formations of the comparatively even-surfaced platform region are mostly thin, but have remarkable lateral uniformity throughout large areas. Southward, these thin beds grade laterally into the red beds of central and south-central Oklahoma. In contrast to these thin, persistent limestone beds of the stable platform area, geosynclinal deposits of southern Oklahoma are distinguished

by great thicknesses of sandstones and chert conglomerates. These rock units are not traceable for long distances, because they are either lenticular in form, or grade laterally into different types of deposits.

The limestones and shale divisions of the Pennsylvanian, together with less important sandstone and coal beds, are arranged in alternating succession. The limestones and some of the shales and sandstones are marine, while coal beds, some of the shales and sandstone are non-marine. Arranged in constant alternating sequence, they are recognized as cyclothems. Cyclical sedimentation is indicative of the continuous or spasmodic movements that occurred throughout Pennsylvanian time. Since the stable platform was almost a topographically featureless plain in upper Pennsylvanian time, comparatively minor fluctuations of either the sea or continent resulted in notable changes in depth and extent of the Pennsylvanian sea.

In the Foraker area, at least five coal beds are recognized, representing a withdrawal of the seas a like number of times. Evidence of corresponding marine cyclical phases is found for all but one coal bed. Cyclothems formed in Reading, Jim Creek and Brownville time, most nearly approach the ideal cyclothem described by Weller.[47] However,

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[47] M. J. Weller, "The Conception of Cyclical Sedimentation During the Pennsylvanian Period," Illinois State Geological Survey, Bull. 60, Pt. 5, 1931.

at least one phase of each transgressive and regressive part of these cyclothems is missing.

Permian beds in the Foraker area were probably deposited without interruption. Apparently this area is situated along the southern edge of a basin located in Kansas. Southward, these marine limestone beds grade laterally into the red beds of central and south central Oklahoma. Northward into the Forest City Basin, there is a noticeable facies change from predominantly limestone to shale.

Structural Geology

According to Bass,[48] the Fort Scott limestone has a total fall of a little more than 2700 feet from its point of outcrop to the Rainbow Bend oil field, in Cowley County, Kansas, a distance of 110 miles. This is an average component dip of 25 feet to the mile. Deviations from this homoclinal dip are manifested by the numerous local steeperings and reversal of dips. Powers[49] concludes that the dominant type of structure for this general area are "anticlines and folds of the anticlinal type, the most common of which is the nose."

Anticlines and other surface folds can be classed as "reflected and surficial types."[50] The amount of closure of

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[48] Bass, op. cit., p. 117.

[49] Sidney Powers, "Structural Geology of the Midcontinent Region, a Field for Research," Geol. Society of America, Bull. Vol. 36, 1924, p. 381.

[50] Ibid.

the reflected folds increases in proportion to the depth, while the surficial type usually die out in the Pennsylvanian shales. The average fold can be enclosed within an area of one square mile. Most of the anticlinal folds are irregularly disposed, without known system, both on the surface and subsurface, except that some are connected underground to form elongate anticlinal ridges.

It is evident by the westward dip, as shown in surface exposures of the Permian beds, that uplift occurred after the deposition of these beds. Less evident in the Foraker area, but disclosed by other workers from well data and other surface studies in the general region, is the occurrence of earlier important structural movements. The following statements are based upon reports dealing with this phase of geology in the Mid-Continent region.

The basement crystalline surface was a peneplain of low relief, with small rounded hills, a few sharp, small monadnocks, and some major low ridges. Following deposition of Cambrian and part of Ordovician strata over this surface, a pronounced uplift that centered near the present Ozark Mountains affected an extensive region in northeastern Oklahoma and eastern Kansas.[51] Sedimentation continued in Ordovician until another uplift ended the period. The folding

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[51] L. H. White, "Subsurface Distribution and Correlation of the Pre-Chattanooga Series of Northeastern Oklahoma," Oklahoma Geol. Survey, Bull. 40-B, 1926, p. 10.

which accompanied and followed this sedimentation rejuvenated the former hills and made anticlines. No anticlines which extended downward into the Ordovician are known to have been formed later; the subsequent periods of folding merely rejuvenated those established at the close of the Ordovician.[52]

After uplift, folding, and erosion of Ordovician strata, the land was again submerged by the seas and Silurian and Devonian sediments were deposited. They did not cover all of the anticlines, and there is a thinning of sediments over those that were covered. Following slight folding and erosion, Mississippian strata were deposited. Preceding the complete inundation of local and regional anticlines by Pennsylvanian sediments, the Mississippian strata were subjected to broad warping, faulting, and erosion. Movement of these buried anticlines was either continuous or spasmodic throughout Pennsylvanian and Permian time. Some anticlines and small folds in the Pennsylvanian were formed between the reflected folds after Permian sedimentation. This surficial type of structure of course disappears in depth. Some disappear in the thick Pennsylvanian shales; others extend down to topographic hills on top of the eroded Mississippi limestone.

Anticlinal structures in the Foraker area apparently

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[52]Powers, op. cit., pp. 382-385.

conform to the general description given above. Heald[53] mapped and described six anticlines in the Foraker area.

Beaver Creek anticline, located in the northwest corner of the area, is the most pronounced fold in the Foraker area. It is the only anticline in the area that is readily detected by the observer. This is one of several small structures that make up the Dexter-Otto anticline of Kansas. Clark and Cooper[54] have traced this large asymmetrical fold southwestward from Dexter, Kansas, through the Mervine and Ponca anticlines of Kay County, Oklahoma. This anticline or ridge is similar to those described by Powers[55] as consisting of groups of small anticlines and domes. The eastward dip of this fold is about 120 feet to the mile, and it has 60 feet of closure.

Heald[56] mapped five other small anticlines in the Foraker area. They are: Lone Tree dome, located in sec. 28, T. 29 N., R. 6 E.; Grainola anticline, located in sec. 32, T. 29 N., R. 6 E.; Brooks anticline, located in sec. 28, T.

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[53]Heald, "The Oil and Gas Geology of the Foraker Quadrangle, Osage County, Oklahoma," op. cit., pp. 33-40.

[54]G. C. Clark and C. L. Cooper, "Oil and Gas Geology of Kay, Grant, Garfield, and Noble Counties," Oklahoma Geol. Survey. Bull. 40-H, 1927, p. 21.

[55]Powers, op. cit., p. 382.

[56]K. C. Heald, "The Oil and Gas Geology of the Foraker Quadrangle, Osage County, Oklahoma," op. cit., pp. 30-40.

28 N., R. 6 E.; Elm Creek anticline, located in W/2 of sec. 9, T. 28 N., R. 7 E.; and Foraker anticline located in sec. 21, T. 28 N., R. 7 E.

All except the Foraker anticline have less than 15 feet of closure and are small in areal extent. The Foraker anticline is slightly over one square mile in area and has over 25 feet of closure. It is the second largest structure in the Foraker area, and is the only one from which oil has been produced. These small upwarpings can probably be classed as surficial folds.

Faulting or evidence of faulting has not been found by work on surface exposures in the Foraker area.

Economic Products

This area is among the least drilled parts of Osage County. The lack of initiative to drill has undoubtedly resulted from poor returns on all previous attempts to recover oil. At the present time, only one well in the area is producing.

In sections 16 and 17, T. 29 N., R. 6 E., a total of 15 wells has been drilled. These wells, known as the Frankfort pool in Oklahoma, are the southern development of the Fall City field of Kansas. All of the wells in the Frankfort field have been abandoned.

Tests have been made on every structure mapped by

Heald.[57] With the exception of the small producing well on the Foraker anticline, all have proved to be either dry or such small producers that they have been abandoned after a short period of production.

There are no other mineral resources that are of any commercial importance. Road surfacing material is plentiful for the needs of this area, but would meet strong competition from the Burbank Gravel Company outside of the area.

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[57] K. C. Heald, "The Oil and Gas Geology of the Foraker Quadrangle, Osage County, Oklahoma," op. cit, pp. 33-40.

APPENDIX

MEASURED STRATIGRAPHIC SECTIONS

I. Sec. 31, T. 28 N., R. 8 E. Measured from exposures along north bank of Sand Creek in northwest corner of section.

STONEBREAKER formation:

Elmont limestone member:

Limestone, massive, algal in upper part, color is gray weathering to a distinctive bright yellow. Fine grained, somewhat sandy. Weathers to thin small slabs. Fossiliferous, an abundance of fossil Crurithyris occurs in this bed 2.3

Covered interval, probably shale, about 6.0

Limestone, gray, weathering to yellowish-tan color, easily recognized by the abundance of "Cryptozoon" and fusulinids. Coarse to medium grained 0.5

Harveyville shale member:

Shale, gray, calcareous, weathering to a yellowish-tan color. Upper part is poorly exposed. A poorly developed underclay occurs near the middle. Lower part contains thin, platy, shaly limestone interbedded with calcareous shale. An abundance of Chonetes occurs in this zone 5.0

Coal 0.5

Shale, gray, calcareous. Poorly developed underclay in upper part. Barren of fossils ... 2.5

Reading limestone member:

Limestone, bluish-gray in upper part, yellow color in lower part. Contains a wide variety of fossils, almost all fragmentary. Lower part is predominately algal, shaly, and somewhat sandy 1.0

Shale, not measured.

II. Sec. 25, T. 29 N., R. 7 E. Measured along south bank of Buck Creek, in the center of section.

STONEBREAKER formation:
Reading limestone member, not measured.
AUBURN shale:
Shale, greenish-gray, weathering drab yellow, sparsely fossiliferous near top, lower part barren and silty 11.0
Sandstone, gray, calcareous, weathering to a light buff, thin and platy, interbedded with silty shale. Grades laterally into a cross-bedded, channel sandstone. Contains a few plant imprints, about 3.0
Shale, light bluish-gray, sandy, somewhat calcareous 3.0
Limestone, thin, shaly, blue-gray, contains fragments of large pelecypod, weathers to brown color 0.5
Shale, gray, barren of fossils 8.0

III. Sec. 25, T. ~~28~~ 29 N., R. 7 E. Measured in one of tributaries running into Buck Creek at approximately the middle of the west section line.
STONEBREAKER formation:
Reading limestone member:
Shale, not measured.
Limestone, gray, weathering yellowish-brown, fine grained and shaly, weathering to hard, rounded boulders which are probably algal forms. Fossils are few and fragmental .. 1.9
Shale, greenish-gray weathering to drab yellow, has a maroon streak near the middle, fossiliferous 7.0
Limestone, fine to coarse grained, gray weathering to brownish-gray. Contains an abundance of fusulinids, especially in lower half. Upper part contains brachiopods, horn coral, "Cryptozoon," and a few fusulinids, shows prominent vertical joints ... 4.7
Shale, bluish-gray 1.5
Coal 0.3
Shale, gray weathering yellow 1.0
Limestone, gray to brown color, weathering gray, surface is irregular and wavy, suggestive of algal content 2.0
AUBURN shale:
Yellow calcareous shale. Contains large, round boulders, probably algal. Fossils are predominately rounded crinoid plates 4.0

IV. Sec. 31, T. 28 N., R. 8 E. Measured from exposures along north bank of Sand Creek in northwest corner

of section.

STONEBREAKER formation:
Reading limestone member:
Shale, not measured.
Limestone, gray weathering brown, contains an abundance of "Cryptozoon," and other algal remains. Very few fusulinids. This bed is rarely exposed or present 0.3
Shale, light gray, calcareous, contains fusulinids, but no other fossils 0.2
Limestone, gray weathering yellowish-brown with blotches of yellow. Contains "Cryptozoon" and fusulinids. Weathers to rectangular blocks, vertical jointing is prominent 1.2
Shale, gray, fusulinids and crinoid plates and stems, calcareous 0.7
Limestone, gray weathering to yellowish-brown, fine grained, hard. A very thin, wavy, shale occurs near the middle. Fusulinids are abundant near the top, not so abundant near the base 3.2
Shale, gray, slightly calcareous, barren of fossils 1.5
Coal 0.3
Shale, gray, barren of fossils 1.5
Limestone, gray, shaly, weathering to round fragments 1.0

V. Sec. 25, T. 29 N., R. 7 E. Measured up south bank of Buck Creek on township line near middle of east section line.

WILLARD-LANGDON shale:
Sandstone, light tan, weathering to dark brown, limonitic stains on broken weathered surfaces, not entirely exposed 2.0
Covered interval, about 32.0
Sandstone, buff, weathering brown, contains plant imprints, has ripple marks, weathers to angular blocks, not measured.
Covered interval, about 33.0

STONEBREAKER formation:
Reading limestone member:
Light brownish-gray, fine to coarse grained, fusulinids are abundant, weathers slabby, about 4.0

AUBURN shale:
Covered interval, near the middle fragments of sandstone, containing a few plant imprints, about 35.0

Limestone, gray weathering dirty-yellow, lower part shaly grading into underlying shale, extremely fossiliferous, most of which are fragmental 1.1
Shale, upper part greenish-gray weathering to dull yellow, lower part is light bluish-gray and calcareous. Near the top it is fossiliferous 28.0
Limestone, bluish-gray, weathering to light gray, contains fusulinids and Cryptozoon 1.2

VI. Sec. 18, T. 28 N., R. 8 E. Measured along the east bank of creek in northeast part of section.

WILLARD-LANGDON shale:
Sandstone, poorly exposed, not measured.
Shale, upper part covered, lower part is silty and weathers yellow, about 18.0
Coal 1.0
Underclay 1.0
Shale, yellow, silty 3.5

STONEBREAKER formation:
Elmont limestone member:
Limestone, light bluish-gray, weathering to brown with blotches of yellow. Shaly in lower part. Fossils have been replaced by coarsely-crystalline calcite. Crurithyris occurs in abundance in lower shaly part 1.2
Shale, yellowish-gray, marly and calcareous, contains an abundance of Crurithyris in upper part. Lower half contains limestone concretions interbedded with limonitic-yellow shale. Same fauna occurs throughout this section 2.0
Shale, black with gray shale streaks, same fauna as beds above 1.5
Shale, carboniferous black shale, barren of fossils 1.5
Limestone, light blue weathering to reddish-brown, very shaly, fossiliferous 0.3
Shale, fissile black, barren of fossils 2.0
Limestone, gray, medium-grained weathering to somewhat darker gray. Fusulinids are rare but "Cryptozoon" is abundant 0.5
Harveyville shale member:
Shale, gray, grades downward into a black platy shale, measured to water level 1.0

VII. Sec. 18, T. 28 N., R. 8 E., and Sec. 13, T. 28 N., R. 7 E. Measured on the south bank of creek in the extreme northwest corner of sec. 18, T. 28 N., R.

8 E. to the top of outlier in northeast corner of sec. 13, T. 28 N., R. 7 E.

JIM CREEK limestone:
Brown to yellow, abundant fusulinids, not measured.
Covered interval, about 16.8
Sandstone, fragments occurring along grass-covered slope, not measured.
Covered interval, about 19.6

DOVER limestone:
Gray, weathering brown, contains fusulinids. Occurs as fragments along grass-covered slope. This is upper member, no evidence of lower member being present, not measured.

WILLARD-LANGDON shale:
Covered interval, about 42.0
Limestone, occurs as fragments along grass-covered slope, very fossiliferous, gray weathering to yellowish-brown, not measured.
Covered interval 19.5
Limestone, gray weathering almost white, contains a few fragmentary fossils, easily recognized by its pyrite nodules which have weathered to limonite, very thin, about 0.3
Covered interval, about 22.4
Sandstone, tan, evenly bedded, contains limonite stain giving it a brown weathered surface, not entirely exposed 2.0
Covered interval, angular blocks of brown, ripple-marked sandstone are strewn along this grass-covered slope 34.0
Limestone, probably Elmont, gray weathering yellow, slabby fragments occur along the grass-covered slope, not measured.
Covered interval, about 18.2

STONEBREAKER formation:
Reading limestone member:
Not measured.

VIII. Sec. 26, T. 29 N., R. 7 E. Measured up eastward facing escarpment on north side of train in southwest part of section.

BROWNVILLE limestone, not measured.

PONY CREEK shale:
Shale, yellow, silty 10.2
Coal and poorly developed underclay 0.4
Covered, probably silty shale 20.6
Sandstone, cross-bedded, tan weathering to brown, contains limonite stains and mica, exposed thickness 1.5

Covered interval, about 14.0

GRAYHORSE limestone:
Gray weathering gray with blotches of yellow, dense and hard, fossils are fragmental. Appears as fragments on the slope, not measured.
Covered interval, about 14.0

NEBRASKA CITY limestone:
Dull gray weathering brown, ferruginous, contains small limestone pebbles which weather to different colors, giving the rock a spotted appearance, not measured.
Covered interval, about 11.2

JIM CREEK limestone:
Gray weathering to yellowish-brown, a few fusulinids are present at this locality. Massive, somewhat sandy, weathering to thin slabs. This limestone is an excellent marker throughout the area 2.0

Covered interval, about 14.0

GRANDHAVEN limestone:
Gray, strongly ferruginous and cross-bedded. Weathers red in some outcrops. A calcarenite containing shale and limestone pebbles. Few fossils other than a large pelecypod, probably Myalina, nearly always replaced by large calcite crystals. This limestone is rarely exposed in southern part of area, thins rapidly southward 2.0

Covered interval, about 22.5

DOVER limestone:
Gray weathering to brown, contains fragments of fossils, a few fusulinids are present 0.5

WILLARD-LANGDON shale:
Covered interval 0.5
Sandstone, not measured.
Covered interval 17.0
Limestone, buff weathering to light brown, fragments of brachiopods and crinoids are present. A large pelecypod, probably Myalina, is the most common fossil 1.0
Limestone, gray to buff weathering buff, an extreme abundance of fusulinids occur in this bed. Limonite stains are common and appear to fill voids left by weathered fusulinids. Some chert is found 2.8
Shale, calcareous, buff colored, contains a few fusulinids 0.2
Limestone, buff weathering, gray, coarse-grained, fusulinids and brachiopod fragments are present 0.7

Shale, calcareous, interbedded with thin limestone. Shale is yellow with a few streaks of orange. Limestones are gray. Fusulinids are common 1.0
Limestone, gray, coarse grained, a few fusulinids. Bryozoans, corals, crinoid plates are more abundant, especially in lower part 1.5
Shale, yellow, drab calcareous shale, fusulinids and other fossils are either absent or rare 0.3
Limestone, buff, coarse-grained, fusulinids are abundant 1.8

Hughes Creek limestone member:
Shale, yellow drab shale, contains large fusulinids in great quantities 2.6
Limestone, gray massive, coarse-grained, somewhat sandy, limonite fills voids 1.9
Shale, yellow drab, barren of fossils 0.5
Limestone, gray massive, medium to coarse-grained, contains fusulinids in large numbers. Chert nodules containing fusulinids occur as irregular lenses. Forms the main ledge of the Foraker bench 11.0
Shale, yellow drab, barren of fossils 0.2
Limestone, light gray, massive, coarsely crystalline, upper part is sparsely populated with fusulinids, while lower part is made up almost entirely of fusulinids. Lower part is much softer, weathering back under the upper part..... 1.6
Covered interval, probably gray calcareous shale 5.5
Limestone, gray, sandy and shaly, crinoid stems and fragments of other fossils weather in relief 1.4
Shale, yellow, drab, contains numerous rod-like objects that are probably burrow fillings, barren of other fossils 6.0

Americus limestone member:
Limestone, blue-gray, dense, fine-grained weathering light blue, Fusulinids are common 1.4

IX. Secs. 26 and 35, T. 29 N., R. 7 E. Measured in drainage ditch up the east-facing escarpment that transverses the south central part of sec. 26 and north central part of sec. 35.

FORAKER formation:
Long Creek limestone member:
Gray to yellow, sandy, contains fusulinids

in abundance. Occurs as fragments on grass-covered slope, about 18.0

Hughes Creek limestone member:
Gray, massive, coarse-grained, contains chert nodules, fusulinids are abundant, about 30.0

Americus limestone member:
Gray, fine to coarsely crystalline, abundant fusulinids, poorly exposed 1.5
With the exception of the Americus limestone, measurements for the other members of the formation are estimates. The Foraker limestone as a composite unit was accurately measured 50.0

Covered interval 15.0

Houchen Creek limestone member:
Soft, porous, silty, impure, color is yellow, not measured.

Covered interval 36.4

BROWNVILLE limestone:
Poorly exposed, brown, massive, fine to coarse-grained, slightly arenaceous, fusulinids are common, exposed thickness 1.5

PONY CREEK shale:
Covered interval 36.6
Sandstone, brown, slightly cross-bedded, exposed thickness 2.0
Covered interval 13.2

CRAYHORSE limestone:
Gray, dense, weathering gray with blotches of limonitic-yellow, not measured.

Covered interval, about 15.5

NEBRASKA CITY limestone:
Gray weathering brown, ferruginous, not measured.

Covered interval 11.2

JIM CREEK limestone:
Tan weathering to yellowish brown, fusulinids are present 2.1

FRIEDRICH shale:
Shale, gray, calcareous, contains broken fragments of large pelecypod, probably Myalina 1.0
Coal 0.3
Shale, yellow drab, silty, barren 3.0
Covered interval 11.5

GRANDHAVEN limestone:
Gray, cross-bedded calcarenite 1.9

X. Sec. 16, T. 29 N., R. 7 E., Measured up west side of road-cut in southwest part of section.

FORAKER formation:
Long Creek limestone member:
Limestone, tan, sandy, soft, fusulinids are abundant weathering in relief of the bed 1.0
Shale, gray, calcareous, made up almost entirely of fusulinids 0.2
Limestone, gray, coarsely crystalline and massive. Fusulinids are not so numerous and evident as in upper bed. A few fragments of brachiopods are present. Crinoid plates and stems also are present in small numbers 2.6
HAMLIN SHALE formation:
Oaks shale member:
Gray to brown shale with thin lenses of black, carbonaceous shale, non-fossiliferous . 2.7
Houchen Creek limestone member:
Limestone, fine grained, dense, massive, dark gray, weathering to a dirty gray. Contains a small phosphatic brachiopod 0.6
Shale, black, fissile in lower part, calcareous in upper part 0.6
Limestone, extremely fine grained, pure, dark gray, barren of fossils 0.3
Shale, calcareous, yellow to gray, barren of fossils 1.3
Limestone, massive, pure, dense, dark gray, weathering light gray 0.7
Shale, gray, calcareous, barren 0.5
Limestone, gray, fossiliferous, shaly, contains tiny helicoid gastropods, fragments of brachiopods 1.0
Shale, black, fissile, contains lobate algal forms, also cylindrical objects which are probably burrow fillings 0.6
Limestone, sandy, soft, porous, yellow, limonitic 2.1
Stine shale member:
Covered, probably yellow shale 20.0
FIVE POINT limestone:
Gray to reddish brown weathering dark brown, fine grained, massive to slightly cross-bedded. The top 0.5 feet is a conuinite, crinoid plates and a few fusulinids occur in lower part. Limonite nodules are common .. 2.1
Shale, dark, grayish-blue, platy, barren of fossils, about 5.0
Limestone, soft, impure, porous, yellowish-tan, weathering yellow, contains a thin shale break near the middle, barren of fossils 1.6

Shale, gray, weathering to yellow-drab, barren 2.7
Sandstone, calcareous, interbedded with silty calcareous shale, barren 2.5
Shale, yellow drab 1.5
BROWNVILLE limestone:
Limestone, gray, weathering yellowish-tan. Contains a few small fusulinids, crinoid stems and fragments of other fossils 0.5
Shale, gray, calcareous 0.1
Limestone, reddish-brown weathering brownish-gray, slightly arenaceous. Upper zone of bed has an abundance of large fusulinids; lower zone is sparsely populated with them 3.4
Shale, yellow drab, barren 5.0
Limestone, organic calcarenite, tan weathering gray to brown. Hard, coarse-grained, with thin shale lentils dispersed through it . 1.9
PONY CREEK shale:
Shale, yellow drab, silty to sandy 7.0
Sandstone, gray to tan, weathering buff to brown. Upper part thinly laminated while lower part is cross-bedded and channel-like. Soft and friable in weathering while fresh surface is cemented by calcite and is well indurated. Contains muscovite and biotite ... 4.0
Shale, yellow, silty, micaceous 12.8
GRAYHORSE limestone:
Gray weathering brown. Contains fossil fragments, weathered surface is spotted due to fossil fragments and small limestone pebbles. Weathers to thin slabs, shaly in lower part. Exposed portion is 1.8
Covered interval 14.0
NEBRASKA CITY limestone:
Gray to tan, weathering to buff, coarse-grained, fossils are rare, replaced by aragonite. Strongly ferruginous, poorly exposed 1.0
Covered interval 16.8
JIM CREEK limestone:
Dark gray to tan, weathering buff. Coarse-grained, sandy and shaly in parts. Bryozoan, and crinoid and brachiopod fragments are present as well as fusulinids 1.9

XI. Sec. 31, T. 28 N., R. 8 E. Measured up the south bank of Sand Creek in northwest corner of section to the road running on the township line.

WILLARD-LANGDON shale:
Limestone, gray, weathered brown, with blotches of red, sandy, medium grained, containing

tiny fragments of fossil shells, poorly exposed, about 1.0
Covered interval, about 16.8
Sandstone, massive, even-bedded, fine grained, tan, weathering brown, not measured.
Covered interval 14.0
Sandstone, tan, weathering brown, cross-bedded, fresh surface is covered with limonite stains, also contains mica, fine grained, about 5.0
Shale, gray to green, barren of fossils, about 12.0
Shale, maroon 5.4
Sandstone, gray weathering brown, calcareous on fresh surface 2.0
Covered interval 14.8
Sandstone, tan weathering to brown, ripple-marked, contains imprints of fossil plants ... 2.0
Covered interval 20.0
ELMONT limestone, not measured.

XII. Sec. 24, T. 28 N., R. 7 E. Measured up outlier that lies in the northeast part of section.
JIM CREEK limestone, not measured.
Covered interval, probably gray, sandy shale 28.0
Sandstone, massive, cross-bedded, fine-grained, buff to brown. Upper part is evenly bedded while lower part is cross-bedded and channel-filling. This is only outcrop that shows this channel-filling. Bed thins rapidly north and south of this exposure, about 11.0
Covered interval 21.0
DOVER limestone:
Limestone, gray, weathering brown with blotches of limonitic stains. Tiny fossil fragments give weathered surface a spotted appearance, fusulinids are rare 1.0
Covered interval, probably thin platy sandstone and silty shale 11.2
Limestone, blue-gray, weathering buff with limonitic stains, sandy and slightly cross-bedded, contains fusulinids that are rare 1.8
WILLARD-LANGDON shale:
Shale, greenish-gray, silty, has a few thin streaks of maroon shale 5.0
Limestone, buff, weathering light brown, stained red probably from overlying maroon shale, dirty and shaly, containing numerous fossils, a large pelecypod is the most prevalent, probably Myalina 1.5

Shale, yellow drab with thin sandstone and maroon shale, not measured.

XIII. Sec. 24, T. 28 N., R. 7 E. Measured up east bank of creek that runs through the south central part of section.

JIM CREEK limestone:
Hard, massive, gray weathering yellow. Fusulinids are plentiful. Other fossils are poorly represented 2.0

FRIEDRICH shale:
Shale, gray, fossiliferous 3.0
Coal 0.4
Shale, gray, sandy, calcareous, contains thin bedded calcareous sandstone interbedded with silty shale, barren of fossils 20.4

GRANDHAVEN limestone:
Gray weathering, red to purple, only fossil present is large Myalina. This is a calcarenite 0.5
Water level.

XIV. Sec. 13, T. 28 N., R. 7 E. Measured up eastward facing escarpment in southwestern part of section.

BROWNVILLE limestone, not measured.
Covered interval 36.4
Sandstone, tan weathering brown, evenly bedded, not measured.
Covered interval 14.0

CRAYHORSE limestone:
Gray weathering to light gray, medium grained, massive, somewhat sandy, sparsely fossiliferous, not measured.
Covered interval 14.0
Limestone, gray, weathering yellow, contains limestone and shale pebbles interbedded with clean, pure dense limestone lenses 0.3
Covered interval 5.3

NEBRASKA CITY limestone:
Bluish-gray, weathering light gray, medium to coarse-grained, not measured.
Covered interval 2.0
Limestone, yellow, soft, impure, silty, not measured.
Covered interval 16.6
JIM CREEK limestone, not measured.

XV. Sec. 13, T. 28 N., R. 7 E. Measured up south bank of creek near center of section, about 1/8 mile south of ranch house.

Limestone, white, weathering light gray, sandy, clean, with no fossils, not measured.

Covered interval 11.2
JIM CREEK limestone:
Tan to gray, weathering yellow, fusulinids are common, not measured.
Covered interval, probably sandy shale and thin sandstone 36.4
DOVER limestone:
Limestone, gray, somewhat sandy, weathering brown, fusulinids are common, about 1.0
Covered interval, probably sandy, gray shale with thin-bedded sandstone, about 21.0
Limestone, blue-gray, weathering buff, sandy, massive, with thin shale break near middle. Upon weathering this bed looks like a sandstone, contains a few large well-preserved fossils, mainly Dictyoclostus, near the top a few fusulinids 3.4
WILLARD-LANGDON shale:
Shale, gray to green, weathering gray, silty. Fossils are either rare or absent 15.0
Shale, maroon, barren of fossils 5.4
Limestone, gray, weathering yellowish-brown, contains numerous brachiopod and molluscan fragments, particularly a large pelecypod which is probably Myalina 0.7
Water level.

XVI. Sections 35 and 36, T. 28 N., R. 7 E. Measured up east facing escarpment near the middle of section line which separates the two sections.
GRAYHORSE limestone:
Gray, weathering almost white with irregular blotches of tan. Fossil remains are fragmentary and are mostly of brachiopods and crinoids. Outcrop is poor and not measured.
Covered interval 14.0
Limestone, gray to yellow, weathering lemon yellow, composed of thin alternating beds of calcarenite and pure, almost lithographic, limestone, no fossils . 0.3
Covered interval 5.6
NEBRASKA CITY limestone:
Light gray, weathering buff to brown, appears as a coquinite weathering to slabby fragments on the grass-covered slope, not measured.
Covered interval 8.0
Limestone, sandy, yellow. Usually present as fragments along the grass-covered slopes, not measured.
Covered interval 6.0

JIM CREEK limestone, not measured.
Covered interval 10.0
Sandstone, brown weathering dark brown with red stains, gastropod casts and molds are common, also ripple-marked and contains imprints of plants, not measured.
Covered interval 7.0
GRANDHAVEN limestone:
Dark gray, weathering dirty-buff, Coarsely crystalline with small, rounded pebbles giving it a spotted appearance on weathering. Ferruginous, contains a variety of fossils, brachiopods, crinoids, bryozoans, mollusks and possibly a few fusulinids. Marginifera occur in pockets along the outcrop. Fossils are difficult to recognize due to weathering .. 0.7

XVII. Sec. 26, T. 28 N., R. 7 E. Measured from water level of Sand Creek to top slope in the north central part of section.
BROWNVILLE limestone, not measured.
PONY CREEK shale:
Covered interval, probably sandy shale 28.6
Sandstone, tan, weathering brown, fine grained, limonite spots are dispersed throughout the bed, about 1.5
Covered interval 21.0
GRAYHORSE limestone:
Gray, weathering light gray, medium grained, fossils are fragmental, not measured.
Covered interval 8.8
Limestone, thin weathers yellow, alternating layers of calcarenite and clean dense limestone 0.3
Covered interval 4.0
NEBRASKA CITY limestone:
Gray, weathering brown. Weathered surface is pitted, shaly in parts. At this locality this bed is a micro-coquina 0.7
Covered interval, probably yellow shale 4.0
Limestone, yellow to white, a limestone bed which can be zoned by variation of lithology and color. Upper zone is a yellow calcarenite grading downward into a clean, white, sandy limestone which in turn grades downward into a shaly, silty, impure limestone. This is the only outcrop of this limestone that was found in place 1.5
Shale, yellow, no fossils 4.0
JIM CREEK limestone, not measured.
Water level.

XVIII. Sec. 13, T. 28 N., R. 7 E. Measured up east facing escarpment on south side of road in northeast part of section.

FORAKER formation:
Hughes Creek limestone, not measured.
Covered interval 8.4
Americus limestone, not measured.
HAMLIN shale formation:
Covered interval, about 7.0
Houchen Creek limestone:
Yellow, soft, porous, impure, barren of fossils 1.5
BROWNVILLE limestone:
Limestone, tan to gray weathering dark brown, fusulinids are plentiful, forms a prominent bench, not measured.
Shale, gray, not measured.
Limestone, yellowish-brown, sandy weathering to thin slabs, coquinoid, bed is made up almost entirely of fragments of Myalina, not measured.
PONY CREEK shale:
Shale, yellow sandy, barren of fossils 7.0
Coal 0.4
Shale, yellow, sandy, thin beds of sandstone 25.2
Sandstone, brown, fresh surface filled with tiny limonite spots 1.0
Shale, yellow, sandy 8.4
GRAYHORSE limestone:
Blue-gray, weathering to light gray, slightly sandy, fragments of fossils are plentiful, medium to coarse grained, partially exposed .. 1.3
Shale, yellow, fossils are rare or absent 4.0
Limestone, yellow, sandy, crumbly, not measured.
Covered interval 8.0
NEBRASKA CITY limestone:
Appears as fragments along the grass-covered slope, gray with streaks of tan, weathering gray, not measured.
Covered interval 14.0
JIM CREEK limestone:
Gray, weathering gray with blotches of yellow and purple, fusulinids are plentiful, brachiopods and crinoid stems are present but in lesser numbers 2.5
FRIEDRICH shale:
Shale, gray covered by soil about 4.0
Coal 0.5
Shale, gray, weathering yellow in lower part, sand and silty 7.0

Covered interval 22.3
DOVER limestone:
Dark gray to blue-gray, weathering brown. Dictyoclostus is found sparingly through the bed; a few fusulinids are found near the top of the bed. Weathers to slabby fragments, sandy, slightly cross-bedded in places, not completely exposed 2.8

XIX. Sec. 26, T. 28 N., R. 7 E. Measured about 1/10 mile north of road running east from the village of Foraker in the southeast corner of section.

Shale, gray, weathering yellow, barren of fossils, not measured.
Limestone, yellow, sandy, appears only as rounded boulders on slope, not measured.
Shale, yellow 6.0
JIM CREEK limestone:
Tan to gray weathering brownish-yellow, massive, top weathers to small, slabby fragments. Contains fossils in abundance, Composita, Marginifera, Dictyoclostus, Chonetes, fusulinids and crinoids. Limonite nodules are present on lower surface 2.8
FRIEDRICH shale:
Shale, gray, calcareous, fossiliferous; Chonetes, Composita and other brachiopods occur in this shale 2.0
Coal 0.5
Shale, gray, not measured.
Water level.

XX. Sec. 25, T. 28 N., R. 7 E. Measured at road-cut on north side of road in the extreme southwest corner of section.

Shale, not measured.
NEBRASKA CITY limestone:
Gray to brown, calcarenite, interbedded with calcareous shale. Pebbles are rounded to sub-angular. They are predominately limestone pebbles with some shale pebbles. Top member is thickest and is a coquinite in upper part 3.5
Shale, gray, sparsely fossiliferous 4.0
Covered interval, probably gray shale containing limestone concretions 7.2
JIM CREEK limestone, not measured.
Covered interval 16.8
GRANDHAVEN limestone:
Gray weathering brown, spotted, red stains

are common, a large pelecypod, probably Myalina, is present 0.8

XXI. Sec. 13, T. 29 N., R. 6 E. Measured up creek starting in Kansas and ending in northeast corner of section near junction of state line and township line which separates R. 6 and R. 7 of Oklahoma.

RED EAGLE formation, not measured.

JOHNSON shale:

Shale, yellow drab, barren 10.0
Shale, maroon 1.5
Shale, gray, weathering yellow 3.6
Limestone, soft, cream-colored, impure, marly 2.6
Shale, tan weathering yellow, sandy, contains thin, sandy limestone 7.0
Shale, greenish-gray 1.5
Limestone, gray, soft, fine grained, weathers to irregular fragments, fossiliferous. Fossils have been replaced by dark coarsely crystalline calcite 3.5
Shale, interbedded with thin limestones, fusulinids are present 5.5

FORAKER formation, not measured.

XXII. Sec. 13, T. 29 N., R. 6 E. Measured up west bank of creek on Oklahoma-Kansas Line in northeast part of section.

RED EAGLE formation:

Howe limestone member:

Gray to tan, weathering nearly white. Top bed is buff to yellow, slightly arenaceous. Outcrop is poor, appearing as thin weathered slabs.

Bennett limestone member:

Limestone, light gray weathering to darker gray, forms the main ledge of the Red Eagle outcrop. Finely crystalline calcite is typical of upper part of this bed; limonite and finely crystalline calcite fill the void spaces 6.5
Limestone, gray weathering to buff, soft, weathering under overlying resistant beds, fossiliferous 1.5
Limestone, gray weathering somewhat darker gray, fine to coarse secondary calcite is typical of this bed. Also limonite and limonite stains, thin bedded 4.0

XXIII. Sec. 14, T. 29 N., R. 6 E. Measured up escarpment on Kansas-Oklahoma Line in northeast corner of section.

GRENOLA formation:

Neva limestone member, not measured.

Salem Point shale member, covered, probably shale 13.0

Burr limestone member:

Covered, thin fossiliferous limestone fragments are strewn along the grass-covered slope, probably interbedded shale and limestone 5.6

Limestone, gray, weathering white, massive, coarse grained, fossiliferous 3.5

Legion shale member:

Interbedded series of thin limestone and shale 4.0

Sallyards limestone member:

Gray, weathering gray to buff, fossiliferous in lower part, sandy, grading upward into calcareous siltstone 3.0

ROCA shale:

Shale, gray, weathering buff, barren 6.0

Shale, maroon, barren 11.5

XXIV. Sec. 28, T. 28 N., R. 6 E. Measured along the west bank of Salt Creek in the west central part of the section.

GRENOLA formation:

Neva limestone member:

Limestone, gray, massive, coarsely crystalline, weathers gray to white. Weathered surface rough and jagged, few fossils 5.9

Chert and thin dolomitic limestone 2.5

Shale, yellow to cream colored, fossiliferous 0.5

Limestone and shale, gray, fine grained, dense, has clear calcite stringers running through it, shales are calcareous, fossiliferous and yellowish-tan. Near the middle is a shale zone that contains Pseudoschwagerina 9.5

Limestone and shale. Limestones are coarse grained and gray in color 2.2

Limestone, gray massive, coarse grained 2.0

Limestone and shale. Limestones are shaly, coarse-grained and blue 1.5

Limestone, gray, massive, somewhat dolomitic. Limonite fills void in this bed 4.5

XXV. Sec. 29, T. 29 N., R. 6 E. Measured up the north facing slope which is about 1/8 mile east of northwest corner of section.

BEATTIE formation:
Cottonwood limestone member, not measured.

ESKRIDGE shale:
Shale, gray weathering buff to yellow, fossiliferous, calcareous, few thin fossiliferous limestones 16.8
Sandstone, cross-bedded, gray, calcareous, not measured.
Shale, maroon, barren 16.8
Sandstone, greenish-gray, fine grained, not measured.
Shale, yellow drab 11.2
Shale, maroon, barren 22.4

GRENOLA formation:
Neva limestone member, not measured.

XXVI. Sec. 17, T. 29 N., R. 6 E. Measured along south bank of drainage ditch near the center of section.

BEATTIE formation:
Cottonwood limestone member:
Limestone, gray, weathering chalky-white. Surface weathers smooth with small cylindrical holes, fusulinids are present, about 1.0
Limestone, gray to tan, surface weathers rough. Contains thin stringers of maroon and yellow shale 1.5

ESKRIDGE shale:
Shale, maroon in lower part, grading upward into drab-gray calcareous shale. Fossiliferous in upper part. Calcareous rod-like objects, which are probably animal burrows, are common in upper part 20.4
Limestone, calcirudite, made up almost entirely of rounded limestone pebbles. Weathers brown. Fragments of a large specimen of Myalina most characteristic fossil 0.5
Shale, maroon, with thin sandstones which are greenish-gray, not measured.

XXVII. Sec. 13, T. 29 N., R. 5 E. Measured up the west bank of creek in north central part of section.

CROUSE limestone:
Limestone, white spotted brown, weathering to gray, massive, fine grained. Vertical cylindrical holes are typical of this bed. A few fossil fragments occur in upper part ... 2.3

Limestone, shaly, fossiliferous, gray, soft, weathering under overlying resistant bed 4.0

EASLY CREEK shale:
Shale, maroon, barren 3.0
Sandstone, maroon, fine grained, evenly bedded 0.4
Shale, partially exposed probably gray shale 5.6
Sandstone, buff color, cross-bedded 0.4
Shale, gray 4.5

BADER formation:
Middleburg limestone member:
Greenish-gray, weathering gray, fine grained with coarsely crystalline calcite and limonite filling void 1.2
Hooser shale member:
Light gray 3.0
Eiss limestone member:
Gray, weathering gray; has fossil fragments .. 0.7

STEARNS shale:
Covered interval with thin, gray slabs of limestone strewn on the slope; probably interbedded shale and limestone 11.2

BEATTIE formation:
Morrill limestone member:
Gray weathering gray with streaks of pink. Fresh surface is gray, fine to medium grained with streaks of maroon shale 1.5
Florena shale member:
Interbedded series of calcarenites and shale. Color is greenish-gray near the bottom, maroon calcareous shale at top 6.0
Shale, dark, brownish-maroon 21.0
Cottonwood limestone member, not measured.

XXVIII. Sec. 23, T. 29 N., R. 5 E. Measured up the southwest side of the Wreford outlier in the southwest part of the section. This traverse started below and on the southwest side of the railroad cut.

WREFORD formation, not measured.

SPEISER shale:
Covered interval, probably shale 22.5
Sandstone, very fine grained, massive, not well indurated, tan. Soft, forming smooth, rounded shoulder on the slope, exposed thickness 7.0
Covered interval, probably shale 9.0

FUNSTON limestone:
Limestone, gray, fossiliferous, exposed thickness 0.3

Covered interval 2.0
Limestone, gray, massive 1.0
BLUE RAPIDS shale, covered interval 15.0
CROUSE limestone, not measured.

XXIX. Sec. 29, T. 29 N., R. 5 E. Measured along road-cut approximately 3/4 mile southeast of Hardy in Kay County, Oklahoma.

WREFORD limestone:
Alternating beds of thin, gray to white limestones and shale. Forms grass-covered slope 8.0
Limestone, gray, massive, with thin stringers of yellow shale. Fossils are siliceous and weather in relief to the bed 1.5
Shale and shaly limestone 1.7
Limestone, gray to white weathering buff. Breaks up into thin slabs upon weathering. Fossils are siliceous, weathering in relief to the bed 2.0
Shale, buff, non-fossiliferous 0.2
Limestone, light tan, weathering buff, finely crystalline, fossiliferous and chert bearing 5.3
Shale, yellow. Composita subtilita characterizes this shale 2.3
Limestone, buff to gray, fine-grained, fossils are siliceous and are mainly fragmental 3.0
Shale, calcareous, tan. Fossils are rare or absent 0.2
Limestone, buff, massive, fossiliferous 2.3

SPEISER shale:
Shale, gray, barren of fossils 3.0
Shale, maroon, barren of fossils, exposed 1.5
Covered.

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