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# GEOLOGY OF THE BURBANK-SHIDLER AREA, OSAGE COUNTY, OKLAHOMA

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DAVID LEE VOSBURG

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# GEOLOGY OF THE BURBANK-SHIDLER AREA, OSAGE COUNTY, OKLAHOMA

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BY

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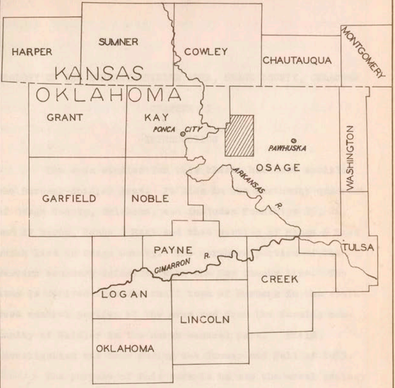


LOCATION MAP
OF
BURBANK-SHIDLER AREA

FIGURE 1

# GEOLOGY OF THE BURBANK-SHIDLER AREA, OSAGE COUNTY, OKLAHOMA

## CHAPTER I

## INTRODUCTION

The area studied for this thesis has been entitled the Burbank-Shidler Area. It lies in the northwest quadrant of Osage County, Oklahoma, and includes Townships 25, 26, and 27 North, Range 6 East and that portion of Range 5 East which lies in Osage County. The northern portion of the western boundary coincides with the Kay County line. The name is derived from the small town of Burbank in the southwest central portion of the area and from the farming community of Shidler in the north central part. Field investigation was done during the Summer and Fall of 1953.

The purpose of this work is to map the areal geology and to make a detailed investigation of the lithology of the outcropping units which are found within the area. Special attention was given to the facies changes found along the strike of the various lithologic units from north to south. Outcropping units within the area consist primarily of rocks of the Wolfcamp Series (Lower Permian). The only exceptions are the rocks of the extreme southeast corner of the area in sections 25, 35, and 36, Township 25 North, Range 6 East. Here are found rocks near the top of the Upper Virgil Series (Upper Pennsylvanian).

The outstanding topographic feature of the area is the comparatively steep east-facing escarpment which, in general, parallels the eastern border. This escarpment is supported by the lower members of the Foraker limestone. A less prominent group of east-facing escarpments occurs along the western edge of the area, namely those supported by the Neva limestone in the north, the Cottonwood limestone in the central portion, and the Crouse limestone in the southern portion along the western edge of Range 5 East. The central portion of the area consists of a series of low, broad cuestas with gentle east-facing slopes which are nearly all well covered with grass. These cuestas, while not always apparent from the ground, can be followed readily by means of aerial photographs. This is partly due to the slight relief, but mainly because of ecological factors which cause distinct banding in the vegetation. The controlling factor in the formation of the present topography is the lithology. It is composed, almost without exception, of limestones alternating with shales.

The strike of the formations is somewhat difficult to determine in the field. This is due to the broad outcrop of individual units, which may extend over several miles as a complex of noses and re-entrants perpendicular to the general strike. The dip likewise is not easily measured by field methods normally employed in work of this nature. Both strike and dip are further complicated by the presence of several slight reversals of dip with a maximum closure of 20 feet. These small structures, together with several broad open folds were mapped by K. C. Heald[1] and C. F. Bowen[2,3]. The strike of the formations in the area is approximately North 20° East, as determined from aerial photographs. The dip ranges from 30 to 50 feet per mile. This figure was determined by application of the three point method, using elevations from the United States Geological Survey topographic maps which cover the area and which have a contour interval of 20 feet.

The Burbank-Shidler area is the extreme southern extension of the Flint Hills of Kansas as they die out toward the Arkansas River in the south. In Cowley County, Kansas, the Wreford limestone forms the principal rim of these hills, while farther south into Oklahoma, the Foraker limestone forms the main escarpment. In this area, even the Foraker

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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]C. F. Bowen, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma; Tps. 24, 25, and 26 N., R. 4 E." United States Geological Survey, Bulletin 686-L, 1916.

[3]C. F. Bowen, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma; Tps. 21-23 N., Rs. 6-7 E., and Tps. 23-25 N., Rs. 3-5 E." United States Geological Survey, Bulletin 686-U, 1916.

limestone begins to lose its identity as part of the Flint Hills, although it is still the most prominent feature in the area.

Salt Creek is the largest and most important stream of the region. It flows into the Burbank-Shidler area from the north in the middle of R. 6 E., and flows in a southerly course into T. 26 N. Here the stream meanders into R. 5 E. and turns south, where it generally parallels the range line until it leaves the area and empties into the Arkansas River farther south.

Almost the entire area is within the drainage basin of Salt Creek. The exceptions are along the extreme western edge where a few minor tributaries leave the area toward the southwest and flow into the Arkansas River in the northern part and into tributaries of Doga Creek farther south in R. 4 E. All of the streams of the area are intermittent with the exception of Salt Creek, which continued a slight flow during the dry spring of 1953. Tributaries of Salt Creek are of minor importance. They are not normally impassable, due to flow, except during wet seasons, but offer, in some instances, topographic difficulties to travel by automobile. These intermittent tributaries have not cut deep enough to expose bed rock, thin channels being grass covered or choked with sand and rubble. Salt Creek itself has cut deep enough to provide excellent exposures, but vegetation is thick and rank, making examination difficult.

Stratigraphic intervals were measured by Brunton compass and hand level, along with a steel tape. The dip was disregarded as being impractical to consider except where the measured section covered a horizontal distance of at least one mile. There, estimates were made using the United States Geological Survey topographic maps and wherever applicable, Plate II, Bulletin 641-B, United States Geological Survey, a topographic map of the Foraker Quadrangle with an overprint of structure contours on the top of the Foraker limestone, by K. C. Heald. In certain places, where the information was available, estimates of stratigraphic interval were made using elevations obtained from ground level elevations of oil wells in the vicinity.

Previous work done in the area is limited and incomplete. In the Fall of 1915, K. C. Heald[4] and others worked in the area and mapped a few key beds in order to recommend drilling locations. He described the Foraker limestone as being 74 feet thick and this thickness probably included the Brownville limestone.[5] The Brownville limestone is now considered to be the upper member of the Virgil Series of the Pennsylvanian System. The top of the Brownville limestone is thus the boundary which has been drawn in this region be-

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[4]K. C. Heald, <u>op. cit.</u>, p. 17.

[5]R. C. Taylor, "Geology of the Foraker Area, Northwestern Osage County, Oklahoma," Master's Thesis, University of Oklahoma, 1953, p. 6.

tween the Pennsylvanian and the Permian systems.[6]

The Foraker limestone is described by R. C. Moore as approximately 50 feet thick a few miles to the north in southern Kansas.[7] By using the Foraker limestone and the Neva limestone as key beds, Heald mapped numerous small anticlines, several of which are in the area under discussion. Heald also carried subsurface correlations as close to the area as was possible at that time and recommended the drilling of several of these closures in the northern part of the Foraker Quadrangle. To date there have been few producing wells in the Foraker Quadrangle. At the present writing there is limited production in the southern part of the Foraker Quadrangle, which is included in the area covered by this work. There has been nothing of importance to justify Heald's confidence, although there are still large tracts which have not received extensive exploration. South of the area mapped by Heald there have been developed some of the most prolific oil fields in the state of Oklahoma, namely the Burbank fields.

Field investigations in the Osage Reservation were conducted with the cooperation of the office of Indian Affairs and the commissioner for the Osage Indians as part of the overall report on the Osage Reservation, in the interest of

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[6] R. C. Moore, et al., "The Kansas Rock Column," Kansas Geological Survey, Bulletin 89, 1951, p. 56, fig. 21.

[7] R. C. Moore, ibid., p. 48.

national oil resources during World War I.[8] Included in this report is work done by C. F. Bowen[9] in which he outlined the stratigraphy and listed those key beds used in the structural mapping of several anticlines.

H. T. Beckwith, at the request of the Oklahoma Geological Survey, prepared a geological report on the subsurface geology of Osage County.[10] It was to be included with others of a similar nature on other counties in a report covering the state of Oklahoma. Primarily concerned with application to the oil industry, Beckwith included a brief resumé of the activity and history of the geological development in the county, along with a summation of the stratigraphy. Also included is a geologic map of the mappable beds on surface, which is the best available picture of the geology of Osage County to be found in published form.

Robert Clark Taylor[11] has recently completed a Master's thesis with a purpose similar to that of this work. Taylor's report covers the area immediately north to the Kansas State line. He presents a detailed geologic map which

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[8] David White, et al., "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma, United States Geological Survey, Bulletin 686, 1922.

[9] C. F. Bowen, op. cit.

[10] H. T. Beckwith, "Geology of Osage County," Oklahoma Geological Survey, Bulletin 40-T, 1928.

[11] R. C. Taylor, op. cit.

supersedes that published with Beckwith's report in the small area it covers. In his thesis Taylor presents a detailed stratigraphic column along with accurate lithologic descriptions, which he correlates with the work published in Kansas covering Cowley County. This is the only recent work done in this portion of Osage County, although several Master's theses are underway at the University of Oklahoma covering other portions of Osage County. This work is being done for the purpose of assembling data for the publication of a detailed work under the sponsorship of the Oklahoma Geological Survey.

## CHAPTER II

## STRATIGRAPHY AND LITHOLOGY

### PENNSYLVANIAN SYSTEM

#### Virgil Series

The Virgil series is the uppermost of the six divisions of the Pennsylvanian system. The interval includes those beds between the unconformity at the base of the Wolfcampian series (lower Permian), and a similar unconformity at the top of the Missourian series (upper Pennsylvanian). The lower unconformity is located at the base of the Chesha-walla sandstone, while the upper is found at the base of the channel-type Indian Cave sandstone. The Pennsylvanian-Permian boundary is considered to be the base of this channel sandstone at those localities where it can be identified. Since identification of this bed is difficult, and since it is comparatively sporadic in its occurrence and exposure, the boundary is placed at the first depositional break to be found above the Brownville limestone. In some instances this bed may also be difficult to recognize. In this case the Pennsylvanian-Permian boundary is placed at the first depositional break below which no fusulinids of the genus Pseudoschwagerina are found.

The Virgilian series is composed of three groups: Wabaunsee, Shawnee, and Douglas, in descending order. Only the upper beds of the Wabaunsee are present in the area under consideration. The Wabaunsee group is further divided into the Richardson, Nemaha, and Sacfox subgroups. Only the Richardson subgroup, which comprises beds from the top of the Elmont limestone to the Pennsylvanian-Permian boundary, includes beds which crop out in the area of this problem.

The stratigraphic units of the Pennsylvanian system which crop out in this area are confined to the extreme southeast corner in secs. 25, 35, and 36, T. 25 N., R. 6 E. The correct identification of these units is extremely difficult due to the character of the topography. A gradual rise builds slowly up to the prominent bluffs of the Foraker limestone in the west. The slope here is heavily sodded with native prairie grasses and is broken by a railway fill. The only exposures are along the rather level road which rings sec. 36, and those which are found in shallow pasture gullies which have been interrupted by the railway fill and forced into relatively new channels. Higher on the slope the best measurable exposures are in the paths worn through the sod by cattle. The units in this interval are well described in Kansas and Nebraska as a series of thin limestones and shales with only a few minor sands. The beds are reported as persistent from Nebraska across Kansas and into Oklahoma, with the sandstone becoming more prominent toward the south and progressively more important, grading downward stratigraphically into middle Pennsylvanian. In Kansas there is clear indication of cyclical sedimentation in the Wabaunsee group, but the record becomes clouded toward the south. In this area the character of the units indicates considerable fluctuation of the sea at fairly short intervals as shown in the very thin beds of one lithologic type adjacent to thin beds of other lithologic types. Positive evidence of cyclical sedimentation is lacking, however, due to the paucity of exposures and to missing units of the ideal cycle. There is slight indication that some of the units are of deltaic origin. This is evidenced by the abrupt and laterally short facies changes observed at one exposure in sec. 25, T. 25 N., R. 6 E.

Wabaunsee Group

In 1895 C. S. Prosser[12] named and described the interval from the base of the Cottonwood limestone to the top of the Osage coal as the Wabaunsee group. R. C. Moore[13] in 1932 restricted the name to beds between the top of the Admire shale and the base of the Severy shale, which he indicated to be about 500 feet thick. After consultation with geologists

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

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

of the United States Geological Survey, the State Geological Surveys of Kansas and Nebraska, and prominent stratigraphers, the boundary between the Pennsylvanian system and the Permian system was lowered to the top of the Brownville limestone by Moore (see figure 2). This revision was accepted by Condra[14], and in 1935 he again changed the boundaries of the Wabaunsee group and restricted it to those beds below the Pennsylvanian-Permian boundary and above the Topeka formation. Following this, in 1936, Moore[15] reaffirmed his stand on the Pennsylvanian-Permian boundary and concurred with Condra on the revision of the Wabaunsee group. Since that time the prolific writing of Moore and his associates has resulted in the acceptance of this classification to the present time.

The Wabaunsee, as mentioned, is broken into three subgroups, primarily on the basis of lithologic difference and topographic expression caused by varying resistance to erosion. Of these we need to consider only the upper, or Richardson, subgroup, named by Condra in 1935 from Richardson County, Nebraska. The Richardson subgroup includes beds from the top of the Brownville limestone down to the top of the Tarkio limestone in Kansas and Nebraska. The Tarkio limestone is

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

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

recognized as such only as far south as Lyon County, Kansas, leaving the lower boundary in question. R. C. Taylor[16] in working immediately to the north suggests that the top of the Elmont limestone be used in Oklahoma on a similar lithologic basis as the Tarkio is used to the north. For the purpose of uniformity this designation will be followed here.

Jim Creek limestone: The Jim Creek limestone is the lowest identifiable bed in the stratigraphic sequence which crops out in the area being examined. Those beds within the interval between the Jim Creek and the base of the Americus limestone are exposed only in the three sections previously mentioned. These are in the southeast corner of the area. The outcroppings here are poor and identification is not conclusive since there are no readily accessible exposures which have been definitely correlated so that they might be used for lithologic comparison. The beds, while definitely Pennsylvanian in age, are nevertheless comparable to those of the Permian just above. They appear to have been deposited in a similar environment and from a similar source. The Jim Creek is a bluish-gray, fine-grained, compact limestone, up to 2 feet in thickness as described in Kansas,[17] where it is of formation rank.

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[16] R. C. Taylor, op. cit., p. 11.

[17] R. C. Moore, J. C. Frye, J. M. Jewett, Wallace Lee, and H. G. O'Conner, "The Kansas Rock Column," University of Kansas Publication, State Geological Survey of Kansas, Bull. 89, 1951, p. 58.

The exposures in this area are not complete, consisting of fragmentary outcrops at several places in the road which borders section 36, T. 25 N., R. 6 E. The thickness is estimated to be less than two feet. The limestone is light bluish to gray, medium to fine grained, and dense, being difficult to break with a hammer. No recognizable fossils were present, but fragments of crinoids were noted, and upon good exposure others could undoubtedly be found. No fusulinids were observed, although these are reported in Kansas and in the Foraker area by R. C. Taylor.

French Creek Shale: The lithology of the French Creek shale was not seen in the area. To the north R. C. Taylor[18] records it as a gray calcareous shale with some limestone concretions and a sandy zone of pure to dirty yellow calcareous sandstone. Coal beds are reported from Kansas but none has been accounted for in this area of Oklahoma.

In sec. 36, T. 25 N., R. 6 E., the French Creek shale is represented by a grass covered slope which is unbroken by the Nebraska City limestone, but continues to the Grayhorse limestone. The slope is underlain by beds twenty-seven feet in thickness, of which the lower ten to twenty feet will be considered here as French Creek shale.

Nebraska City Limestone: The name Nebraska City

[18] R. C. Taylor, op. cit., p. 27.

limestone was introduced by Condra[19] in 1927, after Nebraska City, Nebraska. R. C. Moore[20], in describing the bed in Kansas says, "Gray, impure, soft limestone; contains bryozoans, brachiopods, algae, and sparse mollusks. Thickness ranges from about one foot to five feet."

The Nebraska City limestone does not actually crop out in the Burbank-Shidler area. Since the bed is one which is soft and easily weathered, it is not surprising that it is not well exposed in the grass covered area described. Because there are no roads or active streams in the expected locality of outcrop, there is little chance of finding a natural exposure in this area.

The shale interval between the Nebraska City limestone and the Grayhorse limestone is also part of the same covered interval. No name has been assigned to these beds either in Nebraska, Kansas or Oklahoma. The beds themselves are not prominent either lithologically or topographically in the area under study, and a name given here would be superfluous since no description can be presented for this area.

Grayhorse Limestone: The Grayhorse limestone was named from exposures on the crest of Little Grayhorse anti-

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[19] G. E. Condra, "The Stratigraphy of the Pennsylvanian System in Nebraska," Nebraska Geological Survey, Bulletin I, Second Series, 1927, p. 116.

[20] R. C. Moore, op. cit., p. 58. (footnote no. 15)

cline, in the N.W.¼ sec. 11, T. 24 N., R. 6 E., Osage County, Oklahoma, by C. F. Bowen[21] in 1918. Its presence was reported by K. C. Heald[22] prior to the publication of the work by Bowen.

In the Burbank-Shidler area only the upper bed of the Grayhorse is exposed. It is a grayish-brown, crystalline, somewhat cherty limestone. Some unidentified fossils are present, including a species of Myalina.

The Grayhorse would provide an excellent marker in the field were it not for the fact that it is located below, and in close proximity to, the thick, massive limestone beds of the Foraker limestone. The Grayhorse limestone is immediately overlain by a thin bed of sandstone with a light greenish-brown to gray color. It is fine grained and is tightly cemented, probably with calcium carbonate. The sandstone contains an appreciable amount of some dark mineral, presumably magnetite, which occurs within the sandstone as thin layers only one grain thick. This lamination gives the impression of extreme sorting and perfect bedding in a quiet environment.

Pony Creek Shale: G. E. Condra[23] reports the thick-

[21] C. F. Bowen, op. cit., p. 13.

[22] K. C. Heald, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma: T. 27 N., R. 7 E.," United States Geological Survey, Bulletin 686-K, 1918, p. 130.

[23] G. E. Condra, op. cit., p. 34.

ness of the Pony Creek shale in southern Kansas near the Oklahoma line to be about forty-two feet. Near the southern limits of T. 28 N., R. C. Taylor[24] reports the thickness of the Pony Creek shale as approximately fifty-one feet. If the rate of thickening is assumed to be constant, and the formation is projected southward to the southeast corner of T. 25 N., R. 6 E., the thickness would be approximately sixty feet. The heavy matting of grasses in the Burbank-Shidler area make a more accurate measurement impractical.

The lithology of the Pony Creek shale is reported in the Foraker area to be yellow sandy shale with a sandstone near the middle of the lower part and a coal near the top. R. C. Taylor[25] records the sandstone as being a channel-filling deposit of buff to dark brown color, becoming inconspicuous in the southern part of the Foraker area. Taylor also indicates that the coal bed is not found south of sec. 13, T. 28 N., R. 7 E., in the Foraker area.

Brownville Limestone: The Brownville limestone crops out in an identifiable exposure on the west side of the railway fill in the S.E.$\frac{1}{4}$, sec. 35, T. 25 N., R. 6 E. The formation has a total thickness of 2.8 feet. It consists of three thin limestone beds separated by shales. The upper limestone is a buff yellow bed which is pitted due to weathering. It is highly fossiliferous, with brachiopods, fusulinids,

[24] R. C. Taylor, op. cit., p. 35.

[25] R. C. Taylor, ibid., p. 35.

bryozoans, pelecypods, and fragmental debris. The appearance is dark gray on fresh broken surface. It is finely crystalline with some replacement by calcite which reflects light from cleavage faces and is very noticeable. There is some occurrence of the ferruginous minerals as evidenced by the weathered color. Beneath the upper limestone, which is 0.6 foot thick, there is 0.7 foot of shale of buff yellow that is soft and irregularly bedded. The middle limestone is 0.9 foot thick, dense, sandy textured, and weathers to a buff yellow. On fresh broken exposure it is a medium gray to gray-blue, highly calcitic, with some calcite fossil replacement, making identification of fossils difficult. Large brachiopods and numerous crinoid fragments were noted.

A 0.3 foot shale, which is gray, soft and somewhat limey, separates the middle limestone from the basal bed. The lowest limestone is 0.5 foot thick, dense and massive. The weathered surface is a light, dirty gray and pitted. The bed weathers to large rhombohedral blocks which remain approximately in place in this particular locality because the slope is gentle. Gravity here has little effect since the Brownville limestone does not form any traceable bench.

Immediately below the basal limestone is a thin, gray to white, pasty underclay. There is 0.3 foot of gray calcareous shale exposed below this clay.

The Brownville limestone was originally named and described from exposures in the Missouri bluffs south of

Brownville, Nemaha County, Nebraska, by G. E. Condra and N. A. Bengston[26] in 1915. The Brownville limestone is considered to be the upper unit of the Pennsylvanian system in Nebraska, Kansas, and northern Oklahoma. It is the uppermost formation of the Wabaunsee group and, at a few localities, occurs almost immediately below the channel type Indian Cave sandstone or its equivalent.

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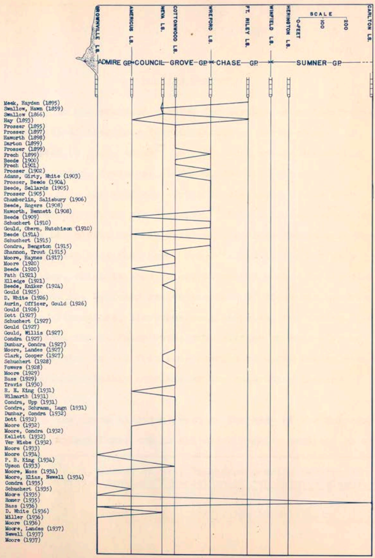
[26] G. E. Condra and N. A. Bengston, "The Pennsylvanian Formations of Southeastern Nebraska," Nebraska Academy of Science Publication, Vol. 9, 1915, p. 17.




PENNSYLVANIAN PERMIAN CONTACTS

Modified from: R.C. Moore, "Carboniferous Permian Boundary", American Association of Petroleum Geologist, vol. 24, pt. I, no. 2, p. 300, 1940.

PERMIAN SYSTEM

In the standard section for North America the Permian system is divided into four divisions of series rank. As advocated by J. E. Adams[27] in 1939, they are in descending order: Ochoa, Guadalupe, Leonard, and Wolfcamp.

Only the Wolfcamp series is displayed in the area under study. J. E. Adams states,[28] "The Wolfcamp series includes the oldest Permian rocks of the Glass Mountain region. It comprises beds that have been referred to the Wolfcamp formation, which is thus raised to series rank. In the Glass Mountains the Wolfcamp series consists of about six hundred feet of limestones, limestone conglomerates, and shales. In West Texas the Wolfcamp rests with angular unconformity on rocks ranging in age from pre-Cambrian to upper Pennsylvanian and is unconformably overlain by the succeeding Leonard series."

The great hiatus present at the base of the Wolfcamp series in West Texas and in all major Permian sections on all

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[27] J. E. Adams, et al., "Standard Permian Section of North America," American Association of Petroleum Geologists, Bull., Vol 23, No. 11, 1939, pp. 1673-1674.

[28] J. E. Adams, et al., ibid., pp. 1673-1674.

continents of the world except Australia, may be partly filled in regions removed from the Marathon disturbance by beds older than the type Wolfcamp of North America. In that event it has been recommended by an American Association of Petroleum Geologists subcommittee[29] that the base of the Wolfcamp series be drawn at the first important hiatus below strata characterized by the following genera: Schwagerina s. s., Pseudoschwagerina, Paraschwagerina, the ammonoid genus Properrinites, the brachiopod genus Parakeyerlingina, and other distinctive Permian genera. The pronounced angular unconformity found in West Texas, decreases toward the north and east. This same subcommittee also recommended that: "The pronounced disconformity or hiatus which in nearly every known American section separates Permian from overlying Triassic or younger strata, should be recognized as the upper boundary of the Permian system."

The Wolfcamp series in the northern mid-continent region ranges in Oklahoma from the top of the Brownville limestone to the top of the Stillwater formation. In Kansas the Wolfcamp series falls in the section from the top of the Brownville limestone to the top of the Herington limestone in the Chase group.[30] Although these are the recognized

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[29] C. W. Tomlinson, Chairman, Subcommittee on the Permian, "Classification of Permian Rocks," American Association of Petroleum Geologists, Bulletin, Vol. 24, 1940, p. 337.

[30] R. H. Dott, "Regional Stratigraphy of Mid-Continent Area," American Association of Petroleum Geologists, Bulletin, Vol. 25, 1941, part II.

boundaries, the boundary between the Permian and Pennsylvanian systems in the northern mid-continent region has never been unalterably established. The major elements of the dilemma are the apparent conformity of the strata embracing parts of both systems, the difficulty in correlating with rocks of the same age in areas of greater mobility, and the generally equivocal nature of the faunal assemblages. The apparent trend in fixing the Pennsylvanian-Permian boundary has been generally downward since the early workers placed it at the top of the Fort Riley limestone in 1859.

Further adding to the complexity of the question of where to draw the Pennsylvanian-Permian boundary, Dunbar[31] in 1940, and others at various times, have discussed the probable fact that the type section of the Permian in Russia, as described by Murchison, does not include the zone of Pseudoschwagerina. If it does not, the problem arises as to whether the standard section for North America should be re-defined to conform to the standard in Russia, or whether geologists in North America and other parts of the world should continue with the present classification in the hope that a revision will take place in Russia. A revision has been advocated by some prominent Russian scholars. At present an agreement has been reached whereby the North American

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[31] Carl O. Dunbar, "The Type Permian, Its Classification and Correlation," American Association Petroleum Geologists Bulletin, Vol. 24, part I, No. 2, p. 270, 1940.

section remains as it is, but the original problem of proper correlation with the type section of Russia still remains.

In the Burbank-Shidler area the most logical lithologic break between the Pennsylvanian and the Permian systems is at the base of the Americus limestone. This break falls within the zone of Pseudoschwagerina. If the break is made on the basis of faunal studies then the accepted boundary at the top of the Brownville limestone, seems the most practical. Correlation would then, of necessity, be on the basis of paleontologic zoning, since the Brownville limestone is not a good marker bed.

## Wolfcamp Series

The Wolfcamp series in the Burbank-Shidler area is divided into three groups. In descending order they are Chase, Council Grove, and Admire. The Wolfcamp series was formerly called the Big Blue series of Kansas. It was named for the area of the Big Blue Valleys of Kansas and Nebraska by Condra and Upp. This same approximate interval was known as the Wanette in Oklahoma.

### Admire Group

G. I. Adams[32], in 1903, proposed the name Admire shale member. In Adams' description this included the predominantly

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

shale interval from the Emporia (Stonebreaker) limestone to the Americus limestone. Adams assigned a thickness of 40 feet to the Admire shale member. This measurement was taken from exposures near Admire in northern Lyon County, Kansas. Adams apparently mis-identified the Emporia limestone, which does not crop out in the vicinity he described.[33] It is probable that the Falls City limestone was the bed identified by Adams as the Emporia limestone.

Due to the confusion, the Admire shale was redefined to include beds from the top of the Brownville to the base of the Americus limestone. This nomenclature was followed by the Kansas and Nebraska geological surveys. The Admire shale member, as described above, was raised in rank by G. E. Condra[34] and R. C. Moore[35] and became the lowermost group of the Wolfcamp series. At the present time the Admire group is divided into nine units in Kansas and Nebraska.

The Indian Cave sandstone does not occur in the Burbank-Shidler area and the Brownville limestone appears to be conformable with the shale above. The interval between the Brownville limestone and the Five Point limestone has not been assigned a name in Oklahoma. In Kansas and Nebraska

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[33] G. E. Condra, op. cit., p. 72 (footnote No. 19).

[34] G. E. Condra, op. cit., p. 8 (footnote No. 14).

[35] R. C. Moore, op. cit., pp. 246-248 (footnote No. 15).

the equivalent interval is divided into five formations.[36] In descending order they are: West Branch shale, Falls City limestone, Hawxby shale, Aspinwall limestone, and Towle shale. In this area possible correlatives are present for the lower three formations.

Towle Shale: R. C. Moore[37] reports that the Towle shale is highly variable in Kansas, consisting of beds from sandy to calcareous. It displays any combination of colors normal for shales interlaced with thin limestones. While the Towle shale is considered definitely Permian in age, the character of the beds indicates a transition zone from Pennsylvanian to Permian rocks. The thickness in southern Kansas ranges from 2 to 17 feet. In the area under study the Towle shale is represented by 7 feet of dark gray, greasy, somewhat fissile shale. Near the top, streaks of impure limestone appear, showing a buff to tan-yellow color.

Aspinwall Limestone: The Aspinwall limestone in Kansas is reported by Moore[38] to consist of one or more sparsely fossiliferous limestone beds that range in thickness from 1 to 15 feet. The formation, as represented in the Burbank-Shidler area, is one bed of limestone nearly a foot

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[36] R. C. Moore, J. C. Frye, J. M. Jewett, Wallace Lee, and H. G. O'Conner, op. cit., pp. 52-53 (footnote No. 17).

[37] R. C. Moore, et al., ibid., p. 52.

[38] R. C. Moore, et al., ibid., p. 52.

thick. Medium gray in color, and tending to be massive, the bed is pitted on the surface and displays some crystalline calcite on fresh surfaces. No fossils are observable, but the pitting may be due to the differential weathering of a few poorly preserved specimens.

Hawxby Shale: The Hawxby shale is represented by beds 6 to 15 feet thick in Kansas.[39] The formation ranges from red or green at the base up to gray or yellow near the top and, at some localities, becomes quite sandy. In the Burbank-Shidler area the Hawxby shale is composed of 5.5 feet of light gray shale, capped by 1.5 feet of tan to gray sandstone. This sandstone is fine-grained and is laminated with streaks of dark minerals which give it a dirty cast. Although the beds appear to be soft and friable they are actually dense and compact.

The Falls City limestone and the West Branch shale were not observed in this area. These Kansas formations are represented by a grass covered slope with a vertical thickness of 17 to 20 feet. This thickness seems inadequate when compared to the Kansas section, which was measured near the Oklahoma line. The computation there ranges from 29 up to 55 feet. However, the lower boundary of the Hawxby shale and the upper limit of the Falls City limestone are not well defined in Kansas. This fact may be a partial explanation of

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[39] R. C. Moore, et al., ibid., p. 52.

the discrepancy.

Five Point Limestone: The correlation between the Five Point limestone in the Burbank-Shidler area and the unit measured in Kansas is not definite. A one foot limestone bed which falls in the proper stratigraphic interval was noted, and this bed is considered to be the correlative of the Five Point limestone. The bed is light gray to brown, crystalline, and weathers with solution holes. It is highly fossiliferous, with a few small fusulinids noted. Moore[40] describes the formation in Kansas as one or more limestone beds from 1 to 8 feet thick. Near the border in southern Kansas the upper part has been described as being a thin coquina. This was also the report given by Taylor[41] in the Foraker area.

Hamlin Shale: In 1935 Condra[42] divided the Hamlin shale into three members. The upper member is the Oaks shale, followed by the Houchen Creek limestone, and the Stine shale at the base. Of these three only the Houchen Creek limestone member can be definitely identified in the Burbank-Shidler area. Those beds above and below the Houchen Creek, which have not been assigned to other formations, are considered Oaks shale and Stine shale respectively.

The Stine shale is represented here by approximately 14 feet of covered slope. The interval is dominantly shale,

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[40] R. C. Moore, et al., ibid., p. 49.

[41] R. C. Taylor, op. cit., p. 42

[42] G. E. Condra, op. cit., p. 8 (footnote No. 14).

but there is a considerable amount of sandstone. The sandstone is mottled maroon to gray with iron stains on exposed fragments. On fresh surfaces the sandstone is fine-grained and light-buff. Indications are that the sandstone occurs near the top of the interval and it is possible that the sandstone is a facies of one of the limestone beds of the Houchen Creek limestone member.

The Houchen Creek limestone member along with the Oaks shale is at nearly all places poorly exposed. These two members are represented by 7 feet of thin limestones interbedded with a considerable amount of shale, which becomes proportionately greater at the top. The best exposures of these top shales are seen below the spillway on Phillip's Lake just south of the town of Shidler. Here the Oaks shale is 3.5 feet thick. It is composed of slate-gray, blocky claystone with streaks of calcite. Locally, crystals of pink celestite occur as vein fillings, but this occurrence could not be determined here since the exposure was covered by a continual flow of water over the lip of the spillway. The Houchen Creek limestone is represented by 1.9 feet of shaly limestone of the same slate-gray color as in the Oaks shale immediately above. The bed is massive, almost non-bedded, and contains no fossils. This is a distinguishing feature when compared to the highly fossiliferous beds of the Foraker limestone formation above. Immediately below the limestone bed is 1.4 feet of gray-blue, blocky shale that appears just above the water level of the pool below the spillway.

Council Grove Group

The Council Grove group was named by Prosser[43] in 1902 from exposures in T. 16 S., R. 8 E., along the bluffs of the Neosho River in the vicinity of Council Grove, Marion County, Kansas. The interval ranges from the base of the Wreford limestone down to the base of the Americus limestone. The Council Grove group has been subdivided in descending order into: Speiser shale, Funston limestone, Blue Rapids shale, Crouse limestone, Easly Creek shale, the Bader limestone (containing three limestone members, the Middleburg limestone, Hooser limestone, and Eiss limestone). Below is found the Stearns shale and the Beattie limestone (also with three members, the Morrill limestone, Florena shale, and Cottonwood limestone). Between the Beattie limestone and the Grenola limestone is the thick Eskridge shale. The Grenola limestone formation contains three limestone members separated by two shale members. They are the thick Neva limestone at the top, the Salem Point shale, Burr limestone, Legion shale, and Sallyards limestone. The Roca shale separates the Grenola limestone from the massive Red Eagle limestone, with its three members, which are the Howe limestone, the Bennett shale, and the Glenrock limestone. The Johnson shale

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[43]C. S. Prosser, J. W. Beede, "Revised Classification of the Upper Paleozoic Formations of Kansas," Journal of Geology, Vol. 10, 1902, pp. 709-711.

separates the Red Eagle limestone from the three members of the thick scarp-forming Foraker limestone. These three are the Long Creek shale, Hughes Creek limestone, and the Americus limestone.

In the basal portion, up to the top of the Howe limestone, the lithology is composed of heavy massive limestones and intervening shales which are generally lighter in color than those found below in the Pennsylvanian system. The upper part contains numerous limestones which are at no place as thick and massive, but are persistent. Generally the shales are somewhat lighter and more varied, with the typical "Permian Red" shales beginning to appear a short distance below the Neva limestone and becoming progressively more prominent above the Cottonwood limestone.

Foraker Limestone: In 1896 M. Z. Kirk[44] named the Americus limestone that was later to be incorporated into the Foraker limestone as its basal member. From rocks exposed on the south bank of the Neosho River one half mile south of Americus, Lyon County, Kansas, in T. 18 S., R. 10 E., Kirk described the Americus limestone as two thin layers of limestone about 4 feet apart, and with a total thickness of 5 to 8 feet.

In 1902 C. S. Prosser[45] named and described the

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[44] M. Z. Kirk, "Geological Section Along the Neosho and Cottonwood Rivers," Kansas University Geological Survey, Vol. I, 1896, p. 80.

[45] Charles S. Prosser and J. W. Beede, op. cit., p. 708.

Figure 3. Lower spillway at Phillip's Lake, N.W.¼ sec. 10, T. 26 N., R. 6 E. Oaks shale, Americus limestone member, and the lower beds of the Hughes Creek limestone member.

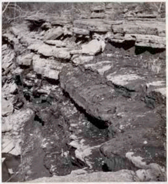

Figure 4. Lower Foraker limestone at Phillip's Lake, N.W.¼ sec. 10, T. 26 N., R. 6 E. Americus limestone member and the lower beds of the Hughes Creek limestone member.

Elmdale shale formation (name later dropped). In this he included the rocks from the base of the Grenola formation to the top of the Five Point limestone. In the interval he listed the Hughes Creek shale and the Long Creek shale as members, but omitted any mention of the previously described Americus limestone. The Hughes Creek shale and the Long Creek shale are now considered as the middle and upper members of the Foraker limestone respectively.

The name Foraker limestone was introduced by K. C. Heald[46] from exposures near the town of Foraker in Osage County, Oklahoma. Heald gives 74 feet as the total thickness of the Foraker limestone near the village of Foraker. This interval probably included all of what is now know as the Admire group, down to the base of the Brownville limestone. In 1935 Condra[47] carried the name Foraker limestone into Missouri and Nebraska and raised it to the status of a formation. He defined it as falling between the Johnson shale and the Hamlin shale. Following the nomenclature of M. Z. Kirk and C. S. Prosser, he divided it into the Long Creek limestone, Hughes Creek shale, and the basal Americus limestone. These names will be used here with the exceptions that the Long Creek is a shale member and the Hughes Creek is a limestone member.

[46] K. C. Heald, op. cit., pp. 21-25, 1918.

[47] G. E. Condra, op. cit., p. 8 (footnote No. 14), 1935.

The Foraker limestone is the outstanding lithologic unit in the area, and the Hughes Creek limestone is its most prominent member because of its massive character and chert content. In the central and southern part of the area the Foraker limestone stands as a high ridge, or in some cases a series of escarpments, which can be followed with ease for eight or ten miles. In the northeastern quadrant of the Burbank-Shidler area the Foraker loses its topographic expression and becomes difficult to follow on surface. This dying out of the Foraker ridge is probably due to the southward extension of a small anticlinal fold mapped by Heald[48] northeast of the village of Foraker.

Americus limestone member; At Phillips Lake the Americus limestone is 13.6 feet thick. The basal bed of the Americus limestone is 2.1 feet thick and is underlain by the Oaks shale. It is a resistant, dark gray, thin bedded, crystalline limestone. The bed contains some thin slabby gray shale and is fossiliferous in the upper part, with brachiopods especially abundant.

Above the basal bed is 1.3 feet of light slate-gray, carbonaceous, blocky shale, which becomes somewhat fissile near the top. The next limestone above is 0.5 foot in thickness. It is a dark gray that weathers to a drab ashy color. In it is a fossil assemblage with brachiopods dominant. This

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[48] K. C. Heald, op. cit., p. 39.

limestone is overlain by an equal thickness of dark gray, platy to blocky shale, followed by 1 foot of limestone above it. This limestone is a dirty mottled gray-to-yellow on surface. It is crystalline and fossiliferous, with brachiopods, especially <u>Composita</u> <u>subtilita</u>. A thin bed, 0.8 foot thick, of fissile, non-fossiliferous, gray shale separates this limestone from a 0.5 foot bed of shaly limestone above. The shaly limestone is light medium gray on fresh surface but weathers to a creamy gray on exposed surfaces. There is a tendency toward banding of darker layers in the limestone.

The next overlying bed is 0.5 foot of flaky gray shale, which in turn is overlain by 3 feet of limestone. This limestone is dense and difficult to break. Half a foot from the bottom is a thin shale break and 0.7 foot from the top is a thin platy zone which appears to carry all the way across the outcrop. The limestone is dark gray, calcitic, almost saccharoidal, and has weathered to a dirty gray on the surface. It is non-fossiliferous in the middle, but highly fossiliferous in the lower part. In it are many brachiopods and an abundance of crinoidal debris. At the top is a zone 0.7 foot thick with a variety of species of small brachiopods, pelecypods, and bryozoans. Medium sized fusulinids are also present in considerable quantity. Immediately above is a 1 foot interval composed of shaly limestone. It displays weak platy characteristics on a yellow-gray surface. However, freshly broken fragments are dark gray and somewhat crystalline. The bed is composed almost entirely of fossil remains. Among the many observed were Bryozoa of a large type, gastropods, crinoidal debris, large fusulinids, horn corals and spiriferoid brachiopods. A 0.5 foot limestone above protects this shaly bed from being weathered completely down. This protecting limestone is a dirty, mottled gray on the surface, with medium sized fusulinids standing in relief or showing as weathered pits in the surface. On broken surface the bed is medium gray in color. There are fusulinids which have been surrounded by calcite and light flashes from the prism faces of the shattered fossils. A thin 0.3 foot bed of buff-yellow shale that is soft and easily weathered separates the top bed of the Americus from the beds below. This shale crumbles readily and is almost completely made up of fusulinids with the clay material acting as a binder. The upper limestone bed of the Americus is 1.5 foot thick. It is medium gray with tan streaks on the surface but appears as dark gray, medium crystalline on fresh surface. The bed is somewhat massive and contains replaced fusulinids of medium size.

Hughes Creek limestone member; The Hughes Creek limestone member is a total of 24.2 feet in thickness in its exposure at Phillip's Lake. The interval is a nearly continuous limestone section, massive in the lower part and containing much light-blue "flint" or chert. Fusulinids are plentiful

Figure 5. Upper spillway at Phillip's Lake, N.W.¼ sec. 10, T. 26 N., R. 6 E. Chert bearing beds of the Hughes Creek limestone member, showing solution work in the limestone.

Figure 6. Upper spillway at Phillip's Lake, N.W.¼ sec. 10, T. 26 N., R. 6 E. Hughes Creek limestone. Typical nodule of blue chert with the white fusulinid fossils showing as specks on the surface.

in the chert and limestone. As the Hughes Creek is traced into central and northern Kansas it becomes much weaker, due to a considerable proportion of the limestone having been replaced in the section by light-gray to nearly black shale. Those limestones which remain are relatively thin, and Moore[49] does not mention any chert in the Hughes Creek member except in southern Kansas. The thickness ranges from 20 to 40 feet.

The lower bed of the Hughes Creek limestone is 2.7 feet of limy shale. The shale is light gray to tan with dark gray and blue streaks parallel to the bedding. It is somewhat plicate, with streaks and lenses of dark, heavy, crystalline limestone. This limestone may be the cause of the gray and blue streaks in the shale itself. These limestone lenses contain brachiopods and fusulinids which have been preserved as casts of calcite. The lowest limestone in the Hughes Creek is 2.5 feet thick, massive, but with shale partings. It weathers to a dirty yellow, and contains brachiopods, small fusulinids, and an abundance of crinoid debris. The thick-shelled brachiopod, Composita subtilita, is especially prominent, even on the dark gray, crystalline surface of a freshly broken fragment.

A thin 0.1 foot gray shale-break separates the basal limestone from a 1.9 foot sandstone. This bed is buff to black on surface, fine-grained with some limonite. There are

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[49] R. C. Moore, et al., op. cit., p. 49 (footnote No. 17).

a few unidentifiable fossils which are preserved as calcite casts. Immediately above this sandstone is a 0.3 foot shale which is very similar to the one below except that it contains some small fusulinids. A thin limestone, 0.4 foot thick, separates this shale from another above. The limestone is blue-gray in color and it weathers to a rough, jagged surface. The bed contains Myalina and a few other fossils in a poor state of preservation. On fresh exposure the bed is a dark gray color.

A 1.6 foot shale interval occurs immediately above this thin limestone. The lower foot is fissile, dark blue-gray, and fossils are rare. The upper portion is buff-gray, crumbly, and highly fossiliferous. It weathers to a fusulinid sand. Neospirifer dunbari, crinoidal debris, and some small brachiopods were noted. A 0.4 foot limestone containing similar fusulinids occurs above the fossil shale. The limestone is a medium pearl-gray, crystalline, and weak. It weathers to a dirty gray and has little more topographic expression than the sandstone below.

Above this weak limestone is a thick, pasty clay. This bed is buff to yellow with some lighter intercalations of shale. The interval contains a variety of fossils, especially fusulinids and brachiopods. This weak clay is overlain by a crystalline limestone which stands out in relief between the clay below and a shale interval above. The limestone weathers with a rough, drab bluish surface, but on fresh exposure the bed is gray to blue. It contains many large fusulinids and an assemblage of other fossils, Composita subtilita and Myalina being dominant.

A light yellow shale bed overlies the limestone. This bed is 2.6 feet in thickness and contains streaks of blocky gray claystone. The interval is highly fossiliferous and is imbedded with spiriferoid brachiopods, bryozoans of various forms, and much fragmental debris composed principally of crinoid remains.

Next, in ascending order, is a heavy, massive limestone section 9.3 feet in thickness. The lower bed is 2 feet thick and is divided by two shale breaks near the base. It is a dirty gray, crystalline bed with much calcite and a considerable amount of limonite. At places the limonite stains the surface with a reddish cast, giving it a mottled appearance. A weak, shaly limestone half a foot thick occurs above the basal bed in this limestone interval. It is dun-yellow to gray in color and some fossil fragments were noted, but preservation is poor. Between this shaly limestone and the massive limestone at the top of the interval there is a platy limestone 1.7 feet thick. The beds are dark gray on weathered surface. On fresh surface the color is light gray and has a snow-covered appearance due to the presence of calcite in considerable quantity. Several fossils were noted. Among these brachiopods and crinoidal debris were the most prominent. Fusulinids are present, but rare.

Immediately above is a 5 foot interval of massive limestone. The beds themselves are platy with shale breaks, but the rocks are prominent topographically because of the presence of blue chert. The chert occurs in spherical masses and lentils which range from a fraction of an inch up to almost one foot in thickness. The predominant color is blue to gray, but at several places were observed to be brown in tone, ranging from a very light tan-yellow to a chocolate shade. Contained within the chert are white, replaced fusulinids in a poor state of preservation. The white spotting due to these fossils gives the beds a characteristic appearance which proves useful in identifying the beds in field work. In this area the only interval that could possibly be confused with it is some of the brown, fusulinid-bearing cherts of the Neva limestone, which might be identified as the predominantly blue cherts belonging to the Hughes Creek. The 5 foot section of limestone which contains these chert lentils is a dirty blue-gray on surface. That it is susceptible to chemical weathering is indicated by the many solution holes and channels in the limestone beds which contain the chert. On fresh surface the limestones are light gray, highly calcitic and have a sugary appearance. Some specks of limonite are present, but very little staining is evident. This is in contrast with those limestones above and below which contain greater amounts of limonite and other iron minerals. There is considerable fossil debris along with numerous brachiopods and the fusulinids mentioned in the chert.

Above the chert-bearing members of the Hughes Creek limestone is 1.5 feet of poorly exposed buff to tan, calcareous shale. This is judged to be the uppermost bed of the Hughes Creek member to be found in this area.

Long Creek shale member; The Long Creek shale is considered the youngest member of the Foraker limestone formation and ranges from 4.5 to 17 feet in Kansas.[50] In this area, at the Phillip's Lake section, the Long Creek shale is 9.8 thick. The lowest bed is 1.1 feet of dull reddish-gray limestone with large fusulinids. On fresh exposure the bed is light gray with a snowy appearance.

Overlying the basal limestone is 1.2 feet of buff-gray, crumbly shale. Above this weak bed is 1.7 feet of dirty gray to reddish limestone with shale partings in the middle. On fresh exposure the bed is medium to dark gray, dense, crystalline, and tends toward massiveness. Brachiopods and pelecypods are present, although not well preserved. A limy, buff-yellow shale 2.3 feet thick lies above and separates two limestones. It is calcareous and weathers to a fusulinid sand, being almost entirely composed of the tests of these animals. The limestone overlying this "fusulinid" bed is 0.6 foot thick. The limestone is dense and resistant, weathering

[50]R. C. Moore, et al., p. 48 (footnote no. 6), 1951.

Figure 7. Top of spillway at Phillip's Lake, N.W.¼ sec. 10, T. 26 N., R. 6 E. Limestone bed in Long Creek shale with the lower Red Eagle limestone in background.

Figure 8. Upper spillway at Phillip's Lake, N.W.¼ sec. 10, T. 26 N., R. 6 E. Upper Hughes Creek limestone above chert zone with Long Creek shale in background.

Figure 9. Middle spillway at Phillip's Lake, N.W.¼ sec. 10, T. 26 N., R. 6 E. Hughes Creek limestone beds below the chert zone.

to a dirty yellow. On fresh exposure the bed is light gray and contains a variety of fossils. The most noticeable fossils are fusulinids, small horn corals and pelecypods. A shale bed overlying this limestone is 0.6 foot thick and resembles the fusulinid limestone below. This is one of the few localities in the area at which possible evidence of cyclic deposition was observed.

Immediately above this second fusulinid shale is a thin resistant bed of dense limestone of a dirty yellow color. The bed is 0.3 foot thick, light gray on fresh exposure, and it too contains fusulinids. Overlying the thin limestone is a 0.4 foot bed of reddish to yellow, slightly sandy shale. This bed lies immediately below the uppermost limestone of the Long Creek shale. The top bed of the Long Creek is 1.5 feet thick. It is a dull dark gray on weathered surface. This bed is a ledge-former in the Phillip's Lake section, but was not definitely identified at any of the other localities in the Burbank-Shidler area. This is probably due to the fact that it falls just below the thick Johnson shale interval and is covered on the gentle slopes. On fresh exposure the bed is medium to dove gray, crystalline, with calcite in large cleavage faces. Considerable limonite is present. The bed is fossiliferous, containing spiriferoid brachiopods along with the thicker shelled varieties such as <u>Composita</u>. Bryozoa and pelecypods are common. The distinguishing feature of the bed is the presence of minor amounts of smoky gray chert with white fusulinids. Except for a slight difference in color the chert is quite similar to that in the Hughes Creek limestone below.

Faunal List

Foraker Limestone: NW¼ sec. 10, T. 26 N., R. 6 E. Collected from the spillway at Phillip's Lake.

- Amphiscapha catilloides (Conrad) - From shale in the Americus limestone member.
- Neospirifer dunbari R. H. King - Present in all members.
- Chonetes granulifer Owen - Upper Foraker limestone.
- Wellerella osagensis Swallow - Middle Foraker limestone.
- Composita subtilita (Hall) - Upper Foraker limestone
- Aviculopecten sp.
- Pleurophorus sp.

Long Creek Shale (upper member of the Foraker limestone): NW¼ sec. 36, T. 25 N., R. 5 E. Collected about half a mile south of the Burbank Rock Company quarry, on the east bank of Salt Creek, at low water.

- Wellerella osagensis Swallow
- Neospirifer dunbari R. H. King
- Juresania nebrascensis (Owen)
- Composita subtilita (Hall)
- Linoproductus prattenianus (Norwood and Pratten)
- Dielasma sp.

Upper Foraker Limestone: Collected from road cut south of Phillip's Lake.

- Dictyoclostus cf. welleri (Dunbar and Condra)
- Composita subtilita (Hall)
- Allorisma subcuneatum (Meek and Hayden)
- Juresania nebrascensis (Owen)
- Neospirifer dunbari R. H. King
- Chonetes granulifer Owen

Foraker Limestone: NE¼ sec. 35, T. 25 N., R. 5 E. Collected below the dam and spillway at Lake Fairfax.

Crurithyris planoconvexa (Shumard)
Juresania sp.
Wellerella osagensis Swallow
Chonetes granulifer Owen
Neospirifer dunbari R. H. King
Hustedia cf. mormoni (Marcou)
Rhombopora lepidodendroides (Meek)
Cyclotrypa cf. bennetti Link
Amphiscapha catilloides (Conrad)
Linoproductus sp.
Productus juresanensis, pedical valves (Tschernyschew)
bryozoans, ramose type
Crinoid remains

Johnson Shale: In 1935 Condra[51] discarded the name Elmdale shale (introduced by Prosser[52] in 1902) and proposed the name of Johnson shale for the rocks of the interval between the top of the Foraker limestone and the base of the Red Eagle limestone. This classification is accepted and will be followed here.

The Johnson shale interval is not exposed in the Burbank-Shidler area except for a few minor exposures of the lower 5 feet immediately above the top of the Foraker limestone. In these limited areas the basal portion consists of a drab yellow to tan bed of weathered clay. The original unweathered rock is probably composed mostly of marine gray shale. At one exposure near Phillip's Lake the interval is broken by a thin platy limestone 1.4 feet thick which carries no recognizable fossils. The interval represented by the Johnson shale seems to be highly variable in thickness. In

[51] G. E. Condra, op. cit., p. 8 (footnote No. 14).

[52] C. S. Prosser, J. W. Beede, op. cit., p. 78 (footnote No. 43).

Kansas the range is from 14 to 25 feet. Taylor reports 35 feet immediately to the north in the Foraker area. In the area under study the wide difference in thickness continues. Near Phillip's Lake a thickness of 33.4 feet was computed for the Johnson shale and at Burbank the section measures 25 feet. Close to the southern limit of the Burbank-Shidler area, near Lake Fairfax, 16 feet is the maximum thickness noted.

Red Eagle Limestone: K. C. Heald[53] named the Red Eagle limestone in 1916 from exposures near Red Eagle School. The school that Heald mentions in his writing has since been destroyed and in the paper naming the formation Heald cites only two localities. The one near Red Eagle School in sec. 26, T. 27 N., R. 6 E., and the second on a tributary of Hay Creek, a quarter of a mile east of the corner of secs. 1, 2, 11, and 12, T. 26 N., R. 5 E. Heald measured a maximum thickness of 17 feet, but he indicated the probability of more unexposed beds below.

In 1935 Condra[54] carried the name into Missouri and Nebraska and defined it as underlying the Roca shale and overlying the Johnson shale. Previous to this, in 1927, Condra[55] had named the Glenrock limestone, Bennett shale,

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[53] K. C. Heald, op. cit., p. 24.

[54] G. E. Condra, op. cit., p. 8 (footnote No. 14).

[55] G. E. Condra, op. cit., p. 86 (footnote No. 19).

<u>Figure 10</u>. Escarpment of Red Eagle limestone just below skyline, N.E.$\frac{1}{4}$ sec. 8, T. 26 N., R. 6 E.

Figure 11. Red Eagle limestone in Burbank Rock Company quarry, N.E.$\frac{1}{4}$ sec. 36, T. 26 N., R. 5 E.

and Howe limestone from exposures in southern Nebraska. Condra traced these members into northern Kansas in the vicinity of Manhattan. In 1929 N. W. Bass [56] identified the Red Eagle limestone in southern Kansas and expressed the opinion that the beds were continuous into central Kansas. Seven years later Bass[57] reported that he recognized beds in the Cottonwood River Valley east of Elmdale as the equivalents of the Red Eagle limestone. These same beds Condra had identified as the Glenrock limestone, Bennett shale, and Howe limestone of northern Kansas and southern Nebraska. These findings indicated a correlation between the Red Eagle limestone of Oklahoma and the Glenrock limestone, Bennett shale, and Howe limestone of southern Nebraska.

The classification of the Red Eagle limestone which will be followed here has been accepted by the state geological surveys of Nebraska, Missouri, Kansas and tentatively by Oklahoma. This classification divides the Red Eagle limestone into the three members named by Condra, with the Howe limestone at the top and the Bennett shale separating the Howe limestone from the lowermost Glenrock limestone. Since the lithology of the Bennett member changes from predominantly

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[56] N. W. Bass, "The Geology of Cowley County, Kansas, with special reference to the occurrence of oil and gas," Kansas Geological Survey, Bulletin 12, pp. 54-55, 1929.

[57] N. W. Bass, "Origin of shoestring sands of Greenwood and Butler counties, Kansas," Kansas Geological Survey, Bull. 23, pp. 41-42, 1936.

shale in Nebraska to predominantly limestone in Oklahoma, it will be referred to as a limestone member.

Glenrock limestone member; The Glenrock limestone is the lowermost unit of the Red Eagle formation. This member is the thinnest in the formation, ranging up to 5 feet, but averaging from 1 to 2 feet at most localities from Nebraska to Oklahoma. The thickness is erratic and difficult to predict. From about 30 miles north of the Oklahoma-Kansas line the beds of this member thin toward the south until they are no longer recognizable about the position of the state line. Taylor[58] does not describe a single exposure in the Foraker area.

In the Burbank-Shidler area the Glenrock limestone is exposed at three localities. All of the outcrops are in Townships 25 and 26 N. The most accessible exposure is in the Burbank Gravel Company quarry just east of Burbank, Oklahoma, in the N.W.$\frac{1}{4}$ of the S.E.$\frac{1}{4}$ sec. 25, T. 26 N., R. 5 E. This exposure is not natural and would not have occurred except for the extensive operations carried on for road materials. The correlation as Glenrock is based primarily on thickness comparisons. The thickness determined as Glenrock limestone is 2 feet. Lithologically the beds are dense and blocky with tight, well formed bedding. The interval is broken in the center by a thin zone of weakness which results

[58]R.C. Taylor, op. cit., p. 52.

in the appearance of two beds of about equal thickness. The limestone itself is a dark dove gray which weathers to a light gray or tan. Included within the beds are small vugs which have been filled with calcite. Fossils are present but are extremely difficult to obtain in suitable condition for identification. Brachiopods seem to be the most numerous. Other forms were primarily composed of debris after attempts to remove them from the quarry walls. Immediately below the Glenrock limestone is a blue shale interval which comprises the floor of the quarry.

The most accessible natural exposure of the Glenrock limestone member is at the south end of the dam at Phillip's Lake, sec. 10, T. 26 N., R. 6 E. Here the interval exposed is only 1.3 feet thick. It is composed of a single massive bed of dark, dirty gray limestone with both calcite and a minor amount of limonite. This limonite gives a reddish stain on the surface.

The third exposure of the Glenrock limestone is in a deep cut made by a tributary just as it enters Salt Creek about a quarter of a mile east of the corner of secs. 1, 2, 11, and 12, T. 26 N., R. 5 E. This locality is the best natural exposure of the Red Eagle formation found in the Burbank-Shidler area. The Glenrock limestone member measures 4.6 feet in thickness. The lower bed is weak, highly soluble, and extremely calcitic. This bed is 0.8 foot thick, massive and weathers to a dull gray color. The upper bed is also highly calcitic and contains a minor amount of limonite. The thickness is 3.8 feet and the bed is massive throughout.

None of the three exposures in this area has been definitely established as Glenrock limestone because positive verification would necessitate lithologic correlations with those known localities some 40 to 50 miles to the north in Kansas.

Bennett limestone member; The Bennett limestone member is the most prominent member of the Red Eagle formation. It is composed of a series of thick, dense, massive limestone beds separated by a varying amount of minor gray to blue shale. This member is found throughout the Burbank-Shidler area and was used as a mapping horizon because of its common, though often incomplete, exposure. In sec. 11, T. 26 N., R. 5 E., there is 10.3 feet of exposure considered to be Bennett. Here a series of limestones of about 2.5 to 3 feet in thickness, separated by shales, makes up the Bennett limestone. (See measured section VII, appendix A.)

The Bennett is similar to the other members of the Red Eagle formation in that it is highly variable in thickness and lithology from place to place in the same area. This characteristic is evident when the section mentioned above is compared with a section measured one quarter of a mile east of the corner of secs. 1, 2, 11, and 12, T. 26 N., R. 5 E. The two are less than one mile apart yet here the Bennett limestone is composed of 11.5 feet of limestone, almost without interruption, capped by 2.8 feet of limy shale. In the southern portion of the Burbank-Shidler area, west of Lake Fairfax, the Bennett limestone ranges from 6 feet of heavy, massive limestone at the top with varying amounts of shale at the bottom, to a series of much thinner limes separated by an equal amount of shale.

Howe limestone member; The uppermost bed of the Red Eagle formation was named from exposures south of Howe, Nebraska. The Howe limestone ranges in thickness from 1 to 5 feet and varies locally from one or two massive beds to a series of thin beds only a few inches thick. The Howe limestone is difficult to separate from the Bennett limestone member below on the basis of field evidence or megascopic paleontology. The most accurate method is by the use of thin sections as used by O'Connor and Jewett,[59] along with the aid of a petrographic microscope. It is beyond the scope of this writer to attempt such separation. For this reason the breaks between the members of the Red Eagle formation are arbitrary ones that have been selected as fitting the lithologic conditions of this particular area.

In the northern portion of the area in sec. 11, T. 26 N., R. 5 E., the Howe limestone is 1.2 feet thick. Here it is one weak, shaly bed of gray crystalline limestone which contains dark gray specks of hard, dense limestone. There

[59] H. G. O'Connor and J. M. Jewett, "The Red Eagle Formation in Kansas," State Geological Survey of Kansas, Bull. 96, part 8 (1952).

are no apparent fossils present. In the Burbank-Shidler area the Howe limestone has its maximum development at an exposure one-fourth mile from the corner of secs. 1, 2, 11, and 12, T. 26 N., R. 5 E. Here the Howe limestone appears as an 8 foot interval, although it is possible that the lower 3.4 feet could be assigned to the Bennett limestone member. The upper bed is 1.7 feet thick. This is a typical Howe exposure as described by Condra. It is sandy looking, with limonite, weathering to a yellowish brown. This upper bed is massive with many solution cavities due to weathering. The rock is gray on fresh exposure.

A 0.7 foot shale break separates the upper limestone from those below. The lower series of limestones are somewhat softer, although less soluble. They are platy with numerous shale breaks. Farther south, near Lake Fairfax, the Howe limestone member is a weak, platy series of thin beds comprising a thickness of 2 feet.

Faunal List

Red Eagle Limestone: NE$\frac{1}{4}$ sec. 36, T. 26 N., R. 5 E. Collected in old part of Burbank Rock Company quarry.

- Bellerophon sp.
- Conocardium sp.
- Fenestrellina sp.
- Juresania nebrascensis (Owen)
- Bascomella fusiformis on Linoproductus sp.
- Dielasma sp.
- Meekella sp.
- Schizodus sp.
- Linoproductus prattenianus (Norwood and Pratten)
- Punctospirifer sp.

"Dictyoclostus" welleri Dunbar and Condra
Clavicosta echinata Newell
Neospirifer dunbari R. H. King
"Marginifera" sp.
Linoproductus sp.
Composita subtilita (Hall)
"Teguliferina" sp.
Lophophyllidium sp.
Allorisma sp.
Derbyia sp.
Hustedia cf. mormoni (Marcou)
Trepospira depressa
Chonetes sp.
Juresania sp.
Nuculopsis sp.

Red Eagle Limestone: SW¼ sec. 10, T. 26 N., R. 6 E. Collected on bluffs overlooking Phillip's Lake from the south end of the dam.

coral, poorly preserved, occurring in a thin zone about two feet from the top of the escarpment.

Red Eagle Limestone: SE¼ sec. 25, T. 26 N., R. 5 E. Collected in the Burbank Rock Company quarry, immediately south of highway 60.

"Teguliferina" sp.

Roca Shale: The Roca shale was named by Condra[60] from exposures near Roca, Lancaster County, Nebraska. There are no exposed sections of the Roca shale in the Burbank-Shidler area. However, a thin interval appears several times either immediately above the Red Eagle or below the Grenola formation to give some indication of the lithology. The Roca shale thickens from north to south. It is approximately 34.5 feet thick just west of Lake Fairfax. This increase in thickness is due to the presence of 12 feet of sandstone in three

[60] G. E. Condra, op. cit., p. 87 (footnote No. 19).

beds that are separated by shales. At Burbank the interval is completely covered and is 20 feet in thickness. Farther north in sec. 11, T. 26 N., R. 5 E., the Roca shale is 13.8 feet thick with two beds of highly calcareous mudstone which is weathered to a greenish gray. The lithology is predominantly gray shale, but is often red or yellow locally.

Grenola Limestone Formation: The Grenola limestone formation was named by Condra and Busby[61] in 1933. It is defined as the interval from the base of the Sallyards limestone to the top of the Neva limestone. The Grenola formation includes five members, in descending order, Neva limestone, Salem Point shale, Burr limestone, Legion shale, and Sallyards limestone. The Neva limestone member was named by C. S. Prosser and J. W. Beede in 1896.[62] The other four members were named Condra and Busby at the same time the Grenola formation was set up in 1933.

The interval below the Neva limestone is one which is rarely exposed in the Burbank-Shidler area. Occasionally the Burr limestone crops out in a manner which can be measured, but, for the most part, estimates of thickness and stratigraphic position must be made from partial exposures and rubble along the slopes below the Neva limestone.

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

[62] C. S. Prosser, and J. W. Beede, op. cit., p. 718 (footnote No. 43).

In T. 25 N., the Sallyards limestone member is less than 1 foot thick to the north in T. 26 and T. 27 N., the Sallyards limestone attains a thickness of 1.5 feet. It is a light gray on weathered surface, darker blue to gray on fresh exposure. It is slightly fossiliferous, but specimens are hard to recover from the grass-covered slopes. The bed seems to be somewhat dense but breaks down easily and weathers rapidly to the rubble now lying on the grassy slopes.

The Legion shale is never seen in the Burbank-Shidler area. Indications are that the interval is gray to tan shale with some minor limestone streaks present. At one locality in sec. 11, T. 26 N., R. 5 E., the interval contains two sandstone beds near the center. These sandstones total about 2 feet in thickness. The Legion shale interval ranges from 9 to 12 feet in thickness.

The Burr limestone member of the Grenola formation is often confused with the lower portion of the Neva limestone member. This confusion is the result of the fact that the stratigraphic interval from the top of the heavy basal member of the Burr limestone up to the first good limestone in the Neva member is about the same distance as the heavy limestone beds at the base of the Neva are from those more massive beds near the top of the Neva limestone. This confusion can be partially eliminated if all measurements are based on the chert bearing members of the Neva limestone. However, locally the Burr limestone member carries a minor amount of chert which may be either brown, such as is found in the Neva limestone, or blue, similar to that which occurs in the Hughes Creek member of the Foraker limestone.

For the most part the Burr limestone exposures are poor, ranging from 1 to 5 feet of gray limestone with an intercalation of thin limestones and gray or tan shales above. In sec. 7, T. 26 N., R. 6 E., the Burr crops out in limestone beds separated by shale. The upper limestone is thin bedded with many shale partings. The interval is fossiliferous, the top bed being composed almost entirely of brachiopods. The middle limestone is brown mottled with dirty gray. On a fresh surface limonite inclusions and calcite are present, along with white specks of chert. Brachiopods, crinoid debris, and small fusulinids are present in abundance. The basal limestone is massive and dense, with limonite staining. In a fresh exposure the rock is light gray with limonite streaks, crystalline in appearance. Some larger fusulinids and a few brachiopods, along with debris from crinoids are present. In the lower portion the limestone becomes somewhat brown in color and, on fresh exposure, displays inclusions of blue chert which contain replaced fragments of small fossils. The total thickness of the Burr limestone at this exposure is 12.5 feet.

The Salem Point shale member is rarely exposed in the Burbank-Shidler area. Near Burbank the interval shows some buff to tan yellow shale at the base, becoming brown to gray near the top. Infrequently the Salem Point shale contains thin beds of limestone which are usually fossiliferous with the brachiopod faunal facies. The interval averages about 10 to 12 feet in most localities.

Neva limestone member; The Neva limestone is the most prominent member of the Grenola formation. It consists of a series of limestones separated by shales. The upper beds comprising the top 5 or 6 feet, are weak and soluble, and are rarely seen. Likewise the lowermost beds are only slightly less soluble and are covered or absent at most places. The topographic expression of the Neva limestone is due to the presence of brown chert which occurs about 6 feet below the top. The shales are predominantly gray or tan, with a few darker breaks near the base at certain localities. Red shale in minor amounts is present in the upper portion at some places. The complete section comprises a thickness from 20 to 30 feet, depending on the amount of shale.

The Neva limestone shows indications of cyclic sedimentation. The upper and lower beds contain a molluscan faunal facies, while those in the center contain brachiopods and fusulinids. The limestones of the Neva are gray, crystalline, and contain varying amounts of secondary calcite. The beds weather to a rough pitted surface, which gives a marly appearance. The chert is brown and contains white fusulinids surrounded by calcite, presenting a striking appearance against the darker background. The Neva limestone is the

Figure 12. Rim formed by the Neva limestone, N.E.$\frac{1}{4}$ sec. 16, T. 26 N., R. 6 E.

Figure 13. Rim formed by the Cottonwood limestone, NW.$\frac{1}{4}$ sec. 33, T. 26 N., R. 5 E.

uppermost member of the Grenola formation and is overlain by the thick Eskridge shale formation.

Faunal List

Neva Limestone: South line of the SW¼ sec. 26, T. 26 N., R. 5 E.

<u>Crurithyris planoconvexa</u> (Shumard)
<u>Chonetes granulifer</u> Owen
<u>Pleurophorus</u> sp.
"<u>Marginifera</u>" sp.
<u>Rhombopora lepidodendroides</u> (Meek)
<u>Mesolobus</u> sp.
<u>Crurithyris</u> sp.
<u>Hustedia</u> cf. <u>mormoni</u> (Marcou)
"<u>Dictyoclostus</u>" <u>welleri</u> Dunbar and Condra

<u>Eskridge Shale</u>: In the Burbank-Shidler area the Eskridge shale is approximately 65 feet thick. The formation was named in 1896 by C. S. Prosser and J. W. Beede[63] from exposures in T. 14 S., R. 12 E., near Eskridge, in Wabaunsee County, Kansas. Where the interval is exposed it is made up of maroon to red shale broken by four limestones, each about a foot thick. The Eskridge normally underlies a long grass-covered slope below the Beattie limestone, with little expression topographically.

The limestones in the Eskridge shale interval are all impure and contain an abundance of fossils. The lower limestone, seventeen feet above the base, is 1.3 feet thick, dark gray, with a mottled appearance due to hematite. The bed is crystalline and fossiliferous, and weathers to a pitted

[63] C. S. Prosser, and J. W. Beede, <u>ibid</u>., p. 718.

surface. The second limestone occurs 24 feet from the base. The rock is dirty gray to brown on weathered surface. Small fusulinids and other fossils, especially brachiopods, are present, along with calcite and specks of limonite. The rock is light gray in color on fresh surfaces. This bed forms a slight slope break which can be observed in profile from a short distance. The third limestone is 40 feet from the base, and is one foot in thickness. Soft gray to buff color on weathered surface, the limestone is light gray on fresh exposure. The bed is not resistant to weathering and breaks easily with a hammer. Fusulinids are the most abundant fossil, although fossil debris of many types is present. The uppermost limestone bed in the Eskridge shale sequence is located 53 feet from the base. This limestone is dense, massive, and difficult to break as compared to those below it. The bed is heavy crystalline in appearance and forms a noticeable topographic break. The outstanding feature of this upper limestone is the purple color on the weathered surface.

Faunal List

Eskridge Shale: SW¼ sec. 11, T. 27 N., R. 5 E., Collected from poorly exposed interval near the top.

<u>Juresania nebrascensis</u> (Owen)
<u>Chonetes granulifer</u> Owen
<u>Streptorhynchus</u> sp.

<u>Beattie Limestone Formation:</u> This formation consists of three members, in descending order, the Morrill limestone

member, the Florena shale member, and the Cottonwood limestone member. In the Burbank-Shidler area the interval between the Cottonwood limestone and the Crouse limestone compares with the intervals reported in Kansas and northern Oklahoma, but incomplete exposures make accurate measurement and correlation of the units within the area difficult and uncertain. The Cottonwood limestone thins toward the south, from 10 feet in Cowley County, Kansas, to 2.5 feet in the Foraker area of Osage County, Oklahoma,[64] and 1.3 feet in the Burbank-Shidler area. Here the Cottonwood limestone is made up of two beds of equal thickness, both carrying fusulinids. The lower bed is platy with shale breaks. It is a dirty gray and is dense and crystalline. The upper limestone is white to gray, massive, and pitted on weathered surface.

The Cottonwood limestone has been recognized through the years by various names, such as Fusulina limestone, Cottonwood Stone, Cottonwood Falls limestone, Alma limestone, and Manhattan limestone. In 1895 C. S. Prosser[65] used the base of the Cottonwood limestons as the base of the Permian system. A year later[66] he renamed the Cottonwood limestone to avoid confusion about his earlier proposal. Both ideas were accepted and used until 1934 when Moore and Moss shifted

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[64] R. C. Taylor, op. cit., p. 64.

[65] C. S. Prosser, op. cit., pp. 764-766 (footnote No. 12).

[66] C. S. Prosser, and J. W. Beede, op. cit., pp. 711-712, (footnote No. 43).

the systemic boundary[67] to the top of the Brownville limestone. The Cottonwood limestone nomenclature proposed by Prosser is still accepted.

The Florena shale is composed of red and maroon shales with occasional thin limestones. The maximum thickness measured was 20.2 feet. Near the top is a calcareous zone with some fossils. The member was named in 1904 by Prosser and Beede.[68]

The Morrill limestone is approximately 1.3 feet thick. The limestone is heavy, massive, and forms a noticeable bench below the Crouse limestone. There is a thin shale parting near the middle. On weathered surfaces the limestone is gray with reddish to maroon stains giving it a mottled appearance. On fresh surfaces the bed is dark gray.

Stearns Shale: The Stearns shale is not well exposed in the Burbank-Shidler area and the lithology is uncertain. Near the base the formation is composed of red to maroon shales. The Bader limestone, which separates the Stearns shale from the Easly Creek shale, does not crop out in a manner that allows definite breaks to be picked. Boundaries are placed on the basis of limestone fragments in the grass along the slopes. The Bader limestone was estimated from

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[67] R. C. Moore, and R. G. Moss, "Permian-Pennsylvanian Boundary in the Northern MidContinent Area," Proc. Geological Society of America, 1933, p. 100.

[68] C. S. Prosser, and J. W. Beede, United States Geological Survey Geologic Atlas, No. 109, 1904, p. 3.

isolated exposure to be about 8 feet thick. The heaviest limestone rubble ceased to appear about 20 to 25 feet above the Morrill limestone. This places the thickness of the Stearns shale at from 12 to 17 feet thick.

Bader Limestone Formation: The Bader limestone is divided into two limestones and a shale member in Kansas. This division would be impractical in this area. Here the interval represented by the Bader is composed of two layers of platy limestone which are indistinctly separated by a thin gray shale. The whole interval is approximately 8 feet thick.

Easly Creek Shale: This formation is approximately 35 feet thick. It consists almost entirely of red to maroon shales interrupted by thin beds of sandstone and occasionally by thin dirty limestones.

Crouse Limestone: The Crouse limestone is the last limestone mapped in the Burbank-Shidler area for this report. The next good limestone (Wreford limestone) lies in R. 4 E. and is not present in this area. The Crouse limestone was named from an exposure in the Foraker Quadrangle to the north by Heald.[69] The Crouse forms a noticeable scarp above the lesser benches of the Cottonwood and Neva limestones. The formation consists of two beds totaling 5.5 feet in thickness. The lower bed is massive, dirty gray limestone with

[69] K. C. Heald, op. cit., p. 22 (footnote No. 1).

shale partings in the middle. On fresh surfaces it is light gray, crystalline, with calcite and light limonite stains. Brachiopods are plentiful, with other organic debris present in considerable quantity. The upper bed is the most distinctive due to the vertical solution holes. This bed is platy with shale partings throughout. The upper surface is pitted and highly fossiliferous. The lower portion of this upper bed is weaker and contains an abundance of fusulinids.

Blue Rapids Shale: The Blue Rapids shale overlies the Crouse limestone and consists of yellowish to tan shale with minor amounts of limestone. This is the uppermost bed found in the Burbank-Shidler area, with only the lower portion present.

## CHAPTER III

## REGIONAL GEOLOGY

### Historical Geology

The Burbank-Shidler area is situated on the western flank of the regional uplift centered in the Ozark Plateau area. This western flank comprises a great area known as the Prairie Plains homocline and includes southwestern Missouri, southeastern Kansas, northeastern Oklahoma and northwestern Arkansas.

Rocks of Pennsylvanian and Permian age are remarkably persistent, and they form long parallel belts of outcrop from southeastern Nebraska, across Kansas, and well into central and east central Oklahoma. The general direction of dip over the whole area is toward the west, but it varies from northwest in Nebraska, to southwest in central Oklahoma.

During the time of Pennsylvanian deposition in this area, the lands were a nearly flat plain of alluviation, containing swamps in the eastern portion. Shallow temporary lakes were abundant in what is now the western part of the homocline. The climate was subtropical, equable, and humid. The epi-continental seas were fluctuating and shallow, with a maximum depth of two hundred feet or less. The faunal assemblage was abundant and diversified.

The rocks of Permian age appear to be conformable on those of Pennsylvanian age over most of the area. Locally there is evidence of depositional breaks which may or may not be associated with slight diastrophic movements which were prevalent during the Pennsylvanian and Permian periods.

Cyclic sedimentation as described by Weller[70] is not found in the Burbank-Shidler area. However, Elias[71] indicates that similar deposition is present in the Big Blue series of Kansas. The same conditions which formed the cyclothems described in Kansas undoubtedly existed to some estent in the Burbank-Shidler area. In the area under study, the Pennsylvanian rocks occur only in a limited locality, and are restricted to the extreme upper Virgil. The limiting factors decrease the probability of good exposures of cyclically deposited sediments even assuming that environmental and climatic conditions were ideal.

The Permian period offers less possibility of classical cyclic sedimentation than the preceding Pennsylvanian, because the environment and climate were gradually changing.

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[70] M. J. Weller, "The Conception of Cyclical Sedimentation during the Pennsylvanian Period," Illinois State Geological Survey, Bulletin 66, pt. 5, 1931.

[71] M. K. Elias, "Cycles of Sedimentation in the Big Blue Series of Kansas," (Abstract) Geological Society of America, Procedings, 1933, p. 366.

The broad, shallow arms of the seas were becoming more isolated and restricted with each new retreat and advance. However, the Permian rocks which crop out in the area under study show several fragmentary and incomplete cyclothems which indicate that oscillation of the shallow seas continued over the area. The indications that the seas were becoming more shallow and restricted are, according to Elias,[72] based on the sequence in which certain groups of animals disappear in the higher Pennsylvanian and Permian cyclothems in Kansas. One example cited that less than ten species of brachiopods are known above the Fort Riley limestone, while over forty are present in the Foraker limestone. This is the first manifestation of the evaporite sections which were to follow during the long arid stage of the late Permian and early Mesozoic periods.

The limestones of the Burbank-Shidler area grade laterally into shales and sandstones of the Ouachita geosyncline in central and southern Oklahoma. The beds thicken toward the south and become difficult to follow due to the rapid facies changes. There are definite indications of the beginning of these facies changes in the southern part of the Burbank-Shidler area. Here, several lensing sandstones are found at various positions in the section. These sandstones

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[72] M. K. Elias, "Depth of Deposition of the Big Blue (Late Paleozoic) Sediments in Kansas," Geological Society of America, Bulletin, Vol. 48, March 1, 1937, pp. 403-432, I Pl., 4 figs.

are almost completely absent in the central and northern portions of the area. Those limestones which are higher in the section grade into the "red" beds of central and west-central Oklahoma.

## Structural Geology

Subsurface beds of Pennsylvanian age underlie the whole county with much the same character as they display on surface. They consist primarily of shale, with numerous thin limestones and sandstones which develop local prominence. Below the Pennsylvanian section beds of Mississippian age are found, consisting principally of limestone which in many cases carries large amounts of chert. At the base of the Mississippian section the Chattanooga black shale may be locally thinned or absent over topographic highs on the pre-Mississippian erosional surface. The Mississippian and Pennsylvanian are generally considered to be conformable, although locally there are reported to be scattered evidences of a slight erosional unconformity. Below the Mississippian there is a wide-spread unconformity of considerable duration as shown by the amount and character of the weathered material reported from bore holes throughout the area.

Beds of Devonian, Silurian and later Ordovician age were subjected to gentle tectonic activity at the close of the pre-Mississippian period. The strata were uplifted, folded slightly, and then eroded to a nearly horizontal surface, leaving the beds with a pronounced dip to the west and

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At the present time, there has not been found any Cambrian sediments otherthan those of the Cambro-Ordovician Arbuckle sequence.

Pre-Cambrian rocks, mostly granite, underlie the whole county. All the pre-Cambrian rocks are igneous, and may be found at comparatively shallow depths on top of some of the major structural highs.

No evidence of faulting was found in the Burbank-Shidler area. This fact does not fit the picture of the tectonic activity postulated for the area. It is probable that the proper stresses were present to produce faulting, but due to the differential compaction of the thick shale sections, the strains were reduced before reaching the heavier limestones such as the Foraker and the Red Eagle. These limestones would definitely show the effects of faulting if it were present. This explanation, of differential compaction, is supported by the fact that to the east there are recognizable faults on surface. These occur in older sediments lower in the section since there were not sufficient thicknesses of shale to relieve the strain enough to prevent faulting in the limestones and heavy massive sandstones.

Below the Foraker limestone in the extreme southeast corner of the Burbank-Shidler area, beds of both Pennsylvanian and Permian age make up the western limit of an erosional surface. This erosional surface was termed the Pawhuska Rock Plain by Dr. F. A. Melton[73]. The existence of such a surface is indicated by concordant summit levels of the many low hills and cuestas. It is believed that this type of "rock plain" is formed by lateral planation by streams, in this case the Arkansas River immediately to the south. The age of the surface represented by the Pawhuska Rock Plain cannot be determined with a great deal of certainty. The best estimate of the age places it in the upper Pliocene. This is the age of the Ogalalla formation, the base of which was projected from central Kansas eastward. The plane of this projection approximately coincides with the surface of the Pawhuska Rock Plain, at the base of the Flint Hills on the east side.

The evidence of the existence of the Pawhuska Rock Plain in the area studied is not apparent to the observer unless the area to the east around Pawhuska is also taken into consideration. Since the area of this problem was limited in the eastward extent by Range 6 East, only parts of

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[73] F. A. Melton, "Rock-Plain, and Depositional-Plain," Geological Society of America, Proc. 1935, 1936, pp. 91-92; cited in "Origin and Age of the Pawhuska Rock Plain of Oklahoma and Kansas," Master's Thesis, Univ. of Oklahoma, by W. E. Ham, 1939.

three sections are included in what is considered the Pawhuska Rock Plain, and no attempt was made to project the surface into the area from farther east, although it is undoubtedly present.

Sidney Powers[74] has published extensive observations on the tectonics of the Mid-Continent and in brief resumé writes:

> Instead of the uniformitarianism which is supposed to characterize the central portion of the United States, most complicated disconformities and unconformities are revealed. Folding is of neither the Appalachian nor the Rocky Mountain type, but is what may be called Plains type. The Paleozoic sediments were deposited on a peneplaned surface of low, but abundant, relief. The topographic hills are now buried hills. After successive periods of sedimentation they were rejuvenated, to that they are invariably overlain by an anticlinal type of folding which, however, is gradually modified and even disappears where the overlying section is over 2,500 feet thick. Size and magnitude of folding are proportional to distance above the pre-Cambrian floor, not to distance from major regional uplifts. Faulting is probably concentrated in echelon lines in different horizons, dying out both above and below as well as laterally.

In the Burbank-Shidler area, Heald[75] mapped several small anticlinal flexures which fit the pattern of tectonics outlined above, by Powers.

### Hay Creek Anticlines

The three anticlines are located near the mouth of

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[74]Sidney Powers, "Structural Geology in the Mid-Continent, Region; a Field for Research," Geological Society of America, Vol. 36, 1925, p. 156 (Abstract).

[75]K. C. Heald, op. cit., 1918.

Hay Creek, where it empties into Salt Creek. The apex of the western anticline is just south of the northeast corner of sec. 1, T. 26 N., R. 5 E. The rocks dip to the east, south, and west at about 70 feet per mile, while the dip to the north is about 50 feet to the mile. The highest point of the middle anticline is one-fourth mile due south of the northwest corner of sec. 32, T. 27 N., R. 6 E., with the axis extending in a NNE-SSW direction for about one and a quarter miles. The dip is approximately 60 feet per mile on both the east and west flanks, while the north and south dip is gentle and merges into the regional dip without apparent change. The closure is nearly twelve feet, based on readings taken on the Neva limestone. The eastern anticline is the smallest of the three folds. Its highest point lies southwest of the center of the section line between secs. 32 and 33, T. 27 N., R. 6 E. The long axis points slightly east of north, and is almost a mile long. The dip to the east is slight, giving closure of about five feet, but the dip to the west is quite steep, being 100 feet per mile for almost a quarter of a mile. The structure has more the appearance of a terrace than that of an anticline.

Brown Anticline

The Brown anticline is a low, broad, terrace-like fold with the apex a quarter of a mile south of the northeast corner of sec. 8, T. 27 N., R. 6 E. The flattening is marked, with a total easterly dip of only twelve feet. The axis trends just east of north for over two miles. The easterly dip is almost 50 feet per mile but extends only about 0.3 of a mile, at which point the dip reverses and becomes westerly at about the same rate. The dip on the western side of the axis is about 12 feet per mile for the first mile, whereupon it steepens gradually where it merges into the terrace structure of the Brooks anticline (sec. 17, T. 28 N., R. 6 E.).

Neva Anticline

The Neva anticline displays dip in only three directions, east being the exception. The structure is a short, blunt fold trending westward from a point about an eighth of a mile east of the southwest corner of sec. 16, T. 27 N., R. 6 E., to the quarter corner between sections 17 and 20, T. 27 N., R. 6 E. On the north side the dip is about 70 feet to the mile, as compared to 100 feet per mile toward the southwest from the south side. The western side shows the most gently dipping beds, which dip only about 10 feet per mile.

Wamsley Creek Anticline

The Wamsley Creek structure is composed of two distinct low folds, with the highest points in the S.E.$\frac{1}{4}$ sec. 25, T. 27 N., R. 6 E., and one tenth of a mile south of the corner of secs. 25, 26, 35, and 36, T. 27 N., R. 6 E. The two folds are shaped in the form of a "V" with the apex pointing northwest. The closure is 10 feet. Considered together, the folds cover an area 2 miles long and 1 mile wide. The structure was mapped on the upper beds of the Foraker limestone.

Potato Creek Anticline

The top of the Potato Creek anticline is located in the S.W.$\frac{1}{4}$ of the S.W.$\frac{1}{4}$ of sec. 32, T. 27 N., R. 7 E. (outside the limits of the area studied). There is a structural terrace on the western flank of the Potato Creek anticline, the form of which extends along the east line of sec. 1, T. 26 N., R. 6 E.

Upper Salt Creek Dome

The Upper Salt Creek dome occupies parts of sec. 3, 4, 5, 8, 9, and 10, T. 26 N., R. 6 E., and has a closure on the northeast of 10 to 20 feet. An east dip of 15 feet in half a mile is shown in the S.E.$\frac{1}{4}$ sec. 9. On the west the dip amounts to 90 feet in the first mile. The crest lies a little northwest of the center of sec. 9.

North Lostman Anticline

This structure is located in parts of secs. 3, 4, 5, 8, and 9, T. 25 N., R. 6 E., and covers about one and a half square miles. Its crest has a low saddle about the middle. The anticline has an east closure of about 10 feet. The dip to the north and south is gentle, while that to the west is 70 feet per mile. The highest points on the anticline lie about 1,200 feet northeast of the west quarter corner of sec. 3, and 1,500 feet northeast of the southeast corner of sec. 4.

Solomon Creek Anticline

The Solomon Creek Anticline is a small fold in the north half of sec. 21, T. 25 N., R. 6 E., covering less than a quarter of a square mile. The east dip is less than 10 feet.

Deadman Anticline

This fold lies in the south half of sec. 33, T. 25 N., R. 6 E. Elevations on the Foraker limestone show that the east dip is about 8 feet and the north and south dips are gentle.

East Bluff Creek Anticline

This is a broad gentle fold lying mainly in the S.W.¼ sec. 17 and the S.E.¼ sec. 18, T. 26 N., R. 5 E. It shows an east dip of about 8 feet, extending eastward for a quarter of a mile. The dip to the north and south is gentle and is not more than 20 feet.

Jim Creek Anticline

The Jim Creek structure occurs as a low, broad nose in secs. 31 and 32, T. 26 N., R. 5 E. The dip to the north and south amounts to about 20 feet in half a mile. It has no east dip.

Syncline

In the southwest corner of the Foraker Quadrangle there is a well-defined syncline whose axis extends from a point 1,000 feet north of the southeast corner of sec. 26, T. 27 N., R. 5 E., to a point 2,300 feet south of the northwest corner of sec. 29, T. 27 N., R. 6 E., just northwest of the Middle Hay Creek anticline.

Economic Products

The Burbank-Shidler area contains some of the most prolific oil production in Oklahoma. The Burbank field was discovered by the Marland Oil Company in May, 1920, the discovery well located in the S.E.¼ sec. 36, T. 27 N., R. 5 E. The Burbank field produces primarily from the Burbank sand of the Boggy formation (middle Pennsylvanian), at a depth from 2,800 to 3,200 feet. The amount of production from a specific well is controlled by sand characteristics such as porosity and permeability. The oil in the Burbank sand seems to occur independent of the structural attitude of the rocks. The mode of deposition of the Burbank sands remains an unsettled question. The sand body may be a beach deposit[76] that was formed on the western shore of the Pennsylvanian sea, but there is evidence which points to a blanket type condition over a relatively large area. It is possible that both conditions existed almost simultaneously within a short span of geologic time.

At the present time an extensive water flood project is being carried on in the Burbank area. This might normally be considered as the final phase of economic oil activity in

[76] N. W. Bass, op. cit., 1936, (footnote No. 57).

the area. This is not the case, however, recently several wells have been drilled which are considered to be major discoveries and have added new impetus to exploration. There are also several sands above the Burbank sand which are known to be productive, although not comparable in productivity to the Burbank interval. These horizons, together with possible Mississippi limestone production, give promise of continued operations in the Burbank-Shidler area for many years.

The Burbank Gravel Company produces quantities of limestone material for use in concrete construction, road material, railway ballast, and other purposes. The quarry from which the limestone is obtained is situated just east of the town of Burbank, on U. S. Highway 60. The limestone being quarried, as mentioned before, is the Red Eagle limestone, which, at this locality, has developed to a thickness of over 20 feet, with only minor percentages of shale. The beds are not massive enough to be used commercially as building stone, and the presence of limonite further detracts from the desirability as building material.

No other mineral deposits of commercial quantity or quality are present in the Burbank-Shidler area.

## APPENDIX A

## MEASURED STRATIGRAPHIC SECTIONS

I. Sec. 36, T. 25 N., R. 6 E. Measured from 0.1 mile east of the railway crossing on section line between secs. 25 and 36, T. 25 N., R. 6 E.

FORAKER LIMESTONE formation:
Hughes Creek limestone member:
Limestone, well bedded, platy, with thin shale breaks, neutral gray to tan. Fossil evidence plentiful, but exposures poor... 6.0
Shale, covered, contains thin dirty calcareous sandstones as evidenced by fragments in grass.................................. 4.0
Limestone, massive in upper part, weaker, with shale breaks in lower part. Fossiliferous in the lower part, which is partially covered.......................................... 6.0
Sandstone, massive, dark brown to maroon due to iron stain. Fine grained, well sorted, shows characteristics of deposition in quiet environment........................ 1.5
Shale, covered, contains thin limestones....... 6.0
Americus limestone member:
Limestone, massive, hard, blue-gray, weathering to light gray. Fine-grained, with fusulinids present in fragments..... 2.5
Shale, covered.............................. 1.0
Limestone, massive, dark gray, with shale breaks. Slope is partially covered...... 4.5
Limestone, massive, medium gray on weathered surface, dove gray on fresh surfaces. Highly fossiliferous....................... 1.2
OAKS shale:
Shale, covered; not measured.
HOUCHEN CREEK limestone:
Limestone and shale thinly interbedded beneath the Foraker limestone. The interval is grass covered and includes the Oaks shale 7.0

STINE shale:
Sandstone, with minor amount of shale. Mottled maroon and gray, with ironstains on weathered surface. The fresh surface is light buff. Fine-grained, well cemented, but easily weathered. Sorting indicates channeling.................... 14.0

FIVE POINT limestone:
Limestone, light gray to dark dove gray, crystalline, fossiliferous, weathers with pitted solution holes.............. 1.0

SHALE undifferentiated:
Shale, covered with grass, approximately....... 83.0
Shale, contains some sandstone beds........... 12.0

GRAYHORSE limestone, upper portion exposed:
Limestone, dark gray, crystalline, weathering to a light gray. Overlain by thin sandstone, light green-gray, fine-grained.... 0.7

SHALE undifferentiated:
Shale, covered slope, approximately............ 27.0

JIM CREEK limestone:
Limestone, crops out in road, not measured.

II. Sec. 35, T. 25 N., R. 6 E. Measured in the shale valley below the Foraker limestone bluffs.

HAWXBY shale:
Sandstone, tan to gray, fine-grained, dirty, sorting causes color lamination, dense and compact............................ 1.5
Shale, light gray, blocky......................... 5.5

ASPINWALL limestone:
Limestone, medium gray, massive, pitted, non-fossiliferous, calcitic............. 1.0

TOWLE shale:
Shale, dark gray, greasy, somewhat fissile, with buff yellow limestone streaks in the upper part.......................... 7.0

BROWNVILLE limestone:
Limestone, buff yellow, pitted, highly fossiliferous, with brachiopods, fusulinids, bryozoans, and pelecypods, along with fragmental debris. Dark gray on fresh surface, finely crystalline with calcite covered fossils.......................... 0.6
Shale, buff yellow, soft, irregularly bedded... 0.6
Limestone, dense, sandy textured, buff yellow on surface, gray on fresh exposure, highly calcitic. Brachiopods of large species with crinoidal debris............ 0.8

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| Shale, gray, soft, calcareous.................. | 0.3 |
| Limestone, dense, massive, weathers with rectangular to rhombohedral pattern, with a pitted rough surface................... | 0.4 |
| PONY CREEK shale: | |
| Shale, not measured. | |

III. Sec. 7, T. 25 N., R. 6 E. Measured along the barrow ditch on State Highway 18.

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| FORAKER limestone: | |
| Long Creek shale member: | |
| Limestone, buff colored, fusulinids are abundant................................. | 0.5 |
| Shale.......................................... | 1.0 |
| Limestone, buff yellow, fusulinids present.. | 0.5 |
| Limestone, light tan, fusulinid bed........ | 0.6 |
| Limestone, buff, platy, with shale breaks... | 0.4 |
| Shale, light gray.......................... | 0.5 |
| Limestone, light gray, fusulinids abundant.. | 0.5 |
| Shale, buff colored........................ | 1.0 |
| Limestone, fusulinids throughout, composed of three beds, separated by thin shale breaks...................................... | 2.0 |
| Shale, buff to yellowish brown............. | 6.0 |
| Limestone, dark to light gray, somewhat mottled crystalline, with poor preservation of unidentified fossils............ | 1.0 |
| Hughes Creek limestone member: | |
| Shale, calcareous, crumbles easily......... | 2.0 |
| Limestone, dark to dirty gray, highly fossiliferous, with fusulinids abundant.. | 1.8 |
| Limestone, shaly, yellow to gray, highly fossiliferous, with fusulinids, crinoidal debris, and brachiopods.................... | 0.2 |
| Shale, dirty yellow........................ | 4.0 |
| Limestone, fusulinid, dirty medium gray..... | 0.5 |
| Shale, soft and friable, highly fossiliferous.............................. | 0.5 |
| Sandstone, red to brown, fine-grained, well indurated, clean........................ | 3.0 |
| Shale, gray.................................. | 12.0 |
| Limestone, weak, shaly, dirty, platy, light brown.............................. | 1.3 |
| Limestone, dark gray, massive, shaly in center...................................... | 2.0 |
| Shale, dirty gray........................... | 0.7 |
| Limestone, dark gray, crystalline.......... | 0.2 |
| Shale, dark gray, dirty, with thin limestone streaks, fossiliferous with brachiopods.. | 0.6 |

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| Limestone, dark gray, gastropods stand on the weathered surface, some calcite replacement.................................... | 0.5 |
| Shale, gray.................................... | 0.1 |
| Limestone, light gray, fossiliferous, with brachiopods, pelecypods and debris....... | 0.3 |
| Shale, dirty gray, with limy streaks, fossils include brachiopods, pelecypods, crinoid fragments, and fusulinids. The bed is blocky.................................... | 1.6 |
| Limestone, hard dense, dirty yellow on surface with fusulinids and crinoidal debris.................................... | 1.3 |
| Shale, buff yellow, very calcareous......... | 1.4 |
| Americus limestone member: | |
| Limestone, yellow to off-gray, weathers to a dirty yellow, platy and somewhat shaly, highly fossiliferous, with fusulinids and crinoidal remains.................................... | 0.4 |
| Limestone, massive, dark gray when fresh, dirty buff on surface.................... | 1.2 |
| Limestone, brown to gray, medium density, crystalline, fossiliferous.............. | 0.9 |
| Shale, brown to light tan near the base, soft and easily broken down.............. | 1.0 |
| Limestone, hard dense, massive, with calcite as secondary material, dark gray, weathering to buff.................................... | 0.2 |
| Shale, bluish-gray, well compacted, undetermined thickness, probably more limestone below. | |

IV. NW$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 25, T. 26 N., R. 6 E. Measured south of U. S. Highway 60, in limestone quarry.

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| RED EAGLE limestone formation: | |
| Howe limestone member: | |
| Shaly limy soil, highly weathered limestone with shaly intercalations, dirty, with some limonite not measured. | |
| Limestone, buff gray, hard dense layer near the top, with the remainder soft and shaly.................................... | 1.0 |
| Shale, calcareous.................................... | 0.2 |
| Limestone, yellow, easily weathered, soft and crumbly.................................... | 1.0 |
| Limestone, massive, very dense, some thin shale partings.................................... | 0.9 |

Bennett shale member:
Shale, thin, not measured.
Limestone, shaly, light tan in color........ 0.3
Underclay, buff............................. 0.1
Limestone, massive, dense, with soft shaly to platy intervals.......................... 0.3
Limestone, massive, with uniform density.... 0.7
Limestone, alternating with shaly limestone, beds of compact gray calcitic limestone, which sparkles with calcite on exposure to direct sunlight, separated by beds of gray-buff to yellow limy shale which contain platy gray fossiliferous beds with calcitic fossil preservation............. 2.5
Limestone, gray, alternated with shale in equal proportions.......................... 1.6
Limestone, dense, difficult to break, weathers buff to gray, calcitic fossil replacement, contains vuggy zone, the limestone exhibits blocky disintegration. 5.5
Limestone, lamellar, highly fractured, shaly...................................... 0.8
Limestone, light gray, contains vugs or cavities, some of which are covered with calcite crystals............................ 1.1
Limestone, gray, dense, massive bedding..... 0.7
Limestone, thin with concretions and brachiopods present in thin shale breaks. 0.8
Glenrock limestone member:
Limestone, dense, blocky, gray in color, contains some vugs crusted with calcite.. 2.0
Shale, blue-gray, not measured.

V. Measured $\frac{1}{4}$ mile east of the corner of secs. 1, 2, 11, and 12, T. 26 N., R. 5 E., on a tributary of Salt Creek.

RED EAGLE limestone formation:
Howe limestone member:
Limestone, sandy to siliceous, with limonite, weathers yellow to brown, gray on fresh exposure, massive, with solution cavities 1.8
Limestone, shaly............................ 0.8
Limestone, tan to gray, medium density...... 1.1
Limestone, platy, with some shale breaks.... 2.4
Limestone, light gray, thin-bedded, with a shale break in the center................. 2.0
Bennett shale member:
Shale calcareous, brown to tan.............. 2.9

Limestone, gray to off-white, fossil replacement, massive, with some bedding visible.................................... 4.9
Limestone, highly calcitic, weathers to dirty buff color, not resistant.......... 2.6
Limestone, gray, massive, dense, weathers to tan or buff.............................. 0.5
Limestone, thin, platy, light tan to gray, non-fossiliferous, varied in its resistance to weathering................. 3.5
Glenrock limestone member:
Limestone, massive to slightly fractured, gray on fresh surface, and gray stained with orange to brown limonite on weathered surface, highly calcitic....... 3.9
Limestone, massive, dense, extremely calcitic, highly susceptible to weathering, and breaks down to cause overhang of bed above, weathers gray..................... 0.8
Shale, dark gray, thickness not measured.

VI. Sec. 7, T. 26 N., R. 6 E. Measured near abandoned railway.

GRENOLA limestone formation:
Burr limestone member:
Limestone, dirty gray on weathered surface, light gray, crystalline, well bedded; the presence of calcite gives a sugary appearance. Becomes platy toward the top. Fossils present, especially brachiopods, along with bryozoans........ 3.4
Shale, limy, with thin limestone streaks.... 1.5
Limestone, brown, mottled, dirty gray, limonite inclusions, massive, with tendency to part. Fossils include brachiopods, crinoid remains, and small fusulinids. A minor amount of chert, both brown and blue........................ 2.1
Shale, gray, covered........................ 3.3
Limestone, massive, dense, dirty gray, light gray with limonite streaks on fresh exposure. Crystalline texture. Fossils include brachiopods, crinoid debris, and large fusulinids.......................... 1.4
Limestone, mottled gray to yellow, tan to brown on fresh exposure. Specks of blue chert.......................................... 0.7

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| Legion shale member: | |
| Shale, gray, grass covered.................. | 2.9 |
| Limestone, hard, massive, dirty dark gray, dense, extremely calcitic, "sparkly", some unidentified fossil fragments....... | 0.7 |
| Limestone, light gray, weak bed with considerable amount of shale............. | 0.3 |
| Shale, covered................................ | 3.7 |
| Sallyards limestone member: | |
| Limestone, massive, forms slight bench, mottled, dirty gray with red iron oxide stains on weathered exposure. On fresh surface the bed appears saccharoidal, gray, with some shale breaks in the upper portion............................ | 1.6 |
| ROCA shale formation: | |
| Shale, covered, gray in upper part............ | 14.0 |
| RED EAGLE limestone formation: | |
| Howe limestone member: | |
| Limestone, dirty gray, with limonite stains, weathers back from edge of escarpment formed by limestone below............... | 2.3 |
| Limestone, dirty tan to gray, with many thin shale partings...................... | 1.2 |
| Bennett shale member: | |
| Limestone, massive, dirty gray on surface, thin shale partings throughout, pitted, some fossil fragments.................... | 5.9 |
| Shale, dirty yellow, platy, some limestones near the top.......................... | 9.0 |

VII. Sec. 11, T. 26 N., R. 5 E. Measured in the NE$\frac{1}{4}$ near Mud Creek.

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| GRENOLA limestone formation: | |
| Neva limestone member: | |
| Limestone, light gray, limonite staining, calcitic, fossiliferous, with large fusulinids, brachiopods, and possibly algae. There is abundant milky blue chert specked with lighter colored fragments of limestone or chert.......... | 0.7 |
| Shale, not exposed.......................... | 4.0 |
| Limestone, partially covered, weathers away from main rim formed by the Neva limestone. The color is yellow to gray on weathered surface, dark gray on fresh surface, slabby and irregularly bedded. Contains small fusulinids, which are difficult to collect because of the density of the limestone................................ | 1.5 |

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|---|---|
| Shale, covered, maroon | 6.5 |
| Limestone, breaks in rhombic pattern, massive, limonite filled vugs, dense, gray, crystalline, dirty gray on weathered surface, wavy parting, small brachiopods, rarely fusulinids, fragments of chert | 1.1 |
| Limestone, buff yellow on fresh surface, fossiliferous, with crinoid remains, brachiopods, bryozoans, and fusulinids; the bed is weak, and sandy, with shale streaks | 0.4 |
| Shale, covered | 1.0 |
| Limestone, good scarp former, very massive, slight parting in places, medium gray, calcitic crystalline, pitted and dirty gray on surface, limonite fillings, non-fossiliferous | 2.1 |
| Salem Point shale member: | |
| Shale, tan to gray, with streaks of limestone | 7.0 |
| Burr limestone member: | |
| Limestone, crystalline, dense, light tan, weathers medium gray, long streaks of calcite filling old cracks, becomes platy at the top. Brachiopods present | 1.2 |
| Legion shale member: | |
| Shale, covered | 2.5 |
| Sandstone, hard resistant, tight and fine-grained, medium to dark gray, reflects light as if one of the mica group were present | 0.5 |
| Sandstone, weak and shaly | 1.9 |
| Sandstone, buff yellow to tan, massive, resistant, fine-grained, with traces of mica | 0.5 |
| Shale, brown, sandy | 1.5 |
| Sandstone, resistant, light brown, with mica | 0.8 |
| Shale, covered | 2.2 |
| Sallyards limestone member: | |
| Limestone, dirty streaked gray, massive, crystalline and shiny, dark gray, weathering to a light gray | 1.2 |
| ROCA shale formation: | |
| Shale, covered | 5.0 |
| Limestone, platy, crystalline and shiny, dark gray, weathers to a light gray | 0.8 |
| Shale, thin splinters, reddish brown | 0.5 |
| Limestone, platy, dark gray, with dark impure calcite crusted fossils, weathers to a greenish gray | 1.5 |

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| Shale, not exposed | 6.0 |
| RED EAGLE limestone formation: | |
| Howe limestone member: | |
| Limestone, neutral gray, with darker gray specks, weak shaly fissile | 1.2 |
| Bennett shale member: | |
| Limestone, massive, highly fossiliferous, dirty yellow to buff on fresh exposure, light gray to tan on fresh surface, contains calcite, shaly at the top. The calcite gives a sugary appearance | 2.5 |
| Limestone, soft, pitted, fossiliferous, tan-yellow on surface, dark gray, crystalline. Fossils include pelecypods, brachiopods, and rarely fusulinids | 1.3 |
| Shale, calcareous, tan to gray | 2.0 |
| Limestone, fossiliferous, soft, pitted, with vugs lines with calcite. Dark gray, with some shale; Fossils are brachiopods and pelecypods | 2.5 |
| Shale, gray to tan, covered with float | 2.0 |

VIII. Sec. 10, T. 26 N., R. 6 E. Measured from below the spillway at Phillip's Lake to the top of the hill about 1000 feet south of the dam.

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| ESKRIDGE shale formation: | |
| Shale, grass covered, lower 5 feet may be Neva limestone | 11.0 |
| GRENOLA limestone formation: | |
| Neva limestone member: | |
| Limestone, variable thickness, mottled shades of gray on weathered surface. Medium gray, crystalline, with inclusions of tobacco-colored chert and nodules of limonite on fresh fragment. Fossils include brachiopods, crinoidal debris, and a few small fusulinids | 0.7 |
| Shale, not exposed | 2.0 |
| Limestone, platy, with shale breaks common. Dirty gray on surface, medium dark gray, crystalline, stringers of milky brown mottled chert found on fresh exposure | 4.0 |
| Shale, not exposed, probably some limestone | 10.0 |
| Limestone, platy, dirty gray with reddish to yellow mottled appearance on surface. On fresh surface the limestone is tan, crystalline, and fossiliferous, with brachiopods abundant | 0.3 |

Shale, grass covered, probably limestone beds........................................ 7.5
Sandstone, poorly exposed, dark tan on weathered surface. On fresh exposure the beds are light buff in color, fine-grained and clean textured............... 3.5
Salem Point shale member:
Shale, covered.................................... 11.0
Burr limestone member:
Limestone, hard, dense, mottled light to dark gray-blue on weathered surface. The limestone is light gray with dark calcitic fossils on fresh surface........ 2.5
Legion shale member:
Shale, covered.
Sallyards limestone member:
Covered.
ROCA shale formation:
Shale, covered, includes Legion shale, and the Sallyards limestone.......................... 32.0
Red Eagle limestone formation:
Howe limestone member:
Not exposed.
Bennett shale member:
Limestone, massive, dirty gray on surface, creamy gray, crystalline, on fresh exposure. Contains inclusions of limonite. The bed is dense and holds up a noticeable scarp at the south end of the dam. Thin zone of colonial corals about 0.7 of a foot from the top.. 4.1
Limestone, massive, weaker than bed above, dirty gray with reddish mottling on surface. Light gray, crystalline, with a sugary appearance due to calcite....... 2.4
Limestone, weak, platy, tan-gray where exposed. Crystalline, light gray on fresh surface............................. 1.9
Limestone, massive, dirty gray, light gray, sugary crystalline, with some limonite, becomes platy at the top................. 2.8
Shale, not exposed.......................... 2.9
Glenrock limestone member:
Limestone, dirty gray to reddish, massive, light gray, calcitic, saccharoidal, limonitic.................................. 1.3
JOHNSON shale formation:
Shale, not exposed, probably gray.............. 21.0
FORAKER limestone formation:
Long Creek shale member:
Limestone, massive, ledge former, dark dirty

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| gray, calcitic with considerable limonite. Fossiliferous, with brachiopods (<u>Spirifer</u>), bryozoans, pelecypods, and numerous fusulinids contained within lentils of smoky gray chert....... | 1.5 |
| Shale, red to yellow, crumbly.............. | 0.4 |
| Limestone, resistant, dirty yellow, dense, light gray on fresh surface, fossiliferous, fusulinids are abundant............ | 0.3 |
| Shale, dirty yellow, contains fusulinids.... | 0.6 |
| Limestone, resistant, dirty yellow, dense, light gray when fresh, fossils include fusulinids, small horn corals, and pelecypods.............................. | 0.6 |
| Shale, buff yellow, limy, weathers to a fusulinid sand.......................... | 2.3 |
| Limestone, dirty gray to reddish on surface, shale partings in middle, medium to dark gray on fresh surface, massive, crystalline, dense, with brachiopods and pelecypods... | 1.7 |
| Shale, buff-gray, crumbles easily.......... | 1.2 |
| Limestone, dirty gray, with reddish mottling, appears light gray and snowy on fresh surface, large fusulinids abundant................................ | 1.1 |
| Hughes Creek limestone member: | |
| Shale, buff to tan, covered................ | 1.5 |
| Limestone, platy, small shale partings, dark dirty blue-gray, susceptible to chemical weathering, light gray, highly calcitic, sugary appearance, limonite specks, fossil debris, fusulinids, brachiopods. Chert is present, composed of secondary lentils gray-blue in color, with white fusulinids embedded in the chert.................... | 5.0 |
| Limestone, platy, dirty gray on surface, light gray, calcitic, with a snow covered appearance; fusulinids are rare, crinoidal debris, brachiopods....................... | 1.7 |
| Limestone, shaly, weak, dirty dark yellow to gray................................ | 0.6 |
| Limestone, two shale partings near the base, dark gray with reddish mottling on surface, medium gray, crystalline, with calcite and a few specks of limonite..... | 2.0 |
| Shale, buff-yellow, extremely fossiliferous, well bedded, with streaks of clay or claystone. Fossils include, <u>Spirifer</u>, <u>Composita subtilita</u>, crinoidal debris, and several types of bryozoans............... | 2.4 |

| | |
|---|---|
| Limestone, dirty blue, rough surface, many large fusulinids, Composita subtilita, Myalina, medium gray, crystalline | 0.8 |
| Clay shale, fine, sticky, buff yellow, fossils | 0.4 |
| Limestone, medium gray, crystalline, fusulinid, weak, dirty gray on surface | 0.4 |
| Shale, dark blue-gray, splintery | 0.7 |
| Shale, buff-gray, fusulinid, weathering to fusulinid sand, Spirifer, small brachiopods, crinoidal debris | 0.9 |
| Limestone, blue-gray on surface, dark gray, crystalline, fossiliferous, with poor preservation, Myalina; weathers to a rough surface | 0.4 |
| Shale, dark gray, splintery to fissile, fusulinid | 0.3 |
| Sandstone, buff with black staining on surface, some limonite, fossils of calcite are present but badly worn due to reworking. Fine-grained and light cream on fresh exposure | 1.9 |
| Shale, dark gray | 0.1 |
| Limestone, massive, with shale partings, dirty yellow on surface, dark gray crystalline on fresh exposure. Fossils include brachiopods, crinoidal debris, Composita subtilita, and a few fusulinids | 2.4 |
| Shale, light tan on surface, light gray to tan with dark gray to blue streaks parallel to the bedding. Slightly fissile, with thin dark limestone streaks present which are crystalline and contain small fusulinids, and brachiopods | 2.7 |
| Americus limestone member: | |
| Limestone, medium gray with tan streaks on surface, massive, dark gray crystalline on fresh surface. Contains fusulinids | 1.5 |
| Shale, buff-yellow, flaky, easily weathered, with numerous fusulinids | 0.3 |
| Limestone, dirty, mottled gray on surface, medium gray, crystalline, with fusulinids common, standing on the weathered surface | 0.4 |
| Limestone, shaly, weak and platy, yellow-gray on surface, dark gray, crystalline when freshly broken. Fossiliferous with a large number of types including large and small bryozoans, gastropods, crinoidal debris, large fusulinids, horn coral and several brachiopods including Spirifer | 1.0 |

Limestone, varied density, half a foot from the bottom is a thin gray shale break, and 0.7 foot from the top is a thin marly zone above which the beds are platy and fossiliferous. The limestone is crystalline, dark gray, calcitic, almost saccharoidal. The bed is dirty gray on surface, non-fossiliferous in the middle, and full of fossils both in the upper and lower portions. Brachiopods and crinoidal debris abundant in the lower portion, while the upper zone also has small brachiopods and crinoidal debris, along with medium-sized fusulinids, pelecypods and bryozoan fragments........ 3.1

Shale, gray platy.......................... 0.4

Limestone, shaly, creamy gray on surface, light medium gray when fresh, slightly fossiliferous, with a tendency to become banded with light and dark shades of gray, depending on the percentage of shale..... 0.6

Shale, gray, fissile, non-fossiliferous...... 0.8

Limestone, dirty mottled gray, some yellow splotches on surface, dark gray crystalline on fresh surface. Fossiliferous, brachiopods, especially <u>Composita subtilita</u>.................................. 0.9

Shale, platy, dark gray..................... 0.6

Limestone, massive, fossiliferous, dirty gray on surface, dark gray crystalline; fossils include brachiopods, crinoidal remains and rarely bryozoans............. 0.6

Shale, well-compacted, lack of visible bedding gives appearance of claystone, light slate gray, blocky................. 1.3

Limestone, resistant, dark gray, thin bedded, crystalline, fossiliferous in upper part, especially brachiopods.................. 2.1

HAMLIN shale formation:

Oaks shale member:

Shale, slate gray, slabs 4 or 5 inches long weather out easily; Streaks of calcite are present as vein fillings but no fossils are evident...................... 3.5

Houchen Creek limestone member:

Limestone, shaly, massive, non-bedded, slate gray, compact.......................... 1.8

Shale, gray-blue, splintery................. 1.2

IX. Sec. 35, T. 25 N., R. 5 E. Measured from below the spillway to the top of the hill at the northeast corner of the section.

| | |
|---|---|
| GRENOLA limestone formation: | |
| Neva limestone member: | |
| Shale, covered, caps hill which is supported by the limestone below.................. | 5.0 |
| Limestone, not well exposed, thin beds up to 1 foot in thickness. Outcrops are irregular slabs in grass, tan to light gray mottled, dense, crystalline, calcitic with limonite.................................. | 6.0 |
| Salem Point shale member: | |
| Shale, covered.............................. | 10.0 |
| Burr limestone member: | |
| Limestone, thin bedded, with shale breaks, not well exposed, probably a basal bed below.................................. | 2.0 |
| Legion shale member: | |
| Shale, covered.............................. | 9.0 |
| Sallyards limestone member: | |
| Limestone, thin, not resistant, found weathered away from bed. Thickness estimated.................................. | 0.5 |
| ROCA shale formation: | |
| Shale, covered.............................. | 10.0 |
| Sandstone, fine-grained, light tan with specks of dark accessory minerals.............. | 2.0 |
| Shale, covered.............................. | 4.0 |
| Sandstone, fine-grained, evenly bedded, with a light tan color on fresh exposure, while weathering to a dark purple or gray, partly due to lichens growing on the surface.................................. | 2.0 |
| Shale, covered.............................. | 6.0 |
| RED EAGLE limestone formation: | |
| Sandstone, fine-grained, light yellow to tan at the bottom, becoming darker at the top, and showing some ironstain, well sorted.. | 7.0 |
| Shale, covered by grass and rubble, possible limestone beds.......................... | 6.0 |
| Limestone, gray to tan with limonite, highly fossiliferous............................ | 1.2 |
| Shale, tan, platy, with concretions of clay ironstone, and some nodules of limestone or weathered chert, fossiliferous......... | 3.3 |
| Limestone, massive, prominent ledge former, fossiliferous, with brachiopods, corals, bryozoans, and fossil debris. Light tan | |

to brown on weathered surfaces, gray, crystalline, with limonite on fresh surface.................................... 1.3

Shale, tan platy to blocky, with ironstone concretions.................................... 0.7

Limestone, tan, limonite-stained, fossiliferous, on fresh exposure, light blue to gray, crystalline.................................... 0.6

Shale, very dark, platy, possibly bituminous... 0.9

Limestone, broken near the middle by 0.3 of a foot of sandy shale which is light tan in color and has calcareous streaks. The upper portion of the limestone is tan, limonite stained, gray, crystalline, and dense on fresh exposure. The lower part is fossiliferous, and gray, dense, and crystalline on fresh exposure, weathering to a yellow-tan.......................... 2.0

JOHNSON shale formation:

Shale, covered, the top 1 foot is fine light tan blocky siltstone.................... 7.0

Limestone, fragments in grass.................... 0.7

Mudstone, dark gray to black, blocky..........12.0

FORAKER limestone formation:

Shale, tan to brown soft and crumbly, somewhat calcareous, with limestone streaks containing pink calcite..................... 8.0

Covered by masonry, part of spillway........... 12.0

Shale, dark gray to blue-black, blocky, weathers to maroon....................... 6.0

Shale, platy, tan, with limestone stringers.... 1.0

Limestone, shaly, thin bedded.................. 0.8

Shale, calcareous, contains limestone lenses with limonite.......................... 1.5

Limestone, gray to blue, poorly bedded........ 0.5

Shale, dark gray, with limestone stringers..... 1.2

Limestone, dirty gray, fossiliferous........... 0.2

Shale, blocky with clay ironstone concretions, black weathering to gray................. 2.0

Limestone, fossiliferous, fusulinids, mottled grey and brown with white fusulinids standing out on surface. On fresh surface, light gray, crystalline, with calcite.... 1.4

Covered by masonry.............................. 5.0

Limestone, thin platy, easily broken, light gray on surface, with limonite stains. Seems to be recemented with brown calcite, and contains some fragments of lithographic limestone, along with some coarse lime sands. Fossils are present in a poor state of preservation.................... 1.1

Limestone, poorly bedded, gray with limonite stains on weathered surface, weathers to a rough uneven surface. Dark gray, heavy crystalline appearance. Calcite and possibly celestite are present giving reddish brown mottled effect. Fossils weather out and stand on surface, gastropods, cephalopods, Composita subtilita and other brachiopods present, along with crinoidal debris. The bed is dense and hard to break with a hammer unless weathered..... 1.5

HAMLIN shale formation:

Oaks shale member:

Shale, gray, splintery to massive, becoming slightly marly with limestone pockets in the upper half foot.................... 1.6

Water level of the lowest pool below the spillway.

X. Secs. 25 and 26, T. 26 N., R. 5 E. Measured from Salt Creek just south of the Highway 60 bridge westward through the town of Burbank to the top of the hill on highway 60 west of the town.

GRENOLA limestone formation:

Neva limestone member:

Limestone, mottled gray, massive with platy zones. Dark gray crystalline with calcite and specks of gray to brown chert. Fossils include small gastropods, brachiopods and fusulinids...................... 2.5

Shale, covered.............................. 3.0

Limestone, gray, crystalline, sparingly fossiliferous............................ 0.7

Shale, gray, partially covered............. 0.9

Limestone, massive, blotched gray on surface, light dirty gray, crystalline, with gray speckled chert. Fusulinids and crinoidal debris abundant.......................... 1.4

Shale, light gray, fissile.................. 0.3

Limestone, massive, yellow brown on surface, blue-gray with tan brown staining, crystalline, highly fossiliferous, including Spirifer, Chonetes, crinoidal debris, solitary corals, and plicate brachiopods. 1.2

Shale, limy, fossiliferous, buff-yellow to gray.................................. 0.2

Limestone, dirty yellow, soft and crumbly, buff to tan-yellow on fresh surface, somewhat sandy in zones. Fossiliferous, fusulinids, brachiopods, pelecypods...... 0.6

Shale, buff-gray, splintery................. 0.7

Limestone, massive, definite shale partings, light gray on weathered surface, some limonite, dark to medium gray, calcitic, fossiliferous, with Composita subtilita abundant. Much secondary replacement in vertical planes.......................... 1.9

Salem Point shale member:

Shale, dirty gray to brown, buff-yellow on fresh exposure, contains limestone or chert nodules, slabby, fossiliferous, with spiriferoid brachiopods............ 1.7

Limestone, dirty yellow on surface, dark gray, crystalline and massive............ 0.9

Shale, tan-brown to gray, buff-yellow on the surface, fossiliferous.................. 3.9

Limestone, dirty yellow on surface, dark blue-gray, calcitic, crystalline, composed entirely of fossils in the upper part, brachiopods, pelecypods, and crinoidal debris.................................. 0.3

Shale, buff-yellow to light tan, splintery to flaky................................ 6.5

Burr limestone member:

Limestone, light to dark gray, dirty, calcitic, crystalline and limonitic. Fossiliferous, composed of debris which is broken and distorted and difficult to identify. Weathers to dirty yellow. Massive near the base, becoming platy toward the top, with shale intercalations 5.1

Legion shale member:

Shale, covered.............................. 11.1

Sallyards limestone member:

Limestone, light tan, contains limonite and calcite, crystalline, weathers to a tan-yellow mottled appearance. Weathering has produced a foamy or spongy appearance due to pitting and solution holes........ 1.6

ROCA shale formation:

Shale, covered.............................. 12.5

RED EAGLE limestone formation:

Limestone, with shale interbedded; the interval is partially covered and breaks are not clear.................................. 27.5

JOHNSON shale formation:
Shale, covered, possibly thin limestones....... 25.0
FORAKER limestone formation:
Long Creek shale member:
Limestone, massive, tending to be platy near the top. Dark gray with reddish mottling on a pitted surface. On fresh surface the color is light gray with calcite, and nearly saccharoidal. Slightly fossiliferous with large fusulinids.......................................... 5.3
Limestone, dark gray on surface, massive, fossiliferous, highly calcitic, crystalline, dark gray with large white fusulinids replaced by calcite. Pelecypods and bryozoans are numerous.............. 1.6
Shale, light gray, splintery, non-fossiliferous.......................................... 0.3
Limestone, buff-yellow on surface, light gray, slightly calcitic. Large fusulinids, bryozoans, and organic debris. Tendency for shale partings somewhat weak as compared to the limestone beds above and below.......................................... 1.7
Hughes Creek limestone member:
Shale, gray-blue, flaky, about half composed of fusulinids.............................. 3.5
Limestone, blue-gray on surface, dense, medium gray mottled with dark gray, crystalline, Myalina zone, this bed exposed only at low water during dry summer season.......................................... 1.6

XI. Sec. 26, T. 25 N., R. 5 E. Measured along a dry gully draining into Lake Fairfax from the southwest ¼ of the section.

GRENOLA limestone formation:
Neva limestone member:
Limestone, dark gray, dense, fossiliferous, with beds from 0.3 to 1.3 feet thick separated by thin shale partings. The upper 2.0 feet is lighter colored, weathering to a dull buff-yellow.......... 6.0
Shale, covered.......................................... 8.0
Limestone, dense, arenaceous, fossiliferous, thin platy bedding, crystalline, weathers to irregular surface. Mottled with limonite staining, fresh surface, reddish to brown mottling on a gray background...... 3.0

Salem Point shale member:
Shale, yellow-buff, calcareous, crumbly to blocky.................................. 6.0
Shale, covered, thin limestone streaks, which are tan-yellow, platy, and marly... 6.0
Burr limestone member:
Limestone, thin platy, composed of 2 beds separated by a thin shale, weathers to a buff-yellow, faintly crystalline, arenaceous, medium density, manganese dendrites.................................. 1.0
Legion shale member:
Shale, partially covered, dirty hard limestone stringers at the top.............. 11.0
Sallyards limestone member:
Limestone, weathers to a light gray, on fresh surface the color is dark blue-gray, dense, crystalline, fossiliferous, difficult to follow on surface, generally covered with shale from above.................... 0.7
ROCA shale formation:
Shale, covered.......................................... 30.0
RED EAGLE limestone formation:
Howe limestone member:
Limestone, platy, thin bedded, weak and easily weathered........................ 2.0
Bennett shale member:
Limestone, massive, well bedded, with thin shale partings. Weathered surface is limonite stained, irregularly pitted. Fresh surface is dark dove-gray, crystalline with calcite. Fossils are present but difficult to collect in proper condition for identification................ 6.0
Shale, not measured.

XII. Sec. 32, T. 27 N., R. 6 E. Measured near the northeast corner along the section line.

GRENOLA limestone formation:
Neva limestone member:
Limestone, yellow to mottled gray-brown on surface. Mottled light to dark gray on fresh surface, with fusulinids........... 1.3
Shale, weathers to a yellow and contains thin dirty limestones.................... 6.0
Limestone, tan, composed of 0.1 to 0.5 foot beds intercalated with shale. Some of these beds contain blue chert............ 12.0

Salem Point shale member:
Shale, broken by thin lensing limestone stringers with iron stains. The shale is tan on surface with only the upper 6 feet exposed........................ 18.0

Burr limestone member:
Limestone, massive, light gray, medium crystalline texture with some brown chert inclusions. The bed weathers to a rough pitted surface, with vertical solution holes. Maroon to brown staining is present on weathered surface. Fusulinids are present in small numbers............. 2.1
Shale, gray, not measured.

XIII. Sec. 14, T. 27 N., R. 5 E. Measured in the extreme northwest corner of the section, on an outlier held up by the Crouse limestone.

CROUSE limestone formation:
Limestone, platy, with shale partings throughout, pitted on weathered surface, vertical solution holes, fossiliferous... 2.7
Limestone, massive, dirty gray, fossiliferous, one thin shale parting in the middle, light gray crystalline with calcite and slight limonite staining on fresh surface 2.9

EASLY CREEK shale formation:
Shale, partially covered, red and sandy........ 14.5
Limestone, white to gray, mottled on weathered surfaces, gray to tan, streaked with limonite and calcite. Calcite encrusted fossils are common, but specimens are poorly preserved........................ 0.3
Shale, red to maroon.......................... 11.0
Sandstone, dirty red on weathered surface, gray with red stains on fresh surface, fine-grained, compact and lamellar, somewhat friable.......................................... 0.8
Shale, red to maroon, covered with grass....... 5.0

BADER limestone formation:
Limestone fragments in grass, estimated thickness approximately......................... 8.0

STEARNS shale formation:
Shale, red to maroon, covered.................. 17.0

BEATTIE limestone formation:
Morrill limestone formation:
Limestone, heavy, massive, with shale parting in the center. Forms noticeable bench on hillside. Gray with reddish stain on

surface, medium to dark gray with slight mottled appearance on fresh surface................................ 1.3

Florena shale member:

Shale, soft slightly sandy, typical "Permian" red.......................................... 14.5

Limestone, dark gray, dense, massive, no visible fossils, contains calcite streaks 0.3

Shale, maroon to red, partially covered..... 5.4

Cottonwood limestone member:

Limestone, light dirty gray, pitted, slightly massive, light gray on fresh exposure, fusulinids are profuse in quantity....... 0.7

Limestone, shaly, platy, light dirty gray, dense, crystalline, with fusulinids...... 0.7

ESKRIDGE shale formation:

Shale, not exposed........................................ 8.0

Limestone, massive, heavy crystalline, purple-gray in color...................................... 1.0

Shale, maroon.............................................. 11.0

Limestone, gray to buff-yellow on weathered surface, light gray, highly calcitic on fresh exposure. Massive but not resistant, easily broken with hammer, fossiliferous, with fusulinids.................. 1.0

Shale, covered............................................ 15.5

Limestone, dirty gray-brown on weathered surface. Light gray with limonite specks and calcite on fresh exposure. Fossiliferous, with small fusulinids and brachiopod debris. Forms slight bench... 1.4

Shale, maroon, somewhat blocky................. 6.0

Limestone, dark gray, speckled with hematite, crystalline, pitted on weathered surface, fossiliferous.......................... 1.3

Shale, maroon, partially covered............... 17.0

GRENOLA limestone formation:

Neva limestone member:

Limestone, massive, dirty gray, rim former, pitted with limonitestains on weathered surface. Light gray on fresh surface. Fusulinids profuse, gastropods present... 2.0

Shale, covered, possible limestone beds..... 6.0

Limestone, platy, dirty gray, light gray on fresh surface, calcitic, shale partings are frequent. Fossils include brachiopods.............................. 1.3

Underclay, light gray, pasty................ 0.1

Limestone, massive, dirty gray on surface, limonite stains are present, light gray to white when broken with hammer......... 1.0

| | |
|---|---|
| Shale, maroon, splintery.................... | 1.3 |
| Limestone, platy, off-gray on surface, dense, crystalline and light gray, with some brachiopods on fresh surface............. | 0.3 |
| Shale, red to maroon........................ | 1.5 |
| Limestone, platy, light gray on surface, resistant, light gray with dark calcite streaks on fresh surfac. Fossiliferous, brachiopods, pelecypods, bryozoans, and debris................................. | 1.0 |
| Limestone, shaly, platy, fossiliferous, buff-yellow on surface, mottled light to dark gray on fresh surface, crystalline, with calcite replacement. Small brachiopods, crinoidal remains and a few small fusulinids................................ | 1.0 |
| Underclay, light blue....................... | 0.5 |
| Salem Point shale member: | |
| Poorly exposed shale, blue-gray on surface, crumbly, maroon to dark gray on fresh exposure. The interval also includes the upper portion of the Burr limestone...... | 24.0 |

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APPENDIX B

FUSULINIDS OF THE BURBANK-SHIDLER AREA

by I. B. Gold

The specimens discussed herein were collected, mounted, and identified in conjunction with the Master's thesis of David L. Vosburg which is entitled, "Geology of the Burbank-Shidler Area, Northwestern Osage County, Oklahoma." Fusulinids were collected from four zones in the Foraker which may be identified as measured section 8 in the Appendix A of the aforementioned thesis. Measured section 8 is located in the NW$\frac{1}{4}$ of section 10, Township 26 N., Range 6 E. In this area, the Foraker limestone is overlain by the Johnson shale and underlain by the Oaks shale. The Foraker, itself, may be divided into three members in ascending fashion - the Americus limestone, Hughes Creek limestone, and Long Creek shale. The four collecting zones, also in ascending arrangement, are oriented in the section as follows: Zone A begins 4 feet from the Americus limestone-Oaks shale contact and extends approximately 11$\frac{1}{2}$ or some 5 feet above the contact between the Hughes Creek and Americus limestones; Zone B commences some 2.7 feet above the top of Zone A and extends 9.5 feet further into the Hughes Creek limestone; Zone C begins at the termination of Zone B or approximately 17.2 feet above the Hughes Creek-Americus contact, Zone C extends for 5 feet to 1.5 feet below the Hughes Creek-Long Creek contact; Zone D originates 1.5 feet above the base of the Long Creek shale and extends 9.5 feet to the base of the Johnson shale and the top of the Foraker limestone.

From Zone A, the following specimens were identified:

Triticites pinguis Dunbar and Skinner
Triticites ventricosus (Meek)
Schwagerina turki (Skinner)

Triticites pinguis is very rare in occurrence, while Triticites ventricosus and Schwagerina turki are in relative abundance.

In Zone B, the following were identified:

Triticites rothi Skinner
Schwagerina turki (Skinner)
Triticites ventricosus (Meek)

Triticites ventricosus and Schwagerina turki are encountered in great abundance; Triticites rothi is rare in occurrence.

All specimens in Zone C were permineralized to an extent which made identification impossible.

In Zone D, specimens of the following were encountered:

Triticites ventricosus (Meek)
Schwagerina forakerensis (Skinner)
Triticites subventricosus Dunbar and Skinner
Schwagerina turki (Skinner)

Schwagerina forakerensis was very abundant; specimens of Triticites ventricosus and Schwagerina turki were common; Triticites subventricosus was relatively rare.

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