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GEOLOGY OF THE GRAY HORSE AREA, OSAGE COUNTY, OKLAHOMA

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degree of

MASTER OF SCIENCE

BY

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APPROVED FOR THE SCHOOL OF GEOLOGY

BY



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CHAPTER I

INTRODUCTION

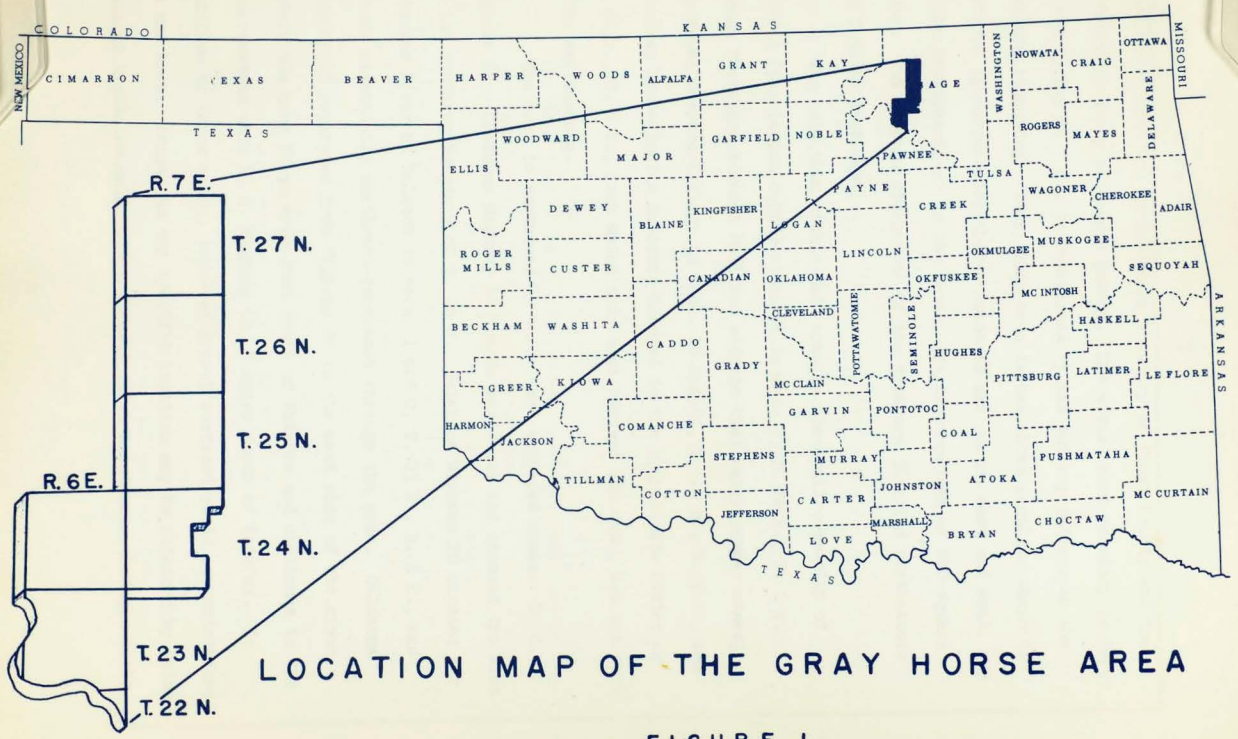
Scope and Purpose

This report is a study of rocks that are exposed at the surface within the Gray Horse area, Osage County, Oklahoma.

The primary objective of this investigation was to map and describe in detail, rock units of Upper Pennsylvanian and Lower Permian age, which constitute the surface rocks of this area. Particular emphasis was placed on areal distribution, changes in lithology, in thickness, and in faunal assemblages along the strike of the beds. In carrying out such an objective a secondary purpose is realized: that of determining the persistence of thin rock units that extend from southeastern Nebraska across Kansas and into north-central Oklahoma as they grade into the basinal deposits in central and southern Oklahoma.

Location and Cultural Description

The Gray Horse area lies in weatern Osage County in north-central Oklahoma. It includes Twps. 27 and 26 N., R. 7 E., most of Twps. 25 and 24 N., R. 7 E., all of Twps. 24 and 23 N., R. 6 E., and that small portion of T. 22 N., R. 6 E., on the north side of the Arkansas River.



LOCATION MAP OF THE GRAY HORSE AREA

FIGURE 1

This river forms the southwestern boundary of Osage County and the northern boundary of Pawnee County. The actual east boundary in Twps. 24 and 25 N., R. 7 E., is determined by the outcrop pattern of the Wakarusa limestone. Thus, this area is one whose peculiar shape is dictated by surrounding theses areas to the north, east and west, and by the Arkansas River to the south. It is comprised of 210 square miles. The average dimensions of the area are 30 miles north-south and 7 miles east-west.

The only town within this area is the small community of Fairfax (population 2,017) situated in sec. 7, T. 24 N., R. 6 E. Though there are several railroad sidings that carry proper names, the Naval Reserve Village in secs. 16 and 21, T 24 N., R. 7 E., and the Gray Horse Indian Reserve, located in the approximate center of T. 24 N., R. 6 E., from which this area derives its name, are the only other settlements.

The area is traversed by three hard surfaced roads. U. S. Highway 60 - Oklahoma Highway 11 trends east-west and crosses the area at the southern boundary of T. 26 N. Oklahoma Highway 20 crosses the Arkansas River at Ralston in secs. 1 and 2, T. 23 N., R. 5 E., and trends essentially northwest-southeast through the area. Oklahoma Highway 18 separates from Highway 20 on the east side of the river, enters the Gray Horse area just south of Fairfax and continues to its intersection with U. S. Highway 60, 9 miles north of Fairfax. In addition to these roads, improved gravel surfaced roads are maintained in the area. Access to any specific location may be obtained by using pasture trails or well location roads which anastomose throughout the

area.

The paucity of improved roads is a reflection of the sparse population associated with cattle raising, which is the principal occupation of the populace, though agriculture is also carried on. The area comprises some of the best grazing land in the state and for the most part is controlled by owners of large blocks of property.

The Gray Horse area is serviced for the most part by the Atchison, Topeka and Santa Fe Railroad, which traverses the area in a general northeast-southwest direction from sec. 19, T. 24 N., R. 6 E. to sec. 12, T. 25 N., R. 7 E., with a north-south spur servicing Fairfax and points north. The northern part of the area is served by the Midland Valley Railroad, which tranverses a small area in secs. 12 and 13, T. 27 N., R. 7 E.

Geography

The Gray Horse area is located regionally in that part of the Central Lowlands Province known as the Osage Plains which is characterized by "Old scarped plains beveling faintly inclined strata;...." (Fenneman and Johnson, 1946). The strata are gently inclined approximately 15° north of west, the respective lithologic units crop out over broad areas, and the surface reflects this somewhat by a gentle westward slope interrupted by cuestas with gentle back slopes to the west and relatively steep east-facing escarpments.

The area lies within a belt of alternating limestones, shales and sandstones. The limestones, though thin, are by far the most prominent and due to their resistance as well as their persistence,

serve as good horizons for mapping. The shales weather rapidly and for this reason form gentle slopes and valleys between the more prominent limestones of the area. The sandstones in the northern three townships are only locally prominent and give rise to topographic expression as small benches beneath the more resistant limestones and where they occur within a thick shale interval. However, the number and thickness of these units increases southward and proportionately their conspicuousness. This is enhanced by the deeper and steeper stream valleys in proximity to the Arkansas River.

Two rather prominent escarpments alternate with gently sloping shale prairies. The escarpments trend essentially north-northeast-south-southwest but display local variations, having projecting points as well as reentrants as a result of stream valley encroachment and associated erosional activity. The more prominent of the two cuestas is by far the most conspicuous topographic feature in the whole area and is capped for the most part by the cherty Hughes Creek limestone member of the Foraker formation. For this reason it is referred to as the Foraker escarpment in this report. Regionally it is the southernmost extension of a series of hills known as the Flint Hills of Kansas.

At its entrance into the area in sec. 2, T. 27 N., R. 7 E., the Foraker escarpment is capped by a resistant limestone in the Pony Creek shale formation and has about 70 feet of relief. Within the same section the Brownville limestone forms the rim of this feature and one mile south is succeeded by the Foraker formation, which maintains this position throughout the course of the escarpment in the Gray Horse area. Southward the relief increases to a maximum of 180 feet and

the escarpment becomes quite steep in the southern part of T. 27 N. and the northern part of T. 26 N. In the central part of T. 27 N. the relief may be said to be 200 feet, but the face of the escarpment steps back more gently, displaying level plateau-like areas over the benches formed by the respective stratigraphic units consituting the escarpment. In the approximate center of T. 26 N. the escarpment veers west and leaves the area. This is due to a decrease in the amount of chert within the Hughes Creek limestone and also to a slight flattening of dip. The escarpment is present in the northwest corner of T. 25 N. and maintains an average relief of 120 feet. The strata are almost flat-lying in this locality. In T. 24 N , R. 6 E., the Foraker escarpment merely fringes the northern boundary.

The land west of the rim of the escarpment in Twps. 27 and 26 N. is a gently sloping plain, dissected by numerous small streams. Though cutting but shallow courses near the rim the streams are entrenched deeply near the western margin of the area, giving rise to steep-sided valleys supported by the resistant limestones of the Foraker formation. In T. 25 N. the area west of the Foraker escarpment is well dissected and locally steeper than the east side.

The view over the escarpment face is the same at all locations in the area; a grass-covered prairie surface gently sloping away from the base and built on easily weathered shale and debris eroded from the face of the escarpment. With the exception of limestone units diverging from the base of the Foraker escarpment with increased distance to the south and a few locally prominent sandstones, the slope continues uninterrupted to the extremely gentle back slope of the

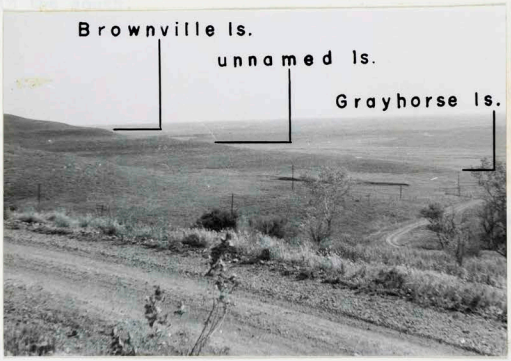


Figure 2. View of the Foraker escarpment, SE¼ sec. 34, T. 27 N., R 7 E.

second prominent escarpment of the area, formed by the Emporia limestone formation.

Though less conspicuous than the Foraker, the Emporia escarpment is, nevertheless, quite prominent and essentially parallels the eastern boundary of the entire Gray Horse area. In the northern part of the area it owes its prominence primarily to the more resistant limestones comprising the Reading member and in general this is true to the south. A sandstone in the lower part of the overlying Willard-Stotler (Dry) shale formation thickens to form prominent protecting ridges in the south.

The maximum relief of the area is more than 480 feet. The highest elevation, more than 1,240 feet, is located in sec. 7, T. 27 N., R. 7 E., and the lowest, less than 760 feet, is along the Arkansas River in the extreme southeast corner of the area. Though maturely dissected in the southern part, the area as a whole may be said to display gentle relief of approximately 60 feet.

The entire Gray Horse area is drained directly by tributaries to the superposed Arkansas River. At the time of this investigation north-central Oklahoma has suffered several abnormally dry years and for this reason otherwise permanent streams are considered intermittent. Salt Creek, the only permanent stream in the area, drains 13 square miles in the extreme west-central part of the area. Its tributaries heading along the back slope of the Foraker escarpment drain approximately 40 square miles. These westward flowing, resequent streams are, from north to south: Dugout Creek, Wamsley Creek, Potato Creek, Rock Creek and Little Chief Creek. Gray Horse Creek

drains 45 square miles, the largest amount of any individual stream in the area. The remainder of the streams, listed in order of their decreasing drainage within the area, are: Hominy, Clear, Middle Bird, North Bird, Sycamore and Dry Creeks.

The drainage pattern is dendritic throughout the area although a radial pattern is partially developed south of the center of T. 24 N., R. 7 E.; influenced by the North Hominy Creek anticline. Except for the superposed Arkansas River, the streams are mostly insequent. Throughout the courses of the respective streams the gradient is gentle to moderate, approximating 20 feet per mile, but increases headward and may increase markedly or decrease with proximity to the Arkansas River, depending on the stage of development of the stream valley.

The area is essentially a grass-covered, rolling plain with trees largely confined to the stream valleys. However, as sandstone units increase and thicken southward, scrub oak covers their exposures at places with a heavy growth. In the southern part of T. 24 N., and T. 23 N. the area is densely covered with such trees.

Previous Investigation

Previous work in this area is confined to a study made of the Foraker Quadrangle by K. C. Heald and others in 1915 (1916, p. 17) and the U. S. Geological Survey rapid reconnaissance survey of 1918-19 which covered all of Osage County (White, 1922). Both of these previous studies were made for the purpose of increasing petroleum reserves through discovery and development to aid the nation's effort in World War I. Though the complete stratigraphic sequence within the area is

not described, those units valuable as marker beds in structural mapping are described in detail and promising drilling locations recommended.

Heald's original work was not duplicated by the U. S. Geological Survey reconnaissance, but he made subsequent changes near the southern boundary of the Foraker Quadrangle in connection with this survey. His work in T. 27 N., R. 7 E. is the only part that is included within the Gray Horse area.

Due to the need for a re-evaluation of petroleum and natural gas resources in Oklahoma, the state geological survey, largely through the efforts of representative geologists of the entire state, compiled additional data that were published in 1928. H. T. Beckwith was responsible for preparing the part dealing with Osage County. No field investigation was made in connection with this publication as the information was gathered from published and unpublished material.

Pioneer work was done on much of the stratigraphic classification in Kansas, Nebraska and northern Oklahoma, and since that time R. C. Moore and G. E. Condra have done much to revise and improve the classification through subsequent studies too numerous to mention.

In addition to the investigations mentioned above, graduate students of the University of Oklahoma, in cooperation with the state geological survey, have contributed greatly through recent thesis studies bordering the area.

Present Investigation

The field work for this report was accomplished during the

months of May, June, July and August, 1956, but some reconnaissance was made during the preceding winter and spring.

The field investigation involved mapping those stratigraphic units considered of value, measuring sections where possible, describing in detail the various lithologies and collecting rock samples and fossils for further study and identification.

The mapping was effected by the use of airplane photographs with transparent acetate overlays on which were traced mappable beds, drainage and boundaries of alluvial material and eolian deposits. This information, with the exception of that on the drainage, was obtained primarily from field investigation but supplemented by stereoscopic examination of the photographs. The drainage was traced completely by such examination. The data were then traced onto a copy of a base map of the area prepared by the writer prior to the field work. This base map was constructed to the same scale as the photographs, 3.16 inches per mile, and the proportional grid system according to the measurements of the original survey of the area obtained from the county surveyor's office in Pawhuska, Oklahoma. The cultural features were taken from the photographs by observation and located in their correct positions relative to the grid system. Section corners were placed on the photographs to coincide with section line roads and elsewhere by plotting their locations.

Stratigraphic sections were measured with the aid of a hand level and six-foot steel tape, and lithologic descriptions made simultaneously. No corrections were made for dip as it proved negligible, and few sections were measured over a horizontal distance

exceeding 150 yards.

The dip was computed by application of the three point method, using elevations obtained from the U. S Geological Survey topographic maps of the area, and averages 40 feet per mile to the west. The strike at most places is about N. 10° E., but varies as does the dip due to numerous small structures within the area.

Insoluble residue analyses were made on the limestone samples, and the insoluble material studied for content.

The data resulting from this investigation will be used in a report on Osage County by the Oklahoma Geological Survey.

CHAPTER II

STRATIGRAPHY AND LITHOLOGY

GENERAL STATEMENT

The stratigraphic sequence exposed in the Gray Horse area comprises approximately 290 feet of Upper Pennsylvanian (Virgil) and 180 feet of Lower Permian (Wolfcamp) rocks. The rocks of the Virgil series are all restricted within the Wabaunsee group and those of the Wolfcamp series within the Admire and Council Grove groups. The oldest stratigraphic unit studied within the area is the Wakarusa limestone and the youngest is no higher than the base of the Neva limestone, though the entire interval above the Red Eagle is largely covered.

PENNSYLVANIAN-PERMIAN BOUNDARY

The Pennsylvanian-Permian contact is essentially a conformable one in the northern Mid-continent region, the dividing line chosen being somewhat arbitrary. Prior to 1932 the base of the Cottonwood limestone had been popularly drawn as the base of the Permian system. At this time, R. C. Moore (1932, p. 89) proposed to lower the boundary to the base of the Americus limestone on the basis that "...the most sharply defined changes from lithologic and paleontologic characters of the Upper Pennsylvanian rocks to those of the Lower Permian beds

occur at this horizon".

Shortly thereafter, the base of the Permian was redefined (Moore and Moss, 1934, p. 100) as the disconformity marked by the Indian Cave channel sand at the base of the Admire shale. This disconformity is found only locally, and though obscure, is the only evidence to date of an interruption of the sedimentary cycle in this part of the section in the northern Mid-Continent region. It is traceable from Nebraska into Oklahoma, and at places the base of the channel is reported to rest as low as the Dover limestone. Where this sandstone is absent, the top of the Brownville limestone is taken as the base of the Permian system.

In the Gray Horse area, the interval between the Brownville limestone and the Americus limestone is 50 feet and the rocks are mostly shale. The only sandstone within this section occurs 10 to 18 feet above the Brownville. It is approximately 4 feet thick and is locally persistent only south of the northern part of T. 26 N. However, in the southern part of T. 25 N., the sandstone begins to develop again and reaches its maximum proportions outside of the area in the C S$\frac{1}{2}$ sec. 35, T. 25 N., R. 6 E. This massive sandstone is approximately 8 feet thick and is so prominent that it all but obscures the Brownville's expression at this location. The possibility that this sandstone is the Indian Cave sandstone is no more than a possibility, but it could be its correlative. No marked channeling at this horizon was observed. At the latter location and in the SE$\frac{1}{4}$ sec. 34, T. 27 N., R 7 E., where the sand is well developed, numerous large fragments of silicified wood occur on the Brownville limestone

and the slope below. A Calamites cast was also found below the Brownville at the former location.

In situ fragments of silicified wood were not found, but the writer is of the opinion that they weather out of this sandstone horizon. Although these fragments are not evidence of any disconformity, they at least represent a period of time when this area was in a near shore environment due to a slight regression of the seas. These fragments and their significance seem to form some basis, however small, for a logical choice of the existing Pennsylvanian-Permian contact within the Gray Horse area.

PENNSYLVANIAN SYSTEM

Virgil Series

The Virgil series is the youngest of the Pennsylvanian system as recognized in the Mid-Continent region, and derives its name from the town of Virgil, Greenwood County, Kansas. Defined by R C. Moore (1932, p. 96) it includes the strata from the base of the Tonganoxie sandstone member of the Stranger formation to the base of the Permian system. In this same paper, he proposed the base of the Americus limestone as this horizon but subsequently lowered it to the base of the Admire shale or the top of the Brownville limestone (Moore and Moss, 1934, p. 100), depending on the presence or absence of the Indian Cave channel sand.

On the basis of "differences in lithology and nature of cyclic deposits," the Virgil of Kansas has been subdivided into three groups (Moore, 1951, p. 55). They are, in ascending order: Douglas, Shawnee,

and Wabunasee. Of these, only the Wabaunsee group is present in the Gray Horse area. The term Wabaunsee is used rather than its central Oklahoma equivalent, the Vanoss, because of the similarity to shelf-type sediments of Kansas rather than the basinal-type of central and southern Oklahoma.

Wabaunsee Group

C. S. Prosser (1895, p. 689) named and described the Wabaunsee from exposures in Wabaunsee County, Kansas. As employed originally, it was of formational rank and included the sequence of beds from the top of the Osage coal (Nodaway coal - Moore, 1948, p. 2036) to the base of the Cottonwood limestone. The sequence was later raised to the status of a group. In 1932 the boundaries were lowered, as re-defined by Moore (p. 94), to include the strata between the top of the Topeka limestone and the base of the Americus limestone, proposed at the same time as the base of the Permian. As the base of the Permian was subsequently lowered to the Brownville limestone, the top of the Wabaunsee was so redefined. As thus restricted, Condra (1935, p. 9-11) published the first paper reflecting the present boundaries, and Moore (1936, p. 200) concurred.

The Wabaunsee of Kansas and Nebraska is divided into three subgroups (Condra, 1935, p. 45) named after type localities in southeastern Nebraska and northeastern Kansas. They are the Richardson, Nemaha and Sacfox subgroups. This division is based on lithologic differences and varying resistance to erosion as reflected by topographic expression. As defined by Condra and Bengston, only beds

within the Richardson and part of the Nemaha are present in the Gray Horse area. South of Lyon County, Kansas the Tarkio limestone, uppermost Nemaha, is not present, and for this reason Taylor (1954, p. 10) extended the base of the Richardson to the top of the Elmont limestone in his adjoining area due north of this one. Though primarily devised for usage in Kansas and Nebraska, this subdivision may be applied with certain modifications to north central Oklahoma. The writer questions the applicability of these units to southern Osage County, but will use those affecting this area as modified by Taylor.

Due to "the desirability of designating larger divisions of the rock column as formations and reducing previously defined thin formations to the rank of members..." a recently published paper (Moore and Mudge, 1956, p. 2271-2278) adopts new nomenclature for the Lower Permian (Admire group) and Upper Pennsylvanian (Wabaunsee group) strata of the northern Mid-Continent region.

Bern Limestone Formation

Definition. Named from the type locality near Bern, Nemaha County, Kansas, it is a newly defined formation (Moore and Mudge, 1956, p. 2276) which includes the strata below the Auburn shale and above the revised Scranton shale (ibid, p. 2277). It is comprised of "persistent escarpment-forming limestones..." and in the Gray Horse area is represented only by the uppermost or Wakarusa limestone member though the formation extends to the base of the Burlingame limestone.

Wakarusa Limestone member

Definition. Beede (1898, p. 30) applied this name to a

limestone unit exposed along Wakarusa Creek south of Auburn, in Shawnee County, Kansas. Later, Condra (1927, p. 66) associated this term with a limestone bed in Nebraska which he thought to concur with the original definition, but when this unit was traced into Kansas it was found to occupy an interval some 40 feet or so below Beede's Wakarusa. Due to the need for a differentiation of Condra's Wakarusa from the Burlingame 20 feet below, and the subsequent usage of his definition, Condra's usage has been retained and Beede's Wakarusa was subsequently named the Reading. The Cryptozoon limestone (Heald, 1918, p. 64) of Oklahoma was identified as the Wakarusa in 1949 (Moore, p. 183).

Distribution and Thickness. The Wakarusa limestone is a thin but continuous unit recognized from Nebraska into Oklahoma. This limestone makes no continuous appearance in the Gray Horse area except for Twps. 24 and 25 N., R. 7 E., where it forms the eastern boundary. Otherwise, its principal exposures are along east-flowing streams that head within the area.

Throughout most of the area, the Wakarusa consists of two limestone beds separated by a thin shale interval with a combined thickness of two to three feet. However, in the extreme southern part of the area a thickness of 5.5 feet was observed. The writer believes this additional thickness is not through divergence, but is due to additional limestone beds and separating shale intervals above the two beds metioned previously. Whether this thickening is gradational toward the south or merely local cannot be ascertained within this area. From reference to theses dealing with this unit east and south

of the Gray Horse area, however, the writer is inclined to believe that the thickness at this location is part of a regional southward thickening.

Character and Remarks. The Wakarusa is comprised of two limestone layers throughout most of this area. Although it derives most of its identifying characteristics from the lower of the two, it was originally named in Oklahoma due to the presence of numerous "Cryptozoon" which occur in both beds. These "Cryptozoon" are concentrically laminated algal organisms and are named "Cryptozoon" due to their likeness to these plants confined to Cambrian and Ordovician time. Their average observed diameter in this area is approximately two inches. Though numerous in the northern three townships, their number declines markedly southward.

The lower of the two beds is an extremely dense, brittle, steel-blue limestone one foot thick, though observed to be almost two feet at one locality. It ranges from fine-crystalline to non-crystalline and displays a sub-conchoidal fracture. Though the term fossiliferous does not seem appropriate, this bed contains, as well as "Cryptozoon", a few fusulinids, becoming numerous in the southern part of the area, brachiopods, bryozoans and fragments of other fossils. The features of this lower bed are those most commonly quoted in reference to the Wakarusa limestone and serve to distinguish it throughout the area.

The upper bed is separated from the lower by 0.5 foot of drab shale and is 0.8 foot thick. It displays the same color as the underlying limestone on a fresh surface but weathers to shades of brown.

Commonly, a one-half inch layer of deep brown limonitic material veneers the upper surface of this bed. Only at a good exposure is this thin layer observable. This limestone contains more numerous "Cryptozoon" and fusulinids than the lower one; displays locally prominent vertical jointing and weathers more rapidly.

The three additional limestone beds in the south are similar to this upper one that is continuous in the area.

Although the Wakarusa is prominent in the northeast part of T. 24 N., R. 7 E., it is at most places topographically inconspicuous. It is readily located by its typical expression of a slight break in slope, along which numerous angular fragments of steel-blue limestone are found. Good exposures are limited to the two mentioned in the Appendix, one in a stream bed in the SE¼ SE¼ sec. 11, T. 25 N., R. 7 E., and along the southern boundary of T. 24 N., R. 7 E.

Insoluble residue analyses reveal that the lower Wakarusa limebed averages 96.5% carbonate. The insoluble material consists predominantly of silt and clay particles. Some carbonaceous material was found in a sample from T. 23 N.

Auburn Shale Formation

Definition. Beede (1898, p. 30) named the Auburn shale from exposures near Auburn in Shawnee County, Kansas. As originally defined, it included the shale known now as the Harveyville. Condra (1927, p. 78) restricted this to the strata between the Wakarusa limestone below and the Emporia limestone above.

Distribution and Thickness. The Auburn shale is 56 to 68 feet



Figure 3. Thickest occurrence (5.5 feet) of the Wakarusa limestone, NW¼ NW¼ sec. 1, T. 22 N., R. 6 E.



Figure 4. The Wakarusa limestone showing its typical nature where well exposed, west edge of the SW¼ SW¼ sec. 34, T. 25 N., R. 7 E.



Figure 5. Lowest and middle beds of the Reading limestone, C E½ sec. 11, T 27 N., R. 7 E.

thick in the Gray Horse area. At most places it forms a steep slope below the Emporia limestone.

Character and Remarks. The strata are predominantly fissile shale, ranging through shades of maroon to gray to drab brown, and are locally fossiliferous. The sandstones within the Auburn are discontinuous and only locally prominent within the northern two townships of the area, but begin to develop with some persistence southward from the southern part of T. 25 N., R. 7 E. In the SE¼ sec. 36, T. 27 N., R. 7 E., a limestone 7 feet thick is exposed along Middle Bird Creek about 18 feet above the Wakarusa. This thickness is local, as southward it is about 2 feet. Although not present at all exposures, a limestone occupies this position as far south as sec. 2, T. 24 N., R. 7 E. This limestone is irregularly bedded and is singularly characterized by its high fossil content, most prominent of which is abundant crinoidal debris; some columnals are prominently fluted. Approximately 40 feet above the Wakarusa lies a bed of limestone, estimated to be one foot thick and containing numerous Myalina sp. and brachiopod fragments. This bed is more persistent than the one discussed previously and some evidence of it is present at most places. Its southern extent is indefinite, but it persists at least as far as sec. 25, T. 23 N., R. 6 E., where it is about 45 feet above the Wakarusa.

Emporia Limestone Formation

Definition. This name was employed originally by M. Z. Kirk in 1898 (p. 80) from studies along the Neosho River near Emporia,

Kansas. Although its application has been controversial, Condra (1927, p. 78) establishes its present limits and defines it as the first limestone below the Willard shale and above the Auburn shale. Moore (1936, p. 224) correlated Heald's Stonebreaker (1928, p. 63) with the Reading limestone, but later (1948, p. 2037) correlated the Stonebreaker with the entire Emporia.

The Emporia limestone consists of three members which were recognized as composing this formation by Condra in 1935 (p. 10). Although the member names had been applied previously, they were generally recognized as formational in rank (Moore, 1936, p. 224) and the name Emporia was discarded. Moore and Mudge (1956, p. 2276) revived the term and reduced the Reading limestone, Harveyville shale and Elmont limestone to member rank. Though no definite type section exists for the Emporia, Moore and Mudge (1956, p. 2276) propose a paratype section and the writer suggests a similar classification for an exposure along the south bank of North Bird Creek in the C E$\frac{1}{2}$ sec. 11, T. 27 N., R. 7 E.

Distribution and Thickness. The Emporia formation is an escarpment-forming limestone from the edge of the area in sec. 12, T. 27 N., R. 7 E., southward to the Arkansas River. The escarpment parallels the eastern boundary of the Gray Horse area, and at most places the formation occupies the upper part of this pronounced feature. South of sec. 11, T. 25 N., R. 7 E., a thick sandstone development in the overlying Willard-Stotler (Dry) shale at many places forms the rim. At these places the Emporia occupies the lower part of the escarpment face. The distribution of the Emporia limestone covers a large area west of

the center of T. 24 N., R. 7 E. Although somewhat restricted on the map (Plate I) to the Elmont member, the fusulinid-bearing bed of the Reading may also be seen along the stream in secs. 16 and 17, T. 24 N., R. 7 E. This restriction is due to the approximate equality of the steepening dip found on the west flank of the North Hominy Creek anticline, and the stream gradient.

The Emporia limestone displays a marked thickening southward. In the C E½ of sec. 11, T. 27 N., R. 7 E., it is 33 feet and in sec. 35, T. 26 N., R. 7 E., it has increased to 42 feet, thickening proportionally within each member. In sec. 8, T. 25 N., R. 7 E., the thickness is 43 feet but southward in sec. 21, T. 24 N., R. 7 E., only 34 feet was measured. Yet, in sec. 13, T. 23 N., R. 6 E., the thickness is 47 feet. A limestone similar to the upper Elmont limestone bed in T. 27 N., is not exposed south of sec. 2, T. 26 N., R. 7 E. However, limestone does occur at the approximate position and for this reason the upper limit of the Emporia is defined not by one distinctive bed or beds, but by a zone of limestone deposition. A sandy, maroon facies of the Emporia interfingers with the area's predominant type along the eastern border of Twps. 22 and 23 N., R. 6 E.

Good exposures, other than those mentioned in the appendix, occur along the stream in the N½ sec. 11, T. 26 N., R. 7 E., and along the south bank of the Gray Horse Creek tributary in the SW¼ sec. 24, and the C N½ sec. 25, T. 24 N., R. 6 E.

Reading Limestone Member

Definition. Smith named this limestone in 1905 (Moore, 1936,

p. 223-224) from exposures nearing Reading in Lyon County, Kansas. It is the basal member of the Emporia formation.

Description and Remarks. The Reading limestone ranges from a thickness of 17 feet in the northern part of the area to 23 feet in the southern part and is the most prominent and readily distinguished member of the Emporia formation. It is composed of four separate limestone beds; only three of which are conspicuous at any place other than a good exposure. The lower layer averages 2 feet, weathers yellowish, and is best characterized by an irregular upper surface caused by an accumulation of small to large, blue-gray, fusiform algal pellets. This lower layer is also fossiliferous, containing numerous pelecypod fragments, and in the southern part of the area it may weather light gray or brownish. Along the west bank of the stream in the SW¼ SE¼ sec. 13, T. 24 N., R. 7 E., a 10-foot algal reef is exposed (Fig. 7). This reef is composed almost entirely of algal pellets in what is probably a calcareous matrix, secreted by algae and is an over-development of this basal algal unit. The next limestone bed is separated from this basal one by 2 feet of gray shale in the northern part of the area. A 0.1 foot smutty coal occurs in the middle of the interval. This coal is not believed to extend south of T. 27 N., but poor exposures prohibit further study of this interval. The two limestone beds above this shale are similar and are separated by 0.5 foot of blue-gray shale in T. 27 N. Both beds are gray to dark gray on a fresh surface, but are blotched by limonite on the weathered surface. They are finely crystalline to non-crystalline, dense, brittle, display prominent vertical jointing and are fossiliferous. The lower of the

two is 1.5 feet thick and is absent, or is altered appreciably in the southern part of T. 26 N. The upper bed averages 2 feet and is by far the most prominent and readily identified bed within the Emporia formation. In addition to those characteristics common to these similar limestones, the upper one contains more numerous fusulinids, abundant "Cryptozoon", a few horn corals, and is persistent throughout the area. Southward the number of "Cryptozoon" decrease and the fusulinids increase markedly both in size and number. Locally in association with this bed is a 0.5 foot layer of deep brown stained limestone that is found at most places to lie immediately over it, but may occupy a lower horizon. In the south and eastern part of T. 24 N., R. 7 E., a light gray limestone containing numerous gastropods replaced by calcite is found locally about 3 feet below this prominent bed, and overlies a light gray, sandy limestone that grades into a sandstone in the C E½ sec. 21, T. 24 N., R. 7 E. The upper limestone in the Reading is separated from the underlying one by 6 feet of drab to maroon shale in the northern part of the area, but closely overlies this bed in the southern part. This upper limestone is similar to the basal layer. It is light gray, averages 1.5 feet, displays locally prominent vertical jointing and has an extremely irregular upper surface. It too is an algal pellet limestone, locally fossiliferous and dense, though crumbly in the southern part of the area.

Insoluble residue analysis of the basal algal unit reveals it to be 97.3% carbonate. The residue consists largely of extremely fine quartz grains. A similar study of the fusulinid and "Cryptozoon"-bearing bed discloses it to be 94% carbonate in T. 27 N., and 93% in

T. 23 N. The residue consists predominantly of clay and silt particles.

Harveyville Shale Member

Definition. This member occupies the position above the Reading limestone and below the Elmont. It was defined and described by Moore (1936, p. 226) from its type locality near Harveyville in southeastern Wabaunsee County, Kansas.

Description and Remarks. The Harveyville shale in the Gray Horse area includes the strata between the top of the upper algal limestone in the Reading, and the base of the first well-bedded limestone encountered above. The interval is about 7 feet in T. 27 N , and is estimated to be about 8 feet in the northern part of T. 26 N. Southward the measurement varies because of the obscurity and changeable character of the Elmont limestone zone.

The Harveyville is predominantly a gray, fissile shale becoming sandy southward. In T. 27 N., a 0.2 foot smutty coal occurs 2 feet above the upper limestone in the Reading and is overlain by 1.5 feet of brownish, compact, irregularly bedded, coquinoid limestone. The coal is traceable to the southern boundary of T. 27 N., and is not present in the northern part of T. 25 N. Its southern extent is therefore limited to T. 26 N., but poor exposure precludes a more definite determination. The coquinoid zone contains mostly broken fragments of fossils and extends at least to the SW$\frac{1}{4}$ sec 7, T. 24 N., R. 7 E.

Elmont Limestone Member

Definition. As originally defined by Beede (1898, p. 30) and as recognized today, this unit is the first limestone below the Willard shale and lies above the Harveyville shale. The type locality is at Elmont, Shawnee County, Kansas.

Description and Remarks. This limestone is the uppermost member of the Emporia formation. It is 8 feet thick in T. 27 N. and is composed of two thin (0.5'), nondescript limestones with an intervening gray shale and an upper limestone 2 feet thick. This upper one is brownish to pale yellow, fossiliferous and weathers readily into irregular fragments. Its character is apparent only at a good exposure but it is traceable into the northern part of T. 26 N., and is the unit mapped. Throughout the rest of the area the Elmont is described from the various limestones mapped at this horizon. In the remainder of T. 26 N., the Elmont consists of three limestones probably with intervening thin shale breaks. The lower two are gray and fine- to medium-crystalline. The upper one is dirty brownish, medium- to coarse-crystalline, appears slightly conglomeratic, weathers into thin slabs and contains an abundance of fossil fragments, most noticeable of which are Myalina subquadrata and brachiopods. This bed is the only one evident at this horizon through T. 25 N. and the northern part of T. 24 N., R. 7 E., and lies about 27 feet above the fusulinid-bearing bed in the Reading. In the western and southern part of T. 24 N., R. 7 E., the eastern part of T. 24 N., R. 6 E., and T. 23 N., R. 6 E., a light gray, sandy appearing, but definitely algal limestone, is mapped as the Elmont. This 2-foot limestone is massive and locally prominent,

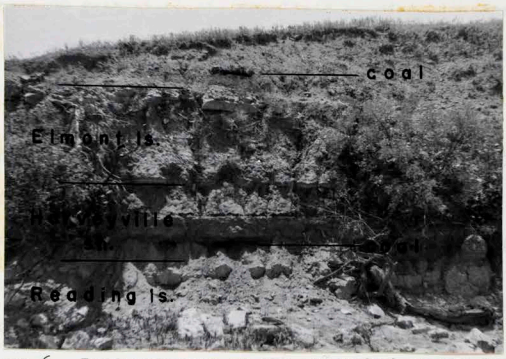


Figure 6. Best exposure of the upper bed of the Reading limestone (lowermost in the picture), the Harveyville shale and the Elmont limestone, C E$\frac{1}{2}$ sec. 11, T. 27 N , R. 7 E.



Figure 7. Irregular bedding displayed by an extreme development of the lower algal limestone at the base of the Reading limestone, SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 13, T. 24 N., R. 6 E.

occurring about 22 feet above the fusulinid-bearing limestone in the Reading.

Willard-Stotler (Dry) Shale Formation

Following a procedure suggested by R. C. Moore (1935, p. 86-87) and followed by Taylor (1954, p. 19), the writer designates the above-named formation to include the strata between the underlying Elmont limestone and the questionable Grandhaven limestone above. This procedure is followed here due to the lateral discontinuity of certain limestone beds that define the boundaries of intermediate formations in Kansas and Nebraska. The Willard shale was named by Beede in 1898 (p. 31) and defined by Moore (1936, p. 22) to include the interval between the Elmont and Tarkio limestones. The latter unit is not recognized south of Lyon County, Kansas. The intervening formations are recognized in Kansas and Nebraska as the Zeandale and Pillsbury shale formations. In the Gray Horse area the top of the latter unit is indistinguishable from the base of the Dry shale member of the Stotler limestone due to the absence of the contact-defining Dover limestone. This formation is a continuous sandstone and shale sequence to the base of the Grandhaven limestone.

Distribution and Thickness. This formation has the widest exposure of any in the Gray Horse area and the belt of outcrop broadens southward. In the northern part of the area the unit crops out from the base of the Foraker escarpment to the top of the Emporia escarpment. As the former veers westward in the southern part of T. 26 N., the Grayhorse limestone becomes prominent and the base of this small

escarpment serves as the limit to the outcrop. As sandstones develop prominence southward, this formation occupies a large part of the Emporia escarpment and extends farther west as the Grayhorse loses all but local prominence.

The Willard-Stotler (Dry) formation ranges from 35 feet in T. 27 N., R 7 E., to approximately 50 feet in T. 24 N., R. 6 E.

Description and Remarks. As the name denotes, this formation is primarily shale, although it also contains appreciable sandstone and siltstone in the south. The shales form gentle grass-covered slopes at most places, but where observed are olive-drab to gray or drab brown and fissile to blocky. A coal occurs about 2 feet above the base of this formation. It ranges from 0.3 to 1 foot thick and is overlain by an extremely fossiliferous shale and subsequently a brownish, coquinoid limestone. The coal extends southward at least to the NE¼ NW¼ sec. 16, T. 24 N., R. 7 E., where it is exposed along the east side of the road about 23 feet above the fusulinid-bearing bed in the Reading limestone. Other than the location mentioned above, and in the Appendix (measured section 8), it is also exposed along the small stream bed in the SE¼ NE¼ SW¼ sec. 2, T. 26 N., R. 7 E. The overlying fossiliferous shale is present at least as far south as the SE¼ NW¼ sec. 33, T. 24 N., R. 6 E., and fragments of the coquinoid limestone may be found at most places throughout the area. The sandstones are, at most places, buff to tan, fine-grained, massive, and show cross-bedding near the base. The most persistent and prominent bed lies from 20 to 28 feet above the Elmont and ranges from 2 to 8 feet, although locally the sandstone may channel appreciably into the gray

shale below, resulting in a greater thickness. The sandstone is particularly prominent above the Emporia limestone along the escarpment in Twps. 25 and 24 N., R. 7 E., and forms the bluffs along Gray Horse Creek in the southeastern part of T. 24 N., R. 6 E. In the southern part of T. 24 N., R. 6 E., a massive sandstone about 30 feet above the previous one attains prominence and caps several butte-like hills. Other than these, the sandstones are only locally developed, grading into siltstone and shale, but the formation as a whole becomes more sandy southward.

Stotler Limestone Formation

Definition. According to Moore and Mudge (1956, p. 2275), "the Stotler limestone comprises strata underlying the Root shale and overlying the Pillsbury shale". The type section is west of Miller, Lyon County, Kansas, and is composed of the Dover limestone, Dry shale, and Grandhaven limestone. For reasons mentioned previously the only member recognized in this area is the Grandhaven limestone and this unit is only tentatively correlated on position alone.

Grandhaven (?) Limestone Member

Definition. Defined by Moore (1936, p. 237) from exposures near Grandhaven in Shawnee County, Kansas, it overlies the Dry shale and is underlain by the Dover limestone. In Kansas it is composed of two beds separated by several feet of shale. Taylor (1954, p. 24-25) found only the upper bed present in the area of his investigation immediately north of the Gray Horse area.

Description and Remarks. In this area the Grandhaven limestone

or limestones occupying its supposed stratigraphic position, is exposed only in sec. 11, T. 27 N., R. 7 E., and sec. 8, T. 23 N., R. 6 E. The northern bed is a 1-foot calcarenite, tan, fine-grained, ferruginous, containing some fossil fragments, and lies 13 feet below the Jim Creek limestone. The southern bed is the same distance below the Jim Creek and is the same thickness as in T. 27 N. It is brownish, non-crystalline to crystalline, and fossiliferous.

Root Shale Formation

Definition. This formation includes the strata between the Stotler limestone and the overlying Wood Siding formation as defined by Moore and Mudge (1956, p. 2275) from exposures in Lyon County, Kansas. It consists of the Friedrich shale, Jim Creek limestone and the French Creek shale members.

Distribution and Thickness. This formation averages 32 feet and attains no prominence. Its distribution is determined by the prominence of the Grayhorse limestone, which influences the degree of slope below.

Friedrich Shale Member

Definition. This member, named by Moore in 1934 (Moore, 1936, p. 238), is the basal member of the Root shale and is overlain by the Jim Creek limestone.

Description and Remarks. The Friedrich shale averages 13 feet in this area. As the Grandhaven limestone is only questionably present the lower limit of the Friedrich shale is impossible to determine throughout most of the area. This member is almost entirely blue-gray,

fissile shale becoming sandy and silty in T. 23 N. Taylor (1954, p. 26) reports a coal in the upper part of the Friedrich. This was observed about 2 feet below the overlying Jim Creek in the SE¼ sec. 26, T. 28 N., R. 7 E., but poor exposures preclude a study of this interval in the northern township of this area. However, an extremely carbonaceous zone persists from the NE¼ SE¼ sec. 3, T. 26 N., R. 7 E., to the southern part of T. 24 N., R. 6 E. In T. 26 N., it is one foot below the Jim creek and about 9 feet below in T. 24 N., R. 6 E. Commonly, a fossiliferous shale and an overlying coquinoid limestone occur above this zone. Limonite or ironstone concretions are also common above the fossiliferous zones in T. 24 N., R. 6 E.

Jim Creek Limestone Member

Definition. Named by Moore in 1934, it was first defined by him in 1936 (p. 239) from exposures on a creek by the same name in Pottawatomie County, Kansas. It is described as a "thin but persistent limestone" and lies between the Friedrich shale and the French Creek shale.

Description and Remarks. This limestone changes markedly from its appearance in sec. 26, T. 28 N., R. 7 E., to its exposure in the Gray Horse area. In this area it is persistent but silty and nowhere prominent. The thickness is 2 feet in T. 27 N. and the northern part of T. 28 N., but averages one foot throughout the remainder of the area. It lies 30 to 35 feet below the Grayhorse limestone. The Jim Creek is blue-gray but weathers yellowish-brown to reddish-brown. It is non-crystalline and commonly fossiliferous,



Figure 8. Typical Jim Creek limestone underlain by the carbonaceous zone (point of pick), NW¼ SE¼ sec. 3, T. 26 N., R. 7 E.



Figure 9. The Grayhorse limestone displaying typical bedding, C N½ N½ sec. 17, T. 24 N., R. 6 E.

though fossils are lacking in T. 23 N., R. 6 E., where it becomes extremely silty and slightly arenaceous.

Insoluble residue analyses disclose the Jim Creek to be 82.7% carbonate in T. 27 N. and the carbonate content to decrease southward to 78.9% in T. 24 N. The insoluble material consists of fine particles of quartz and carbonaceous matter for the most part, but muscovite flakes are also evident in T. 27 N.

French Creek Shale Member

Definition. The name was derived from the "French" shale as used by Moore and Condra (1932, p. 97), and was named by the former in 1934 from exposures along French Creek in northeastern Pottawatomie County, Kansas. Moore defined it in 1936 (p. 240) as the strata between the base of the "Caneyville" limestone and the Jim Creek limestone.

Description and Remarks. The thickness of this formation is variable in the Gray Horse area. The overlying Nebraska City limestone is present only in T. 27 N., and the northern part of T. 26 N., and does not occupy a consistent position. This shale averages 18 feet where the Nebraska City is present but consists of strata that are referred to in the measured sections as the French Creek-Plum shale in most of the area and is there 30 to 35 feet thick. The French Creek is a gray, fissile and unfossiliferous shale; but in Twps. 24 and 23 N., R. 6 E., the French Creek-Plum shale is entirely maroon at most places.

Wood Siding Formation

Definition. Though previously used to designate the location

of a measured section, the name was first applied to a formation by Condra (1943, p. 41) from exposures in Nemaha County, Nebraska. This formation included the strata from the base of the "Caneyville" limestone to the base of the Brownville limestone. Acceptance of the term for the entire northern Mid-Continent region was not until 1956, when it was redefined (Moore and Mudge, p. 2273) to include the Brownville limestone.

Nebraska City Limestone Member

Definition. First proposed by Condra (1927, p. 108) as a limestone within the Admire-McKissick Grove shale member of the Wabaunsee formation, it was later defined by Moore (1936, p. 241) as the basal member of the "Caneyville" limestone. The term "Caneyville" has since been discarded and the Nebraska City was recognized as formational in rank until the recent revision by Moore and Mudge. The type locality is in Caneyville Township, Chautauqua County, Kansas.

Description and Remarks. This limestone overlies the French Creek shale, underlies the Plumb shale, and is present only in Twps. 27 and 26 N. One of two different limestones is possibly the Nebraska City. The limestone most probably the Nebraska City is established with reference to both the Jim Creek and the Grayhorse limestones. In sec. 11, T. 27 N., R. 7 E., it is found 5 feet below the Grayhorse and 25 feet above the Jim Creek. In sec. 3, T. 26 N., R. 7 E., it is 13 feet below the former and 19 feet above the latter. It is about 2 feet thick, brownish-yellow, soft, porous, extremely limonitic and weathers rapidly. Locally it stains the underlying shale member maroon

for several feet. The other possibility is dark gray, weathers brownish, is coarsely crystalline, conglomeratic and fossiliferous. It is restricted to the northern part of T. 27 N., where it is locally prominent at the base of the Foraker escarpment and ranges from about 3 to 5.5 feet in thickness. This limestone is the bed Taylor (1954, p. 28-31) described as the Nebraska City in T. 28 N., R. 7 E. The relationship of this bed to the Grayhorse and Jim Creek limestones was only possible to establish in measured section 8 (Appendix, p. 92). At this location this limestone lies 17 feet above the Jim Creek but 30 feet below the position of the Grayhorse. No reason is advanced for this abnormal interval.

Insoluble residue analysis of the extremely limonitic bed discloses it to be 73.6% carbonate. The insoluble material consists almost entirely of clay and silt particles.

Plumb Shale Member

Definition. This shale between the Nebraska City limestone and the Grayhorse limestone, until recently, has remained unnamed though considered a part of the discarded "Caneyville" limestone. It is named by Mudge and Burton (Moore and Mudge, 1956, p. 2275) from exposures in the township by the same name in southeast Wabaunsee County, Kansas.

Character and Thickness. The Plumb shale underlies the Grayhorse limestone. It averages 14 feet in thickness and is composed entirely of maroon, fissile shale. Where the Nebraska City is absent, this maroon color extends down to the Jim Creek at most places.

Grayhorse Limestone Member

Definition. This thin limestone was defined by Bowen in 1918 (p. 138) from its "excellent exposure on the crest of the Little Grayhorse anticline in the NW¼ sec. 11, T. 24 N., R. 6 E." Although its identification may be positive from this location, as well as others, this exposure has become obscure and the writer proposes a paratype section at the center of the section line separating secs. 8 and 17, T. 24 N., R. 6 E. The presence of this limestone in Kansas was almost ignored until 1936 (Moore, p. 241-242) when it was recognized as entering at least the two southernmost townships in Chautauqua County. Further work in this area should determine its northern character and extent.

Distribution and Thickness. In the northern half of T. 27 N., the Grayhorse limestone occupies a position in the middle to lower part of the Foraker escarpment, though exposures are spotty. Southward it is exposed increasingly lower in the slope and is found along the base in the southern part of T. 27 N. It diverges from the escarpment as the latter veers gently southwestward in the center of T. 26 N. The Grayhorse attains its maximum prominence in the southern part of this township but is readily traced southward, essentially following the gravel road from U. S. Highway 60-Oklahoma Highway 11. In the southwest quarter of T. 25 N., an overlying sandstone obscures the exposure of the Grayhorse but evidence of its presence is found at the ends of most of the projecting spurs. In T. 24 N., R. 6 E., it is readily traced, but exposures become more obscure southward as the soil cover thickens and locally thick sandstones are introduced. Wind-

blown material obscures any exposures in the southwest corner of T. 24 N., R. 6 E., and partially in T. 23 N.

The Grayhorse limestone ranges from 0.8 feet to 3 feet thick in this area but averages 1.5 feet. Most of the exposures are poor for any purpose other than identification, as the typical expression is slump blocks or thin weathered slabs.

Description and Remarks. Due to its characteristics this limestone is one of the most easily identified beds in the area.

The only beds likely to be confused with it are the upper bed of the Elmont in T. 25 N., R. 7 E., a thin, brownish, fossiliferous limestone about 30 feet above the Grayhorse, and the fossiliferous Nebraska City limestone in secs. 2 and 12, T. 27 N., R. 7 E.

The Grayhorse is dark gray on the fresh surface, but weathers brownish. In addition, it is medium- to coarse-crystalline, slightly algal, massive to cross-bedded, conglomeratic and fossiliferous. The algal nature is evident only on a fresh surface where a few small pellets can be seen. The conglomeratic material is at most places one centimeter in diameter or smaller, and appears as small gray-blue to brown spots. This material weathers more readily than the matrix, and commonly occurs in ill-defined zones which are accented during weathering. This causes the bedding to appear irregular to cross-bedded. Good exposures illustrating this are found at the tip of the spur in the SW$\frac{1}{4}$ sec. 29, T. 25 N., R. 7 E., and along the western edge of the NW$\frac{1}{4}$ sec. 20, T. 25 N., R. 7 E. The fossils that compose the limestone are mostly small fragments but Myalina sp. are numerous. Most of these occur in the basal part, constituting at places a 4-inch

layer. The Grayhorse is locally composed entirely of these pelecypods and may be seen as such in the banks of small streams in the SW¼ SW¼ sec. 17, T. 25 N., R. 7 E. and in the NE¼ NE¼ NE¼ sec. 2, T. 24 N., R. 6 E. At these locations the shale below the bed is extremely sandy, reflecting the special environment resulting in the highly abundant pelecypods.

Insoluble residue analyses reveal the Grayhorse to be 94% carbonate in T. 27 N., but that the carbonate content decreases southward to 86.4% in T. 24 N. The insoluble material consists predominantly of fine quartz grains and numerous pink particles of celestite.

Pony Creek Shale Member

Definition. This name was first used by Condra (1927, p. 81) in referring to the strata between the Dover and the Brownville limestones and was considered a part of the McKissick shale. In 1934 (as cited by Moore, 1936, p. 243), Moore restricted its application by raising the base to the top of the "Caneyville" or the Grayhorse limestone. The type locality is along Pony Creek in the vicinity of Falls City, Nebraska.

Distribution and Thickness. The Pony Creek shale is composed of 85 feet of strata in the northern part of the area and approximately 100 feet in the southern part. It is predominantly shale and as a unit weathers readily, although certain beds are prominent.

Along the trend of the Foraker escarpment this formation forms a steep slope below the Brownville limestone. As the Grayhorse limestone diverges from the escarpment the lower part of the Pony Creek

slopes away from the base gently. The formation is exposed over a maximum area in the southwest part of T. 26 N., R. 7 E. and through much of T. 24 N., R. 6 E.

Description and Remarks. This shale formation may be divided into two parts. The lower 50 feet consists primarily of alternating thin limestones and shales throughout most of the area. The only persistent sandstone bed lies 6 to 8 feet above the Grayhorse and is particularly evident south of the center of T. 26 N., where it slumps to obscure the Grayhorse. The limestones of this lower part are all about one foot thick and are poorly exposed. Along the Foraker escarpment their presence is evident from small discontinuous benches. There are five such beds in this lower part. From limited exposures the older four seem to be similar; gray, crystalline and fossiliferous, containing abundant crinoidal debris and brachiopods. At a good exposure in sec. 31, T. 26 N., T. 7 E. (see measured section 12) a 0.6 foot coal bed lies an estimated 15 feet above the Grayhorse and below the previously mentioned limestones. This same coal is found in the railroad cut in the NW¼ sec. 10, the SE¼ NW¼ sec. 3, in the east bank of the stream in the NW¼ NE¼ SE¼ sec. 5, and the south bank of Salt Creek along the north section line of the NW¼ NW¼ sec. 7, T. 24 N., R. 6 E. At these exposures the coal is about 22 feet above the Grayhorse limestone (the only limestone exposed is at the former two) and the coal ranges up to one foot thick in sec. 7 above. Poor exposures preclude study of this interval southward. The youngest of these limestones is not recognizable by its lithologic characteristics alone, but rather by its persistance,

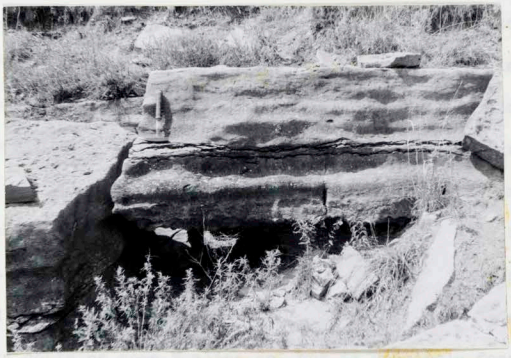


Figure 10. Massive nature of the unnamed limestone in the Pony Creek shale, SE¼ NW¼ sec. 3, T. 26 N., R. 7 E.



Figure 11. The unnamed limestone capping the Foraker escarpment and weathering back along a thin parting, NE¼ NE¼ sec. 2, T. 27 N., R. 7 E.

prominence and relationship to other strata. For these reasons, it is mapped through most of the area. It lies about 50 feet above the Grayhorse and 35 feet below the upper or prominent fusulinid-bearing bed in the Brownville limestone. These measurements range to 60 and 40 feet respectively, southward. This unnamed limestone rims the Foraker escarpment in sec. 2, T. 27 N., R. 7 E , and is easily traced by both field observation and airplane photographs throughout the remainder of the escarpment's course. It ranges from 2 feet thick in sec. 2, T. 27 N., R. 7 E., where it consists of two beds with a 0.4-foot shale parting, to a massive 3 feet in sec. 3, T. 26 N., R. 7 E. This limestone is light gray, medium-crystalline and commonly contains some Myalina sp. but is sparingly fossiliferous as a whole.

Insoluble residue analysis reveals this unnamed limestone to be 92.8% carbonate. The residue consists largely of extremely fine quartz particles and minor amounts of biotite.

The upper part of the Pony Creek shale is largely shale, drab to blue-gray and fissile. However, a sandstone about 2 to 3 feet thick lies approximately 6 feet above the limestone just discussed. This sandstone is tan to brownish, fine-grained, massive and highly micaceous. It is persistent and prominent throughout T. 27 N., and much of T. 26 N. A 0.3 foot coal bed lies about 10 feet below the Brownville. In addition to those locations mentioned in the measured sections (Appendix, pp. 98 and 99), this coal is also exposed on the east side of the road in the $SW\frac{1}{4}$ $NW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 21, T. 26 N., R. 7 E., and along the west side of the road in the $NW\frac{1}{4}$ $NE\frac{1}{4}$ $NW\frac{1}{4}$ sec. 18,

T. 25 N., R. 7 E. Poor exposures preclude study of this interval southward.

A conspicuous channel sandstone is evident in the northeast quarter of T. 24 N., R. 6 E. Where determinable, this sandstone channels to a position approximately 20 feet above the Grayhorse and is 12 feet thick, massive to irregularly bedded, cross-bedded and conglomeratic in the lower part. This sandstone attains a maximum thickness of 35 feet in the NW¼ NW¼ NW¼ sec. 9, T. 24 N., R. 6 E., and forms the steep walls of Three Mile Canyon. At this location the sandstone must closely overlie the Grayhorse or channel barely through it. The Grayhorse is not exposed. Evidence of this thick sandstone is restricted to the aforementioned area though the sandstones in the Pony Creek do increase noticeably south of this location.

Brownville Limestone Member

Definition. This limestone was named by Condra and Bengston in 1915 (Moore, 1936, p. 244) from exposures south of Brownville in Nemaha County, Nebraska. The history of its relative stratigraphic position is reviewed under the discussion of the Pennsylvanian- Permian boundary. It defines the top of the Pennsylvanian system in the northern Mid-Continent region.

Distribution and Thickness. This member is 6 to 7 feet thick, but at most places only the upper bed is exposed. The Brownville outcrop at the north is first encountered in sec. 3, T. 27 N., R. 7 E., but is obscure until it attains a position rimming the Foraker escarpment along the center of the section line dividing secs. 2 and 3,

T. 27 N., R. 7 E. From this location southward, it maintains a prominent position at the middle to upper part of the escarpment and as outliers proximate to the escarpment. In T. 23 N., R. 6 E., the Brownville is obscure beneath the overlying massive sandstone developed in the Foraker, but is prominent at the ends of projecting spurs. It is one of the most readily traceable units in the Gray Horse area.

Description and Remarks. The Brownville is composed of two limestone beds separated by 4 to 5 feet of drab shale, and siltstones. The most prominent and easily recognized bed is the upper one. Its thickness ranges from 1.5 to 2 feet. Commonly massive, it may contain a 0.1 foot parting at the approximate middle and in addition, is gray to brownish, fine- to medium-crystalline, dense, argillaceous and contains numerous fossils of which fusulinids are most abundant. Large crinoid columnals are also abundant. This limestone forms an abrupt bench and large slump blocks commonly mark its position. The lower bed, or similar beds, is 0.5 to one foot thick and is evident only at good exposures. It weathers tan to brownish, is silty but crystalline, and contains numerous pelecypod fragments (Myalina sp.) commonly replaced by calcite. In the northern part of T. 27 N., this lower part consists of a fusulinid-bearing bed. It forms a small bench beneath the more prominent upper bed and weathered buff fragments mark its position. The lower bed is also prominent in the northeast corner of T. 24 N., R. 6 E., where it lies about 7 feet below the upper bed.

The Brownville limestone mapped in the Gray Horse area is the same bed mapped by Taylor in his area (1954, Pl. I and reconnaissance),



Figure 12. Lower beds of the Brownville limestone underlying slump blocks of the upper or fusulinid-bearing bed, SW¼ SE¼ sec. 17, T. 26 N., R. 7 E. (Hammer in left-center).



Figure 13. Lower massive beds of the Americus limestone, NE¼ NW¼ sec. 3, T. 26 N., R. 6 E.

and Fisher (1956, personal communication), but was mapped by Bowen (1922, Pl. XXIII) and Vosburg (1954, Pl. I) as the base of the Foraker.

Insoluble residue analyses disclose the upper bed of the Brownville to be 88.9% carbonate in the northern part of the area and 87.5% in the southern part. The insoluble material consists largely of clay and silt particles, minor amounts of fine quartz grains, and numerous fragments of partially silicified fusulinids.

PERMIAN SYSTEM

The Permian system in North America is divided into the Wolfcamp, Leonard, Guadalupe and Ochoa series (Adams, 1939, pp. 1673-1674). Only the lowermost Wolfcamp is present in the Gray Horse area.

Wolfcamp Series

The Wolfcamp series is represented by approximately 835 feet of sediments in Kansas (Moore, 1944, p. 160). Previously called the Big Blue series, as named by F. W. Cragin (Wilmarth, 1938, p. 180), it entered Kansas nomenclature as a group in 1917 and was raised to series status in 1932 (Moore and Condra, p. 95). The base of this series fluctuated with the placing of the Pennsylvanian-Permian boundary, but the upper boundary remained stationary at the top of the Wellington shale of the Sumner group. In 1943, Condra and Reed (p. 30) lowered the upper limits to the top of the Herington limestone of the revised Chase group, thereby restricting the included strata. The name Big Blue was discarded by Moore in 1944, (p. 160) and the present name, as advocated by Adams, applied.

The Wolfcamp strata of the Gray Horse area, as may be said of

the entire northern Mid-Continent region, display a definite contrast to those of Wabaunsee age. Those of the Wolfcamp are composed of alternating light colored limestones, some of which contain an appreciable amount of chert and occur in thick sequence; gray to varicolored shales and a small amount of sandstone that increases considerably southward. In comparison, the Virgil rocks are composed of numerous, thin, pure to silty, dark to brown to gray limestones, althernating with thick units of gray to drab to maroon shales and brownish sandstones.

The Wolfcamp series is composed of the Admire, Council Grove and Chase groups, of which only the first two are present in this area.

Admire Group

Definition. The Admire group, or as originally named by Adams (1903, p. 53) the Admire shale, constitutes the strata from the top of the Brownville limestone to the base of the Americus limestone. It was named from exposures near Admire in Lyon County, Kansas, and at this time was considered to occupy the position between the Emporia limestone and the Americus limestone. Since first named, the application of the term has been controversial due to a lack of definite boundaries, resulting from what Condra (1927, p. 72) termed an erroneous correlation of the Emporia limestone. Adams assigned a thickness of only 40 feet to this interval that is actually some 240 feet in the Gray Horse area. For this reason Condra redefined the Admire shale, restricting it to its present boundaries though it was considered Pennsylvanian until 1934. The Admire attained group status

in 1935 (Condra, p. 8) and was composed of seven formations. Recent revision (Moore and Mudge, 1956, p. 2274) has reduced this number to three. The former formations are reduced to members and old member names are discarded. The formations comprising the Admire group are: the Onaga shale, Falls City limestone and Janesville shale. The Falls City limestone is not recognized in the Gray Horse area nor are any other limestone units within this interval, which is therefore referred to as the Admire shale.

Admire Shale Formation

Distribution and Thickness. Throughout the area this formation is restricted to the steep slope between the Brownville and Foraker limestones.

The Admire shale ranges from 48 feet in the northern part of the area to 55 feet in the southern part.

Description and Remarks. This formation consists predominantly of gray to drab to maroon shale and a small amount of siltstone. Sandstone in this formation is restricted to the lower part and is discussed under the section dealing with the Pennsylvanian-Permian boundary. The only characteristic limestones of this formation are found in the upper part. The upper of these limestones is 3 to 5 feet below the base of the Americus limestone. These four limestones are all similar and are separated by 0.3 to 0.8 foot shale intervals. The limestones range from 0.3 to 0.9 foot and are dark gray, non-crystalline, dense, brittle and have prominent vertical jointing. The bed below the upper one displays numerous Aviculopecten

sp. on the upper surface. A 0.1 foot coal bed is found locally 0.5 foot below the Americus in the southern part of T. 27 N. and the northern part of T. 26 N. A one foot thick carbonaceous shale zone with numerous irregular 1/4-inch seams of coal occurs one foot below the lower of the four similar limestones in a stream bed in the NE¼ SE¼ SE¼ sec. 30, T. 27 N., R. 7 E. A gray, crystalline, locally fusulinid-bearing limestone is found about 20 feet below the Americus at most places in the southern half of Twps. 26 and 25 N., R. 7 E., and the northern part of T. 24 N., R. 6 E.

The only evidence of the Five Point limestone is fragments containing numerous small gastropods found behind the house in the SW¼ SE¼ NW¼ sec. 3, T. 27 N., R. 7 E. These fragments occur about 16 feet above the Brownville limestone and compose the upper part of the Five Point limestone in the Foraker area (Taylor, 1954, p. 42).

Council Grove Group

Definition. The Council Grove group was named by Prosser (1902, p. 709) from exposures near the town of Council Grove in Morris County, Kansas. It included strata from the base of the Cottonwood limestone to the base of the Wreford limestone. The base was later lowered by Beede to include the Neva limestone, and in 1932 (Moore and Condra, p. 95) it was extended to its present position to include the Americus limestone.

This group is represented in this area by approximately 130 feet of sediments falling within the defining limits of the first five of the following constituent formations: Foraker limestone, Johnson

shale, Red Eagle limestone, Roca shale, Grenola limestone, Eskridge shale, Beattie limestone, Stearns shale, Bader limestone, Easly Creek shale, Crouse limestone, Blue Rapids shale, Funston limestone and the uppermost Speiser shale.

Foraker Limestone Formation

Definition. This limestone was named by Heald (1916, p. 25) from exposures north of the town of Foraker in Osage County, Oklahoma. Due to its chert content and thickness, it forms the prominent rim of Ekler Canyon in sec. 16, T. 29 N., R. 7 E. In his description, Heald approximates the thickness at 74 feet. This measurement, exaggerated about 25 feet when compared with its assigned thickness in this area and in surrounding areas, is believed by Taylor (1954, p. 44) to include the Admire group and the Brownville limestone as well. The writer is in agreement with Taylor in so far as the exaggeration of Heald's assigned thickness, but the base of this interval would have to have been about 30 feet lower to include the Brownville. Bowen's reported thickness of 110 feet (1922, p. 282) undoubtedly included the Brownville.

The Foraker limestone formation includes the strata above the Admire shale and below the Johnson shale, and is composed of three members as defined by Condra in 1935 (p. 8). They are: the Americus limestone, the Hughes Creek limestone and the Long Creek limestone. The intermediate Hughes Creek is termed a shale in Kansas and Nebraska, but for obvious reasons is treated as a limestone in this area.

Distribution and Thickness. This limestone constitutes some

45 to 55 feet of Council Grove strata within the Gray Horse area. It is restricted to the rim of the Foraker escarpment and the gentle back slope of the cuesta. It is exposed over most of T. 27 N., the northwest quarter of T. 26 N., in the western part of T. 25 N., the northern border of T. 24 N., R. 6 E. and the west central part of T. 23 N.

Americus Limestone Member

Definition. This limestone was named by Kirk in 1896 (p. 80) from exposures along the Neosho River just south of Americus in Lyon County, Kansas. Originally, it was considered a member of the Wabaunsee formation separate from the Hughes Creek and Long Creek limestones, which were placed in the since discarded "Elmdale" shale member (Prosser and Beede, 1902, p. 708).

Description and Remarks. The Americus averages 10 feet in thickness in the Gray Horse area. It is largely limestone with intervening thin shale intervals. The only truly characteristic beds in this unit are two lower massive limestones. Together these two limestones constitute about 4 feet with a marly, shaley zone separating them and a one foot shale interval overlying them. This separating zone is extremely fossiliferous as to number and variety of fossils and ranges from 0.5 to one foot. Fusulinids are extremely abundant. Though both of these limestones are similar, the lower one averages 1.7 feet and is more prominent because it retains its massive nature, whereas the upper one is commonly divided by shale partings. Both limestones are gray, crystalline, dense and contain abundant small to large

fusulinids. The upper one displays the more numerous specimens and at some places it is literally packed. Of the remaining beds, there are no particularly characteristic ones. They consist of limestones, commonly fusulinid-bearing and range up to one foot thick, alternating with drab to gray, fissile shales. The contact with the overlying Hughes Creek is commonly picked at the base of the first shale that weathers back noticeably.

Along the rim and back slope of the Foraker escarpment north of T. 25 N., the Americus is mapped only where its outcrop noticeably diverges from the prominent expression of the overlying Hughes Creek limestone; and at outliers where the Hughes Creek is absent or limited to a small exposure.

Insoluble residue analyses of the lower massive bed disclose it to be 91% carbonate in the northern part of the area and 88% in the southern part. The insoluble material consists of limonitic material, small chert fragments and minor amounts of extremely fine quartz particles.

Hughes Creek Limestone Member

Definition. The member was named and described by Condra in 1927 (p. 85) and was proposed at that time as a shale, tentatively within the "Elmdale" shale. Named by Prosser and Beede in 1902 (p. 708), the "Elmdale" included strata from the top of the Americus to the base of the Neva limestone. Bass, in 1929 (p. 52), restricted the base of the "Elmdale" to the top unit of the Foraker.

Description and Remarks. The Hughes Creek limestone ranges



Figure 14. The more prominent lower massive bed of the Americus limestone overlain by the weathered upper massive bed, NW$\frac{1}{4}$ sec. 31, T. 27 N., R. 7 E.



Figure 15. Hughes Creek limestone displaying the interbedded character of chert lenses, NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 19, T. 27 N., R. 7 E.

from 22 feet thick in T. 27 N., to approximately 33 feet in T. 23 N. The base of this limestone member is chosen at the base of the first well-defined shale interval that weathers back over the Americus. In Twps. 27 and 26 N., a yellow-brown, crystalline limestone, containing abundant crinoidal debris, lies above this shale. This limestone ranges from 1 to 1.5 feet, and slabs are commonly seen along the Foraker road in these townships. The top of this member is chosen at most places at the base of the first thick limestone sequence that occurs over a conspicuous shale break.

Throughout most of T. 27 N. and T. 26 N. this member forms the rim of the Foraker escarpment as well as the walls of the steep-sided stream valleys. In this part of the area this member is composed largely of light gray, crystalline, medium- to thick-bedded, cherty, fusulinid-bearing limestone. The cherty limestone sequence is a continuous one ranging from 9 to 18 feet with no observable shale intervals. Fusulinids are abundant, restricted to no particular beds, and are just as numerous in the associated chert. The limestone commonly has a cavernous appearance where chert nodules have weathered out.

The chert is gray or gray-blue on the fresh surface but commonly weathers brownish to flesh pink. The contained fusulinids are white to off-white. The porous appearance of much of this chert is due to fusulinids and other organisms weathering out. Though it may be found as nodules 3 inches in diameter or smaller, it normally occurs as lenses interbedded with the limestone. These lenses range up to 5 inches in vertical dimension and may be measured in feet horizontally. Twenhofel (1919, p. 407-429) believes that this chert is primarily of

replacement origin penecontemporaneous with limestone deposition.

There is no observable chert in the Hughes Creek south of T. 26 N., though a minor amount may persist for exposures are poor. A sandstone occurs in the lower part of the Hughes Creek in T. 25 N. and though not evident in sec. 6, T. 24 N., R. 6 E., Fisher (1956, p. 81) reports this member to consist largely of sandstone and shale in the SW¼ sec. 11, T. 24 N., R. 5 E. This is true in the Gray Horse area in the west central part of T. 23 N., R. 6 E. At this location the Hughes Creek is composed predominantly of sandstone and covered intervals presumed to be shale. A massive sandstone in the lower part is the most prominent bed. It ranges from 6 to 12 feet and is tan to buff, fine- to medium-grained and cross-bedded in the lower part.

Insoluble residue analyses reveal the Hughes Creek to be 97% carbonate in T. 27 N. and 95.6% in T. 24 N., R. 6 E. The insoluble material consists of highly abundant limonitic particles and extremely fine quartz grains in the northern part of the area, and is predominantly clay and silt particles in T. 24 N., R. 6 E.

Long Creek Limestone Member

Definition. The Long Creek is the uppermost member of the Foraker limestone formation, underlying the Johnson shale. The history of its nomenclature is similar to that of the preceding Hughes Creek, as they entered the literature simultaneously.

Description and Remarks. The thickness of this limestone member ranges from an average of 12 feet in T. 27 N., to a maximum of

17 feet in the southern part of the Gray Horse area. It is poorly exposed throughout the area as it weathers back as a unit and for this reason is a difficult bed to map.

In Twps. 27, 26 and the northern part of 25 N., it resembles the Hughes Creek in most respects except that the Long Creek is thin- to medium-bedded, displays locally prominent vertical jointing, weathers slightly pit and cusp, and the chert appears to occur more as nodules than lenses. The base weathers back noticeably along the shale at the top of the Hughes Creek. The cavernous appearance in the Long Creek is evident as far south as the northern part of T. 25 N. Chert fragments are rare at this location but a cherty coating lines the walls of a few cavities. Any shale intervals within the Long Creek are ill-defined in the northern two townships due to its poor exposure, but they become evident as well-defined covered intervals in T. 25 N. and increase southward. In T. 23 N., this member consists of three limestone beds with intervening shale. The limestones are gray, blotched by limonite stains, crystalline, dense, and the lower two contain abundant fusulinids. Those in the middle bed are long and slender, whereas they are plump in the lowest bed.

Insoluble residue analyses disclose the Long Creek to average 95% carbonate. The insoluble material consists of relatively large chert fragments and in T. 24 N., R. 6 E., it is restricted to abundant, fine quartz particles.

Johnson Shale Formation

Definition. This shale formation was established by Condra

(1935, p. 8) upon the division and discontinuance of the "Elmdale" shale. As defined, it occupies the interval between the Foraker limestone formation and the Red Eagle limestone formation.

Distribution and Thickness. The Johnson shale is 30 to 35 feet thick in the Gray Horse area and is restricted to the upper part of the stream divides on the back slope of the Foraker escarpment in the western part of T. 27 N. and the northwestern part of T. 26 N.

Description and Remarks. This shale formation is grass covered in this area except for approximately 2 feet of poorly exposed limestone that lies about 9 feet above the base. The limestone is gray to tan, fine to coarsely crystalline, pitted and contains abundant small fusulinids. Fragment concentrations of similar limestones locally occur below this bed as well as above. No sandstone fragments were observed in the covered interval so the remainder of the formation is probably shale with a minor amount of siltstone. Taylor (1954, p. 51) reports it to be a gray shale except for a thin bed of maroon shale that lies about 10 feet below the Red Eagle limestone.

Red Eagle Limestone Formation

Definition. Originally named by Heald in 1916 (p. 24), its present boundaries were defined by Condra (1927, p. 86) as the strata between the Johnson shale and the overlying Roca shale formation. Heald described the formation from exposures near the now destroyed Red Eagle school in the NW¼ NW¼ SW¼ sec. 26, T. 26 N., R. 6 E. Condra subdivided the Red Eagle into the Glenrock limestone, the Bennett shale and the uppermost Howe limestone. South of southeastern

Greenwood County, Kansas, the Bennett is a limestone (O'Connor and Jewett, 1952, pp. 338-339). Though an attempt has been made to follow this subdivision in the measured stratigraphic sections, the exposures are extremely poor and any attempt by the writer to describe this unit under the defined subdivisions would be senseless.

Distribution and Thickness. The Red Eagle limestone is present only in the western one-third of T. 27 N. and along the west edge of the northwest part of T. 26 N. Other than small outliers, the only exposures are limited to the northwest part of T. 27 N., and the two projecting spurs in T. 26 N.

At the only location where a complete thickness could be measured it is 12 feet.

Description and Remarks. The rocks of this interval are poorly exposed but appear to consist entirely of limestone, divisible into three parts. The lower 4 feet is thin-bedded, gray to off-white, medium to coarsely crystalline, appearing sugary on a fresh surface, and displays numerous small (no larger than one centimeter) inclusions of limonitic material. The weathered surface displays a banding or lineation of crystalline calcite that may have resulted from algal growth.

The thickness of the middle limestone is 3 to 4 feet and it is the most distinctive and prominent bed of the Red Eagle in this area. It probably belongs to the Bennett limestone member. It is off-white to light gray, medium- to thick-bedded, the surface feels chalky and it is extremely pitted and cavernous. Abundant fragments of this rock occur in the southern part of sec. 8, T. 27 N., R. 7 E.



Figure 16. Typical pitted, cavernous appearance of the medium- to thick-bedded Red Eagle limestone, SE¼ SE¼ sec. 8, T. 27 N., R. 7 E.

The upper part of the Red Eagle is light gray, medium-crystalline, thin-bedded and weathers back so as to be inconspicuous.

Insoluble residue analysis reveals the pitted and cavernous bed to be 98.4% carbonate. The insoluble material is mostly limonitic, but it also contains a minor amount of extremely fine quartz grains.

Interval from the Red Eagle Limestone to the Neva Limestone

The only strata in the Gray Horse area within these limits occur in sec. 7, T. 27 N., R. 7 E. The rocks are essentially covered, except for one thin limestone in the upper part and for this reason are assumed to be largely shale. The description of the included strata will be summarized and interpreted from the reports of Taylor (1954, pp. 57-61) and Vosburg (1954, pp. 56-60) in surrounding areas.

The only exposure of the Roca shale in Taylor's area is just south of the Kansas state line. It has a thickness of 18 feet at this location and consists of about 12 feet of maroon shale overlain by 6 feet of yellowish-drab shale. Vosburg's description discloses the Roca to be 14 feet thick in T. 26 N., R. 5 E. Though there is 29 feet of covered interval in the Gray Horse area from the top of the Red Eagle to the base of a slightly prominent limestone exposure above, the writer arbitrarily selects Taylor's measurement (18 feet) as the Roca thickness and places the remaining 11 feet within the Grenola limestone formation.

The Grenola formation is divided into the following members in ascending order: Sallyards limestone, Legion shale, Burr limestone, Salem Point shale and the Neva limestone. From intervals determined

by Taylor and Vosburg, the 11 feet mentioned above probably include the first two members. The exposed limestone would then be the base of the Burr limestone. It is gray, medium to coarsely crystalline, medium-bedded and contains extremely abundant small fragments of fossils. These may be tiny algal pellets, but it is doubtful. Above this limestone there is 10 feet of covered interval that is restricted to a small crescent shaped hill; the highest point in the Gray Horse area with reference to both elevation and stratigraphy. The slope is littered with numerous small, brown chert fragments and the interval probably approximates the strata below the eroded Neva.

QUATERNARY DEPOSITS

In this area extensive deposits of eolian and terrace material form a surficial cover over much of the area north and northeast of the Arkansas River. This veneer extends as far as 4 miles from the river and up to 160 feet higher. In addition to being unstratified, these deposits are buff to dirt gray but locally display a pale orange color, and form essentially vertical slopes along road cuts and streams. The size of this material is largely silt and fine-grained sand, but with increasing proximity to the Arkansas River the ratio of fine and medium-grained sand to silt increases. The constituent grains are predominantly quartz and for the most part are subangular to subrounded, although well rounded grains are common and frosted ones are numerous. It is probable that this material was derived from the Arkansas River flood plain and transported by wind during the Pleistocene and Recent epochs.

Flood plain deposits of alluvium fill the valleys of the Arkansas

River and Salt Creek and partially those of Gray Horse, Dry, Sycamore, Hominy and Clear Creeks. These deposits consist of clay, silt, sand and gravel that are essentially unstratified and are strikingly similar to eolian material except that they are poorly sorted. The larger fragments display typical polished and abraded surfaces. It also displays the characteristic of vertical walls along stream courses. These deposits probably originated as the result of fluviatile and eolian deposition during the Pleistocene and Recent epochs.

CHAPTER III

HISTORICAL GEOLOGY

Rock units in the Gray Horse area are represented by 480 feet of upper Pennsylvanian (Virgil) and lower Permian (Wolfcamp) strata. These units consist primarily of marine beds of limestone, shale and sandstone, and coal of terrestrial origin.

Deposition of these sediments occurred on an essentially featureless, shallow water platform extending from southeastern Nebraska and Iowa, across Kansas, and into the northern part of Oklahoma. Alternating transgressions and regressions of these shallow seas, however slight, were still sufficient to effect sedimentation over this vast shelf so that the depositional environment was widespread, causing thin units to persist over large areas.

During the deposition of the Pennsylvanian sediments, mountains in southern Oklahoma were repeatedly uplifted and eroded, affording a vast supply of clastic debris that accumulated in adjacent basins and spread in all directions. The Gray Horse area occupies a position that may be termed the northern part of a gradual transition zone from the persistent, platform type of sedimentation, to the basinal type in central and southern Oklahoma. In tracing these persistent units southward, certain beds lose their identity by lateral gradation into

other lithologies but the cyclic alternation of these beds is still evident and continues to be so throughout the Gray Horse area. It is just as apparent that the amount of clastic material increases markedly southward toward the source. Sandstones increase in number and thickness, shales thicken and grade into sandstones, and limestones are silty and thinner.

Manifestations of the shallow seas which Elias limits to a maximum depth of 200 feet (1937, p. 423), and Moore approximately the same (1929, pp. 459-487) are seen in the occurrence of sandstones displaying gentle cross-bedding, ripple-marks, steinkerns and imprints of pelecypods, maroon shales, and limestones largely of algal origin and others composed of abundant fossils essentially characteristic of the neritic and littoral zones.

Cyclic repetition or alternation of marine and non-marine beds is clearly displayed. Though a close approximation of the ideal cyclothem is not present in any sequence, all of the representative members are seen within the area except for those commonly absent as described by Pettijohn (1949, pp. 470-471) from the ideal Illinois cyclothem.

As expressed in this area, the initial or sandstone phase of Moore's "typical Wabaunsee group cyclothem" (1936, p. 25) is inconspicuous as a definite unit. This phase in the cyclothem including the coal below the Brownville (Moore, 1949, p. 75) is represented by a prominent, micaceous sandstone in the northern two townships. The second, or shale-underclay phase, is present throughout the area and is represented by a gray shale. The underclay is commonly absent or ill-defined, although the shale is slightly clayey below the coal at

all exposures. There are eight different coal or extremely carbonaceous horizons within this area, but only five of them are within a sequence suggesting a cyclothem as other units are either inconspicuous or absent in the remaining three. Each of these coals does not persist throughout the area. The coal in the lower Willard-Stotler (Dry) shale, the carbonaceous zone below the Jim Creek limestone and the lower coal in the Pony Creek shale are known to extend at least as far south as the northern half of T. 24 N., and the coal 10 feet below the Brownville limestone is thought to extend that far but poor exposures preclude observation of its position. Above the coal the fossiliferous shale unit is commonly present as well as the subsequent coquinoid limestone phase. The former displays extremely numerous Chonetes sp., Dictyoclostus sp. and other productids, as well as abundant bryozoans, crinoidal debris and other fragments. The latter is well compacted and consists largely of fragments, of which pieces of Myalina sp. are most conspicuous. The following shale phase is present but non-fossiliferous, commonly fissile, blue-gray to drab brown and contains small ironstone concretions where exposed below the Jim Creek limestone in sec. 8, T. 24 N., R. 6 E. Phase ".5" is comprised of fossiliferous, fusulinid-bearing limestones which comprise the more prominent and characteristic beds of this area. Unit ".6" consists of a non-descript, gray to drab brown, at places maroon shale, and is commonly overlain by a conspicuous algal limestone. This sequence is particularly exemplified by the Reading limestone, by the Grayhorse limestone and by the algal limestone in the lower part of the Pony Creek shale. Phase ".8-.9" is represented by a thick sequence of gray to drab,

commonly maroon, shale that alternates with siltstones and sandstones and represents both the terminal and the beginning of the transgressive phase. Measured sections 8, 12 and 26 best display the characteristics discussed above.

Following the mild uplift that produced an obscure unconformity at best, Permian seas transgressed over this essentially unmodified platform. However, as stated by Jewett (1939, p. 137) differences of beds "...point toward a greater prevalence of marine conditions during Permian than Pennsylvanian time". His opinion is a logical one based largely on observations that any reported coals in the Permian are of a "very local extent; ... sandstone is nearly or quiet absent in the lower part of the Permian; stratigraphic units are more persistent along their line of outcrop ...".

Although cyclic sedimentation existed, it is not as conspicuous as in the Pennsylvanian beds. Jewett bases his cyclic relationships (1933, pp. 137-140) on the recurrence of limestone and shale lithologies and Elias (1937, pp. 403-428) primarily on the repetition of certain faunal zones. Two of the eight coals mentioned previously are of Permian age and each is only local. Faunal zones, as discussed by Elias, are not distinguishable in this area except for the fusulinid phase. Similarly, poor exposures preclude any study of the respective associated lithologies except for the cherty limestones corresponding to the fusulinid phase. The writer believes that Jewett's observations of the repetition of four basic units is the more applicable of the two theories as concerns the Gray Horse area, though primarily more applicable to strata above the lower Council Grove group.

The lateral uniformity of the stratigraphic features as found in this area, and enumerated previously, seem to be consistent with those found in regions to the north as well as in surrounding areas and attest to the nature of sedimentation upon this platform.

CHAPTER IV

STRUCTURAL GEOLOGY

Osage County is situated structurally on the Prairie Plains homocline or the gentle westward dipping flank of the Ozark Plateau. This structure is bounded on the south by the McAlester basin, the Ouachita and Arbuckle Mountains and to the west by the Nemaha Ridge and the Anadarko basin.

The inclination of the strata ranges from less than one-half degree to slightly over one degree. Locally the regional dip is interrupted by minor faults and folds.

The strata of the Gray Horse area dip persistently westward about 40 feet per mile and strike N. 10° E., except where both are slightly influenced by local structure.

Most of the faults in the northeastern part of the state, and in particular in Osage County, belong to a broad linear belt of en échelon faults trending north-northeast from Seminole, Okfuskee and Creek Counties, almost to Kansas (Miser, 1954). These faults may be summarized from Fath's description (1920, p. 78) as approximately parallel belts or series of individually parallel normal faults that strike mainly north-northwest but trend as a group at an angle approximately 45° from the strike of the individual faults. He describes

them further as being of minor extent both vertically and horizontally and essentially straight or only slightly curving.

Numerous theories have been advanced as explanations for this phenomenon but a full discussion of these is beyond the scope of this paper. Powers (1931, p. 129) believes their origin to be due to "rotational stresses acting against the Nemaha Mountain fracture system...". The forces involved were derived from "differential movement" associated with the broad warping of the Pennsylvanian basin caused by the Ozark uplift on the east and mountain masses on the south. Melton (1930, pp. 57-72) advanced the idea that these faults are the result of stresses produced by Ouachita thrusting in the late Paleozoic. Fath (1920, pp. 75-84) offers a logical explanation in relating their origin to horizontal movement of competent basement rocks along pre-existing planes of weakness. The less competent overlying sediments absorbed much of the stress by folding but tensional forces were still of such a magnitude as to produce these faults about 45° to the direction of the basement movement.

The faults of the Gray Horse area do not belong to the en échelon trends farther east, but are probably related in being contemporary. It is probable that they represent the maximum effective western limit of the forces active in developing the en echelon faults, though some are associated with local structure.

All of the faults were mapped from linears on airplane photographs in areas where field study suggested their existence. Relative movement was determined by a combination of rarely observed displacement in the field and outcrop patterns on the photographs. At numerous

places limestones used as mapping horizons disappear by downward faulting and the throw is difficult if not impossible to determine by using other beds.

The faults of this area are all normal and are divided almost equally between those striking northeast and those northwest. In either category, the downthrown side favors no particular side with reference to direction. From observed and extrapolated displacement the throw of the faults ranges from 3 feet to approximately 30 feet. The fault in the western part of sec. 3, T. 24 N., R. 6 E., and the long curving one lying largely in secs. 8 and 17, T. 24 N., R. 6 E., have the maximum throw of any in the area. It is estimated in both to approximate 25 to 30 feet.

The folds on this homoclinal structure are of the "Plains type" (Powers, 1931, p. 129) and consist largely of low domes, anticlines, noses and a few shallow synclines. On the basis of subsurface correlation with the surface structures, Powers (1931, p. 121) divides these flexures into normal, reflected and surficial types. Those of Osage County belong to the reflected category. These become more pronounced with depth and owe their origin and position to preexisting structures which Powers believes to have been rhythmic or spasmodically active since Ordovician time at least.

Most of these small structures in the Gray Horse area are anticlines with little or no closure and consist of local deviations of dip to the north and south resulting in low noses. Local steepening and flattening of inclination gives rise to small terraces. The smallest of surface structures is conspicuously reflected by the

configuration of the outcropping units.

Due to the low dip an accurate determination of the dimensions of these structures is difficult to obtain by using airplane photographs. Plane table and alidade mapping of this area was accomplished by the United States Geological Survey in 1918-19, and the following information is summarized from the subsequent publication of the data (White and others, 1922) with a few remarks by the writer.

T. 27 N., R. 7 E.

North Bird Creek Anticline

The axis trends northeast-southwest through secs. 11 and 15, T. 27 N., R. 7 E. and the NW¼ NW¼ sec. 14. It enters sec. 21 at the extreme northeast corner and then curves due west and plunges steeply westward in the north half of this same section. Although the flanks of this structure dip rather steeply, there is no evidence of east closure within this area. The Blackland field is located northeast of the northern tip of this structure and though the writer has no evidence to corroborate the following, he believes that the structure may gain enough prominence and closure with increased depth, at least to the Mississippi "chat", to accommodate the accumulation of oil and gas that is being produced.

Dugout Creek Anticline

The axis trends northeast-southwest, bisecting secs. 8 and 18, T. 27 N., R. 7 E. There is no reversal of dip except for a small dome-like bulge in the east-central part of sec. 18.

Potato Creek Anticline

The axis of this anticline bisects sec. 32, T. 27 N., R. 7 E. in a northeast-southwest trend and extends to the center of sec. 28. It is saddle-shaped and is most pronounced in the southwest corner of both secs. 32 and 28, where there are small domal structures with closures of 15 and 10 feet respectively.

Whiteface Dome

The crest of this dome lies in the SE$\frac{1}{4}$ sec. 35, T. 27 N., R. 7 E., but it has a north-south trend as a whole, extending into section 26 and much of sec. 2, T. 26 N., R. 7 E. This is a pronounced fold with a closure of 25 feet and whose flanks influence the exposures in the SW$\frac{1}{4}$ sec. 36 and most of sec. 2, T. 26 N., R. 7 E.

T. 26 N., R. 7 E.

Little Chief Terrace

This flattening of strata trends essentially north-south and covers much of sec. 16, T. 26 N., R. 7 E., and appears to influence exposures in most of section 21, where the Foraker escarpment continues due south as opposed to the normal south-southwest trend. There are no pronounced changes in inclination on either side of this structure.

Upper Little Chief Dome

The crest of this dome lies in the northern part of sec. 29, T. 26 N., R. 7 E. It is a gentle fold that covers several square miles, including secs. 19, 20, 29 and 30, although it has 20 feet of closure only covering one-half square mile.

Lower Little Chief Dome

The crest lies about one-quarter mile north-northeast of the southwest corner of sec. 31, T. 26 N., R. 7 E., but the major part also includes sec. 6, T. 25 N., R. 7 E., and extends into R. 6 E. as well. It has about 10 feet of closure and dips abruptly westward from the crest, though gently in other directions. This structure is chiefly reflected by the reappearance of the Grayhorse limestone exposed on its southwest flank.

T. 25 N., R. 7 E.

Clear Creek Anticline

This structure is a gentle, low nose with no east closure and extends northwestward through secs. 13, 12, 11 and 10, T. 25 N., R. 7 E.

Upper Grayhorse Anticline

This anticline is largely restricted to sec. 31, T. 25 N., R. 7 E. It noses west with well-defined dips but has no closure. There are no mappable beds close enough to reflect this flexure whose crest lies in the SE$\frac{1}{4}$ sec. 31.

T. 24 N., Rgs. 6 and 7 E.

North Hominy Creek Anticline

The crest of this anticline lies in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 22, T. 24 N., R. 7 E., and trends northeast-southwest. It has a closure of 10 to 15 feet and covers the largest area of any anticline in the Gray Horse area.

It occupies all of section 22 and most of the surrounding sections. The north and south dips are gentle but the west flank dips slightly more than one degree in the first mile. This structure exerts great influence on the outcrop of the Emporia and Wakarusa limestones and supports the Naval Reserve Unit field, which presently produces about two-fifths of the total of the Naval Reserve field which is the third largest producer in the county.

Little Grayhorse Anticline

The surface expression of this anticline is a long, narrow nose trending approximately northeast-southwest from the southern boundary of sec. 10, T. 24 N., R. 6 E., through the NW¼ sec. 11 to the NW¼ sec. 1. It has no reported closure but from field observation the strata are almost flat on the east flank and may have several feet of closure. The highest point is in the SE¼ NW¼ sec. 11.

Middle Grayhorse Anticline

This flexure is actually a broad flat terrace lying mainly in the northern and eastern part of sec. 25, T. 24 N., R. 6 E., but extends southeastward into sec. 30, T. 24 N., R. 7 E. North and south dips are gentle but rather abrupt westward.

Lower Grayhorse Anticline

The crest of this extremely low, narrow flexure trends almost due east-west in the northern part of secs. 35 and 36, T. 24 N., R. 6 E. and barely into sec. 31, T. 24 N., R. 7 E. There is a slight reversal of dip at the extreme east end of this gentle structure.

Twps. 23 and 22 N., R. 6 E.

Lower Sycamore Anticline

The crest of this structure trends northwest-southeast from the NE¼ SW¼ sec. 35, T. 23 N., R. 6 E., through the SW¼ sec. 36, to the approximate center of sec. 1, T. 22 N., R. 6 E. The highest point lies at the position where the crest intersects the south boundary of sec. 36. There is slight but insignificant closure.

CHAPTER V

ECONOMIC GEOLOGY

Osage County is known to petroleum geologists the world over for its record of prolific production. Following a relapse during the 1930's and 1940's, this area has rapidly revived and at the present time is one of the most active oil development areas in the country. Two good reasons for the rapid increase in development in "the Osage" are the success of water flooding, introduced in 1950, and exploitation of deeper substantial production from the "Mississippi chat".

The daily production average at the present time is 60,500 barrels (Revival in the Osage, 1956, p. 44). As of January 1, 1956, Osage County had 8,380 producing wells and of this number about 400 were located in the Gray Horse area (Vance Rowe Reports, Dec. 1955). The total cumulative production from the wells in this area was approximately 27,700,000 barrels at that time. The most prolific producer in this area is the Burbank sand, which lies about 2,400 feet below the surface.

In the Gray Horse area, only the Blackland and Naval Reserve pools (Unit, Non-unit and West) are entirely within the borders, but the southeastern part of the Burbank field extends into the area in

the northwest part of T. 25 N., R. 7 E. The Blackland field is located for the most part in sec. 1, T. 27 N., R 7 E., but several wells are producing in sections 11 and 12.

The Naval Reserve (Unit) is the largest and most productive field and is generally restricted to secs. 16, 21, 22, 27, 28 and 33, T. 24 N., R. 7 E., though it is essentially continuous into the main body of the Non-unit wells in the northwestern part of T. 24 N., R. 7 E., and the southwestern part of T. 25 N., R. 7 E. The Naval Reserve, West field is composed of at least three wells in sec. 19, T. 24 N., R. 7 E. With development continuing in its present trend it is likely that the Burbank field and the Naval Reserve fields will join.

Other resources within the area are few. Most of the limestones are too thin or impure for lime or building stones, but the thicker Permian limestones are quarried to the west of this area and are suitable for road gravels, railroad ballast and concrete aggregate. Locally, a well-bedded sandstone within the Willard-Stotler (Dry) shale formation is quarried within the area by individuals,but does not merit commerical exploitation.

Though coals are numerous, none of commercial quantity or quality exist. The coal exposed along the south bank of Salt Creek in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 6, T. 24 N., R. 7 E. could be used by individuals in an emergency, but it is of questionable quantity and poor quality.

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APPENDIX

APPENDIX A

MEASURED STRATIGRAPHIC SECTIONS

Township 27 North

Feet

1. Secs. 6 and 7, T. 27 N., R. 7 E.; measured in a southerly direction from the SW¼ of sec. 6 to the outlier at the center of the west edge of sec. 7.

GRENOLA limestone formation:
Covered interval, strewn with numerous brown chert fragments. 10.0
Burr limestone
Limestone, gray, weathering gray, medium to coarsely crystalline, medium- to thick-bedded, contains extremely abundant small fossil fragments or what might possibly be algal pellets, about. 2.0
Covered interval. 11.0
ROCA shale formation:
Covered interval. 18.0
RED EAGLE limestone formation:
Howe limestone formation:
Limestone, light gray, medium-crystalline, thin-bedded. 5.0
Bennett limestone member:
Limestone, off-white to light gray, weathering the same, medium-crystalline, medium- to thick-bedded, extremely pitted and cavernous . . 3.0
Limestone, gray to off-white, weathering light gray, medium to coarsely crystalline, appearing sugary on a fresh surface, thin- to medium-bedded, contains a few fossils, Derbyia sp., horn corals, and the surface is distinctive due to a lineation of crystalline calcite possibly due to an algal effect 4.0
JOHNSON shale formation:
Covered interval, probably shale. 30.0
FORAKER limestone formation:

2. Sec. 19, T. 27 N., R. 7 E.; measured from the abandoned railroad

	Feet
up the slope in the NW¼.	
RED EAGLE limestone formation:	
Limestone, gray, weathering the same, non-crystalline to coarsely crystalline, thin-bedded in the lower part, medium-bedded and extremely pitted and cavernous in the upper portion, irregular fractures, and shows distinctive lines or markings on a smooth surface due to the lineation of crystalline calcite or possibly to algal influence.	6.0
JOHNSON shale formation:	
Covered interval, with occasional float of thin-bedded limestone noticeable.	22.0
Limestone, gray, algal?, contains small fusulinids	N.M.
Limestone, tan, limonitic, prominent cavities, and contains abundant fusulinids	N.M.
Covered interval, probably shale.	5.0
Limestone, tan, contains an extreme abundance of fusulinids	N.M.
Covered interval, probably shale, weathers back . .	3.0
FORAKER limestone formation:	
Long Creek limestone member:	
Limestone, gray to white, weathering gray, medium-crystalline, medium-bedded, shows prominent vertical jointing, fossiliferous, fusulinids are far and above the most prominent. The base is marked by a yellowish-brown bed and an extreme abundance of fusulinids and abundant chert occurs in an upper bed. The unit weathers pit and cusp	10.0
Hughes Creek limestone member:	
Covered interval, weathers back	11.0
Limestone, light gray to off-white, weathering light gray, finely crystalline, dense, dolomitic, medium-bedded, shows pit and cusp weathering and is extremely cherty. Upon weathering out the chert leaves numerous cavities, though most of the chert occurs as lenses along bedding planes. The limestone, as well as the chert, contains numerous small to large fusulinids. The chert is generally a pale blue-gray color but may be a pale pink. .	9.0
Covered interval, probably shale, weathers back . .	2.5
Americus limestone member:	
Limestone, gray, weathering light gray, finely crystalline, dense, vertical jointing, and contains extremely abundant small to medium	

	Feet
fusulinids	0.6
Limestone, dark gray, weathering yellowish, finely crystalline, and contains extremely abundant medium to large fusulinids that weather out and mix in the shale below	0.6
Shale, drab, fissile.	1.5
Limestone, dark gray, weathering gray to yellow-brown, finely crystalline, dense, slightly irregular jointing and fossiliferous	0.8
Shale, drab, fissile.	0.5
Shale, dark gray, calcareous.	0.5
Limestone, dark gray, weathering gray, finely-crystalline to non-crystalline, dense, extremely irregular jointing, with a thin (0.1) shale parting 0.8' from the base, weathers into chips.	1.5
Shale, drab brown, fissile.	1.0
Limestone, dark gray, weathering gray to yellow-brown, non-crystalline, dense, contains numerous brachiopods	0.4
Shale, drab, splintery.	0.4
Limestone, same as previous limestone	0.4
Limestone, brownish, crystalline, fine-bedded, extremely fossiliferous.	0.5
Limestone, gray, weathering the same, medium-crystalline, dense, massive, with a slight parting in the approximate middle of this interval, fossiliferous, containing an abundance of medium fusulinids, large crinoid columnals, Chonetes granulifer, Dictyoclostus americanus, and Neospirifer dunbari as well as fossils not as distinctive	2.0
ADMIRE shale formation:	
Shale, drab, fissile to blocky.	0.5
Coal, smutty to platy	0.1
Shale, drab, fissile, with thin dark limestone stringers and some zones of blue-gray shale. . .	3.5
Limestone, dark gray to black, weathering gray, non-crystalline, moderately dense, irregular jointing, suggests argillaceousness.	0.8

3. Sec. 31, T. 27 N., R. 7 E.; measured up the south bank of the stream in the NW$\frac{1}{4}$ NW$\frac{1}{4}$.

JOHNSON shale formation:	
Limestone, gray, weathering gray, but may show local limonite stains, fine to coarsely crystalline, medium-bedded, badly pitted, appears slightly algal, and contains abundant small fusulinids, about.	2.0

	Feet
Covered interval, probably shale.	9.5
FORAKER limestone formation:	
Long Creek limestone member:	
Limestone, gray, weathering gray, medium-crystalline, thin- to medium-bedded, cherty about the middle of the interval and contains highly abundant medium to large fusulinids	12.0
Hughes Creek limestone member:	
Covered interval, probably shale, weathers back . .	3.0
Limestone, gray, weathering gray, finely crystalline, dolomitic, cherty, medium- to thick-bedded, the chert content increases upwards in this interval as the large cavities are left from weathered out chert, and the whole interval contains abundant fusulinids	18.0
Americus limestone member:	
Covered interval, covered with limestone debris but it probably consists of shale.	4.0
Limestone, gray, weathering dirty gray, fine- to medium-crystalline, the lower 1.4' is irregularly bedded and generally shows prominent vertical jointing; the upper 0.2' weathers to a caprock appearance locally and though this whole interval contains abundant fusulinids this upper portion contains an extreme amount. This limestone is quite susceptible to weathering, such that its expression varies in appearance locally	1.6
Covered interval, probably shale.	0.3
Limestone, gray, weathering gray, medium-crystalline, massive, with a parting one foot above the base, weathering more rapidly above this parting, contains highly abundant small to large fusulinids.	1.7
ADMIRE shale formation:	
Shale, drab, fissile to splintery, with a one inch coal seam locally, several inches below the overlying limestone.	2.5
Limestone, steel-gray, weathering the same, non-crystalline, moderately dense, brittle, argillaceous, with prominent vertical jointing, non-fossiliferous, smooth on the fresh surface and has a slight parting several inches from the top	0.8
Shale, drab brown, fissile to platy	0.3
Limestone, dark steel-gray, weathering the same, non-crystalline, dense, brittle, argillaceous, and contains abundant Aviculopecten sp. on the upper surface.	0.3
Shale, as above	0.3

	Feet
Limestone, as above but shows prominent vertical jointing and absence of pelecypods	0.6
Shale, drab, fissile.	0.8
Limestone, as above	0.4
Shale, drab, fissile.	10.0

4. Sec. 23, T. 27 N., R. 7 E.; measured up the steep slope in the $NE\frac{1}{4}$ $NE\frac{1}{4}$.

WOOD SIDING formation:

Brownville limestone member:	
The prominent fusulinid layer	N.M.
Pony Creek shale member:	
Covered interval.	25.0
Sandstone, buff to tan, micaceous, about.	2.0
Covered interval.	8.0
Unnamed limestone:	
Limestone, light gray, medium to coarsely crystalline, containing some fossil fragments that weather in relief, about	2.0
Covered interval.	20.0
Limestone, light gray, weathering gray, fine- to medium-crystalline, brittle, pure, forms slight bench.	N.M.
Covered interval.	18.0
Limestone, gray, to dark gray, with considerable limonitic blotches, fine- to medium-crystalline, dense, weathers into irregular, somewhat rounded fragments, fossiliferous, most noticeable of which is crinoidal debris but also a few small to medium fusulinids and a few brachiopods . . .	N.M.
Covered interval.	10.0
Grayhorse limestone member:	
Limestone, dark-gray, medium-crystalline, conglomeratic, contains numerous Myalina subquadrata along bedding	1.8

5. Sec. 11, T. 27 N., R. 7 E.; measured in the C $SW\frac{1}{4}$.

WOOD SIDING formation:

Brownville limestone member:	
Limestone, gray, weathering light gray, fine- to medium-crystalline, brittle, massive, weathering into large slabs, prominent, and contains abundant medium to large fusulinids.	2.0
Covered interval with a possible limestone forming a small bench 8' from base of this interval. The limestone is believed to be yellowish, dense, nodular, and is packed with small fusulinids . .	14.0

	Feet
Pony Creek shale member: (Extends into the interval above)	
Shale, drab to variegated, fissile to platy	8.0
Covered interval, probably shale.	3.5
Sandstone, silty, micaceous, thin-bedded.	2.0
Shale, drab, fissile in the lower 4' but becoming increasingly sandy and platy in the upper 5' to such an extent it might be termed a siltstone. . .	9.0
Unnamed Limestone:	
Limestone, gray, weathering brownish, moderately dense, finely crystalline, massive, and contains abundant fossil fragments of which Myalina sp. is most noticeable	0.6
Shale, drab, fissile.	0.3
Limestone, same as above but none of the contained fossil fragments are distinctive	1.0

6. Sec. 11, T. 27 N., R. 7 E.; measured from a stream bottom up the south bank in the NW¼ NW¼.

WOOD SIDING formation:	
Grayhorse limestone member:	
Limestone, dark gray, weathering drab brown, medium-crystalline, conglomeratic, weathers into large slabs that slump so bad that accurate measurement of anything other than slump blocks cannot be made, contains fossil fragments of which Myalina subquadrata is the most noticeable	1.2
Plumb shale member:	
Shale marron fissile.	5.0
Nebraska City limestone member: ??	
Limestone, brown to tan, extremely limonitic, soft, porous, and weathers rapidly, about.	2.0
ROOT shale formation:	
French Creek shale member:	
Shale, maroon, fissile to platey, ferruginous . . .	6.0
Covered interval, probably shale.	4.0
Shale, gray, fissile.	13.0
Jim Creek limestone member:	
Limestone, blue-gray, weathering yellowish-brown to reddish-brown in the upper part, non-crystalline to finely so, dense, slightly silty, with partings that, due to weathering, divide the bed into three approximately equal portions. The middle layer is the most resistant and both the middle and upper one are fossiliferous, containing mostly fragments but a few fusulinids are noticeable	2.0
Shale, gray, fissile to platy	2.0

	Feet
7. Sec. 11, T. 27 N., R. 7 E.; measured up a gully on the east facing escarpment at approximately the C W½.	
WOOD SIDING formation:	
Pony Creek shale member:	
Unnamed limestone:	N.M.
Covered interval, littered with considerable limestone debris	28.0
Limestone, gray, weathering gray with limonite stains, finely crystalline, resistant, and fossiliferous with a few small fusulinids and abundant crinoidal debris, about	2.0
Covered interval.	6.0
Limestone, gray, weathering gray to tan, finely crystalline, fossiliferous, some fragments showing an abundance of crinoidal debris	N.M.
Covered interval.	11.0
Grayhorse limestone member:	
Limestone, dark gray, weathering brownish, medium-crystalline, shows conglomeratic nature and occurs merely as weathered fragments	N.M.
Plumb shale member:	
Covered interval.	12.0
Shale, drab brown, fissile to blocky.	3.0
Covered interval.	15.0
Nebraska City limestone member: ??	
Limestone, dark gray, weathering brown, medium- to coarsely-crystalline, thin-bedded, ferruginous, fossiliferous, containing extremely abundant fossil fragments and numerous Myalina sp..	5.5
ROOT shale formation:	
French Creek shale member:	
Shale, blue-gray to brown, fissile to splintery	1.0
Covered interval.	16.0
Jim Creek limestone member:	
Limestone, gray, weathering gray with some limonitic staining, fine- to medium-crystalline, slightly silty, one bed, and fossiliferous, containing Myalina sp., Bryozoa and a few small fusulinids	1.0
Friedrich shale member:	
Covered interval, possible sandstone 4' from the base of this interval.	13.0
STOTLER limestone formation:	
Grandhaven limestone member: ?	
Calcarenite, gray to brown, weathering yellow-brown, fine-grained, ferruginous, contains fossil fragments, and weathers into thin to medium beds.	1.0

	Feet
WILLARD-STOTLER (Dry) shale formation:	
Shale, drab, sandy, fissile	2.0
Siltstone, drab, sandy, thin-bedded	1.5
Covered interval, but littered with pieces of ripple-marked sandstone with several Aviculopecten sp. imprints in the lower part.	4.0
Sandstone, buff, fine-grained, cross-bedded, probably massive but weathers to thin-bedded appearance	3.0
Sandstone, buff, fine-grained, thin to shaley bedded and cross-bedded.	4.5
Covered interval.	19.0
EMPORIA limestone formation: not measured.	

8. Sec. 11, T. 27 N., R. 7 E.; measured along the south bank of North Bird Creek in the C E½.

WILLARD-STOTLER (Dry) shale formation:	
Siltstone, probably continues up to 2' sandstone bed 6' above	6.0
Shale, drab, fissile, lower 5', becoming extremely sandy and platy upward.	11.0
Sandstone, light buff to brown, fine-grained.	1.0
Shale, drab to tan, blocky to platy and sandy.	3.0
Siltstone, drab, thin-bedded.	1.0
Shale, drab, fissile to platy with a few thin sandstone stringers.	6.5
Limestone, gray, weathering yellowish to brown, fine- to medium-crystalline, moderately dense, probably massive but weathers into thin-bedded appearance, fossiliferous, containing Myalina sp. predominantly and some large crinoid columnals.	2.0
Shale, drab brown, highly fossiliferous, containing predominately Chonetes granulifer but some Hustedia mormoni and numerous fossil fragments	7.0
Coal, extremely smutty. Upstream approximately 100 yards and to the south this coal is about one foot thick	0.3
Underclay, poor.	0.3
Shale, blue-gray, blocky.	2.0
EMPORIA limestone formation:	
Elmont limestone member:	
Limestone, gray, weathering pale yellow, the lower one foot is massive and dense while the upper one foot is rather silty and nodular. The nodular appearance is probably due to extreme weathering. The limestone is finely crystalline and has irregular bedding	2.0

	Feet
Shale, drab brown, and seemingly fossiliferous though probably derived in part from the shale above.	2.0
Limestone, gray to brown, weathering yellowish-brown, finely crystalline to non-crystalline, moderately dense	0.4
Shale, blue-gray, fissile, becoming platy in the upper part	3.0
Limestone, gray, weathering yellowish, fine- to medium-crystalline, moderately dense, and contains fossil fragments more of which are distinctive. Some of the limestone fragments are extremely weathered and rather soft to brittle	0.8
Harveyville shale member:	
Shale, blue-gray, extremely fissile with some platy zones	2.5
Limestone, drab brownish-gray, coquinoid, the fossil representatives are largely fragmental, and thin- to irregular bedding.	1.5
Shale, drab to gray, splintery.	0.5
Coal, platy to blocky.	0.1
Shale, blue-gray, splintery	2.0
Reading limestone member:	
Limestone, yellowish, non-crystalline, algal, soft and silty at the base becoming denser towards the upper part. The upper surface is highly irregular, probably due to algal secretion, but the bed shows prominent vertical jointing. The upper part is dense, weathers rapidly and fossils are inconspicuous. (At another exposure in the same vicinity this limestone consists of an upper one foot massive bed with prominent vertical jointing and at least (base covered) 1.5' of soft to dense calcareous nodules in a clayey shale matrix) . .	1.5
Shale, drab with a maroon tinge in the middle of the interval, fissile	6.0
Limestone, dark gray, weathering gray with some limonitic staining (locally strong), extremely fine - crystalline, dense, brittle, massive, shows prominent vertical jointing but not as prominent as the limestone below, fossiliferous, containing numerous "Cryptozoon", a few large brachiopods, numerous small to medium fusulinids, and an occasional horn coral	2.4
Shale, blue-gray.	0.5
Limestone, gray, weathering gray with minor limonitic staining (locally strong), finely crystalline,	

Feet

dense, brittle, massive, well-bedded, with a parting plane approximately in the middle of the interval, prominent vertical jointing to the extent that it appears to have almost perfect cubic cleavage although rhombic jointing was noted, fossiliferous, containing many small fusulinids and an abundance of small fossil fragments. 1.5

Shale, drab, splintery. 1.0

Coal, smutty to platy. 0.1

Shale, drab blue-gray, splintery to fissile, clayey in the upper portion. 1.0

Limestone, the basal one foot of which is yellow, nodular, rather dense, fossiliferous; the middle part is gray, weathering pale yellow, massive and fossiliferous, containing Myalina subquadrata, and a few small fusulinids, brachiopods, Bryozoa, and rather large algal pellets and is finely crystalline to non-crystalline; the upper part ranges from 1/2 to one foot due to a very irregular surface, it consists of a blue-gray mass of small algal pellets in an organically secreted cement 3.0

AUBURN shale formation:

Shale, blue-gray, slightly fissile with a few thin sandstone stringers 20.0

Township 26 North

9. Sec. 3, T. 26 N., R. 7 E.; measured in the road cut down the eastward facing escarpment in the NE¼ NE¼.

FORAKER limestone formation:

Hughes Creek limestone member:

Limestone, gray, weathering light gray, non-crystalline to finely crystalline, medium-bedded, slightly dolomitic, cherty, and contains abundant fusulinids. The chert weathers brown but is a pale gray-blue on the fresh surface . . 7.5

Limestone, gray-brown, weathering yellowish-brown, finely crystalline, probably massive, weathering medium-bedded, and contains profuse crinoidal debris 1.5

Shale, drab brown, splintery. 1.5

Americus limestone member:

Limestone, gray, weathering gray, non-crystalline to finely crystalline, moderately dense, one bed, vertically jointed, and contains extremely

	Feet
abundant small to large fusulinids	0.6
Shale, drab brown, contains fusulinids but they are probably wash.	0.4
Limestone, gray, weathering yellowish, finely crystalline, one bed, and contains extremely abundant medium to large fusulinids.	0.5
Shale, drab to blue-gray, fissile	1.5
Limestone, dark gray, weathering brown, finely crystalline, massive with a small parting 3" from the top, fossiliferous but not prominently so	1.2
Shale, drab	0.3
Limestone, gray, weathering brownish, finely crystalline, sparingly fossiliferous	0.2
Shale, drab	1.0
Limestone, gray, weathering gray, extremely fine- crystalline, dense, massive and contains abundant small to large fusulinids	1.3
Shale, drab, fissile, fossiliferous	0.3
Limestone, gray, weathering brownish, finely crystalline, moderately dense, containing fusulinids	0.2
Limestone, gray, marly, thin-bedded, extremely fossiliferous.	0.5
Limestone, gray, weathering gray, fine to medium crystalline, moderately dense, massive, contains abundant small to medium fusulinids and numerous brachiopods.	1.6
ADMIRE shale formation:	
Shale, drab, fissile to splintery, with a non-persistent coal streak 4" from the base of the overlying limestone.	3.0
Limestone, gray, weathering gray, non-crystalline, brittle, argillaceous, smooth surfaced	0.2
Shale, drab, fissile to platy	0.3
Limestone, as above, with Aviculopecten sp. locally abundant	0.5
Shale, drab, platy	0.8
Limestone, as above without the pelecypod	0.7
Shale, drab, platy	0.7
Limestone, as above	0.6
Covered interval essentially but probably maroon shale grading upward into drab to gray shale with a yellowish, soft, silty, thoroughly leached limestone marking the change in color about 8' below the top of this interval.	20.0
Sandstone, buff, weathering darker, fine-grained, massive to irregular bedded, with some gentle cross-bedding, about	4.0

	Feet
Covered interval, probably shale.	3.5
Limestone, gray, weathering yellowish-gray, finely crystalline, slightly silty, one bed, sparingly fossiliferous, containing numerous pelecypod fragments and a few brachiopods. . . .	0.5
Shale, drab brown, fissile, with a non-persistent nodular to shaly limestone in the upper foot. .	9.5
Limestone, yellowish, non-crystalline, silty, soft, thoroughly leached, with solution veins of limonitic material standing out as a network.	1.0
Shale, drab, crumbly, with a nodular to shaley calcareous siltstone zone in the approximate middle of the interval	4.0
WOOD SIDING formation:	
Brownville limestone member:	
Limestone, gray, weathering gray to brownish, finely crystalline, slightly argillaceous, and fossiliferous, containing highly abundant crinoidal debris of which large columnals are most noticeable, and a few horn corals	0.7
Shale parting	0.1
Limestone, gray, weathering brownish, finely crystalline, dense, highly fossiliferous, containing extremely abundant small fusulinids and abundant crinoidal debris.	1.0
Shale, drab, fissile, badly washed.	3.5
Limestone, gray, weathering brownish, finely crystalline, massive, silty, containing numerous pelecypod fragments	0.9
Pony Creek shale member:	
Covered interval, undoubtedly shale	11.5
Shale, drab, fissile, with a one foot sandstone stringer zone 1.5' from the top of the interval and an irregular calcareous, nodular siltstone at the top, badly washed	14.0
Limestone, yellowish-brown, non-crystalline, soft, silty, porous, about	1.0
Covered interval.	8.5
Unnamed limestone:	
Limestone, light gray, crystalline, good bench former though not evident at this particular exposure	N.M.

10. Sec. 21, T. 26 N., R. 7 E.; measured up the eastward facing escarpment in the NW¼ NW¼ NE¼ sec. 21, T. 26 N., R. 7 E.

FORAKER limestone formation:
Americus limestone member: The approximate base.
ADMIRE shale formation:

	Feet
Limestone, dark gray, weathers tan, extremely fine-crystalline	0.3
Shale, tan, fragments partially coated with a calcareous powder that is probably derived from leaching of the Americus limestone and possibly the source of the calcareous nodules covering the slope below	3.0
Limestone, yellowish, soft, silty, one bed, weathers easily	0.7
Shale, gray to maroon, fissile at the base becoming light maroon and blocky at the top	21.0
Limestone, gray, weathering brownish, locally stained greenish, fine-crystalline, slightly silty, one bed, weathers easily, and contains numerous small phosphatic shell fragments	0.6
Shale, brownish to gray, the upper 5' being blue-gray to brown, blocky, becoming extremely fissile in the upper 5', the surface is covered with small calcareous pebbles of secondary origin	18.0
Siltstone, greenish, sandy, nodular to wavy-bedded, the surface is covered with pebbles as above	1.0
Covered interval, probably shale	2.5
WOOD SIDING formation:	
Brownville limestone member:	
Limestone, no description	N.M.
Pony Creek shale member:	
Shale, drab, sandy, fissile	10.0
Coal, blocky to platy	0.2
Shale, blue-gray to brown, fissile to platey, and contains numerous thin silty sandstone stringers and becomes clayey at the top	15.5
Sandstone, tan, fine-grained, silty, micaceous, thin-bedded	1.0
Covered interval, probably the same as above	2.0
Sandstone, same as above	2.5
Covered interval, probably shale	4.0
Unnamed limestone:	
Limestone, gray, weathering gray to gray-brown, finely crystalline, slightly argillaceous, probably massive but weathers here into thin fragments, good bench former, the approximate middle of this interval contains numerous fragments of Myalina sp., about	2.5
Note: This limestone lies 50' above the Grayhorse limestone from a measurement up the eastward facing escarpment in the center of sec. 3, T. 26 N., R. 7 E.	

Feet

11. Sec. 17, T. 26 N., R. 7 E.; measured up the south bank of the stream on the west side of the Foraker road in the SE¼.

WOOD SIDING formation:
Brownville limestone member:
Limestone, gray, with some brownish stains, weathering brownish-gray, fine- to medium-crystalline, moderately dense, massive, with abundant small to large fusulinids and large crinoid columnals, and the base is rough as if solution work had taken place 1.5
Shale, drab,crumbly 1.0
Covered interval, probably shale. 3.0
Limestone, gray, weathering brownish, medium-crystalline, one bed, and contains an abundance of pelecypod remains that have been replaced by secondary calcite 0.7
Siltstone, drab, nodular, calcareous. 1.0
Limestone, gray, weathering brownish, non-crystalline, silty, one bed, with abundant fossil fragments of which only Myalina sp. is identifiable 0.5
Pony Creek shale member:
Shale with interbedded thin, silty sandstone stringers. 3.0
Shale, drab, fissile. 3.0

12. Sec. 31, T. 26 N., R. 7 E.; measured up a stream in the NW¼ NW¼ to the outlier of Brownville limestone in the NE¼.

WOOD SIDING formation:
Brownville limestone member:
Limestone, gray, weathering brownish, fine- to medium-crystalline, and contains numerous Myalina sp. fragments. . . . . N.M.
Pony Creek shale member:
Covered interval. 29.0
Sandstone, tan to buff, weathering darker, with brown spots on the fresh surface, fine-grained, slightly micaceous, occurs as fragments and forms a slight bench, about. 2.0
Covered interval, probably shale. 5.5
Unnamed limestone:
Limestone, light gray, weathering gray, medium-crystalline, probably massive, bench former, contains no characteristic fossils, about. 2.0
Covered interval, probably shale. 3.8
Limestone, gray, weathering gray, finely crystalline, some fragments show numerous small gastropod casts

	Feet
replaced by calcite, occurs merely as fragments.	N.M.
Covered interval, probably shale.	5.5
Limestone, gray, weathering brownish, crystalline, argillaceous, possibly algal, slightly conglomeratic with conglomeratic material up to one centimeter, and weathers into thin fragments.	0.3
Limestone, weathers maroon to yellow-brown, non-crystalline, irregularly bedded, soft, silty, ferruginous, algal; the lower 0.6' is porous and a 0.3' parting probably separates this bed from the limestone described above.	2.0
Shale, drab, firm, with local maroon staining in the upper part	6.0
Limestone, gray, weathering light gray, finely crystalline, knobby, irregular-bedded as if algal, extremely fossiliferous, Chonetes granulifer, Marginifera wabashensis, Crurithyris planoconvexa and other brachiopods not as noticeable	0.3
Limestone, gray, weathering with a yellowish-brown to maroon stain, finely crystalline, massive, irregular surface, highly fossiliferous, containing in addition to those mentioned above, Dictyoclostus americanus, Neospirifer dunbari, Wellerella osagensis, and other productids . . .	1.0
Covered interval.	1.0
Limestone, gray, weathering light gray to off-white, finely crystalline, fossiliferous, mostly Crurithyris planoconvexa but also Marginifera wabashensis, Dictyoclostus americanus, and Composita subtilita.	0.6
Shale, drab brown to gray, splintery.	0.4
Limestone, as above	0.5
Shale, brownish, splintery, highly fossiliferous, containing Neospirifer sp., Chonetes sp., Myalina sp., Dictyoclostus sp., Derbyia sp., and encrusting bryozoans	2.0
Coal, blocky to platy	0.6
Underclay, blue-gray.	N.M.

Note: Though the interval from the unnamed limestone and the Brownville limestone in this measured section is conformable with other sections of these beds, the interval below this is exaggerated as the Grayhorse limestone (not exposed at this location) is approximately 20' below the coal mentioned above and approximately 50' below the unnamed limestone. These last two figures were derived from measured sections in other localities.

Feet

13. Sec. 3, T. 26 N., R. 7 E.; measured up a drainage gully in the NE¼ SE¼.

WOOD SIDING formation:
Grayhorse limestone member:
Limestone, not described. . . . . N.M.
Root shale - Wood Siding transition:
French Creek-Plumb shale:
Covered interval, probably shale. 7.0
Shale, blue-gray to brown becoming maroon in the upper 6', extremely fissile to platy. At the approximate change in color a few fragments of yellowish, limonitic, leached, soft, porous limestone are noticeable 25.0
ROOT shale formation:
Jim Creek limestone member:
Limestone, gray, weathering brown, non-crystalline to finely crystalline, slightly silty, fossiliferous. 0.6
Shale, blue-gray to brown, fissile. 1.0
Limestone, gray, weathering brown, finely crystalline to non-crystalline, slightly silty, and fossiliferous, containing a few locally numerous fusulinids, the upper 0.4' weathers into shaley fragments. 0.8
Shale, drab, fissile. 0.2
Limestone, gray, weathering tan, non-crystalline, silty, and fossiliferous, containing numerous fragments of Dictyoclostus americanus and an occasional horn coral. 0.2
Friedrich shale member: Base indeterminable.
Shale with interbedded shaly, nodular limestone, becoming highly carbonaceous at the top of this interval 1.0
Shale, blue-gray to brown with a few local maroon zones, fissile to platy to blocky 33.0
WILLARD-STOTLER (Dry) shale formation: The top extends into the interval above.
Sandstone, off-white to buff, fine-grained, irregular bedding, cross-bedded . . . . . N.M.

14. Sec. 2, T. 26 N., R. 7 E.; measured along a stream in the C E½.

WILLARD-STOTLER (Dry) shale formation:
Limestone, gray, weathering yellowish, medium-crystalline, denseness varies, massive, fossiliferous, containing abundant Neospirifer dunbari and pelecypods 0.8
Shale, bluish in the lower 2' becoming drab for the

	Feet
remainder, fissile, contains a few calcareous concretions, there are a few coquinoid zones in the upper portion whose extreme fossil content litters this shale interval.	11.0
Coal, platy to blocky	0.9
Underclay, gray-blue, well-developed.	1.0
Shale, drab brown	5.0
EMPORIA limestone formation:	
Elmont limestone member:	
Limestone, gray, weathering dirty yellowish-brown, non-crystalline, irregularly bedded, the upper 0.3' consisting of a soft, porous, limonitic layer.	1.0

15. Sec. 35, T. 26 N., R. 7 E.; measured up the steep bank in the NE¼ SE¼.

EMPORIA limestone formation:	
Elmont limestone member:	
Limestone, gray, weathering dirty brownish, medium to coarsely crystalline, seems slightly clastic, moderately dense, thin-bedded and contains an abundance of small fossil fragments, about . . .	3.5
Covered interval.	4.5
Limestone, dirty gray, weathering brownish, medium to coarsely crystalline, seems a bit clastic (extremely small particles), no distinctive fossils, but it does contain some fossil fragments; occurs as thin, relatively flat pieces	N.M.
Harveyville shale member:	
Covered interval with some brownish limestone fragments 8' from the base of this interval. . .	13.0
Reading limestone member:	
Limestone, light gray, weathering the same, medium to coarsely crystalline, contains small algal pellets and some small fossil fragments, about	2.0
Covered interval.	6.5
Limestone, gray, weathering with distinct limonitic blotches and stained a deep brown locally in the upper 6", finely crystalline to non-crystalline, dense, vertical jointing slightly prominent and contains abundant medium fusulinids, numerous "Cryptozoon" and a few horn corals, about.	2.0
Covered interval.	7.0
Limestone, gray, weathering gray with minor limonitic staining, crystalline, massive, slightly argillaceous at the base becoming dense at the top, contains abundant fossil	

	Feet
fragments in the upper part.	2.0
Limestone, yellowish-gray, weathering yellowish, soft, silty, with an 0.2' shale or highly argillaceous zone at the top	1.5
AUBURN shale formation:	
Shale, drab, fissile becoming slightly maroon in the upper part	11.5
Siltstone, gray, weathering reddish brown, calcareous, thin-bedded to laminated	0.7
Shale, blue-gray to drab, fissile	6.5
Limestone, weathering a reddish-brown, thin-bedded, and contains extremely abundant brachiopod remains	1.3
Shale, drab to maroon, fissile to blocky, with a possible insignificant sandstone stringer zone in the approximate middle of this interval . . .	36.0

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16. Sec. 6, T. 25 N., R 7 E.; measured up the steep slope in the SW¼ NW¼.

FORAKER limestone formation:	
Long Creek limestone member:	
Limestone, gray, weathering gray, finely crystalline, thin- to medium-bedded, predominantly the latter, and contains extremely abundant small to large fusulinids and weathers slightly pit and cusp	7.0
Covered interval essentially but there is considerable limestone debris	9.5
Hughes Creek limestone member: The top probably extends several feet into the overlying interval.	
Limestone, gray, weathering gray, medium to coarsely crystalline, medium-bedded, and contains abundant tiny fossil remains of which fusulinids are only locally abundant	3.5
Covered interval, probably shale because the overlying limestone is weathered back forming a small bench.	2.0
Limestone, gray, weathering gray, finely crystalline, and contains abundant medium to large fusulinids, about.	2.0
Covered interval, some limestone debris	2.0
Limestone, gray, weathering light gray, fine- to medium-crystalline, moderately dense, essentially medium-bedded, with a possible shale break 2' from the top of the interval, contains	

	Feet
abundant small to large fusulinids and occurs as fragments largely.	11.0
Americus limestone member:	
Covered interval, limestone float near the base of this interval and a few fragments of sandstone above these. The base of the Hughes Creek limestone extends about 6' into this interval. . . .	15.0
Limestone, gray, weathering gray, finely crystalline, moderately dense, massive, forms a prominent bench, and fossiliferous, containing abundant fusulinids.	1.6
ADMIRE shale formation:	

17. Sec. 7, T. 25 N., R. 7 E.; measured at the road cut at the top of a hill along the west section line in the $SW\frac{1}{4}$ $SW\frac{1}{4}$.

FORAKER limestone formation:	
Hughes Creek limestone member:	
Sandstone	N.M.
Covered interval, probably shale.	2.0
Shale, brown, blocky, clayey.	5.5
Americus limestone member:	
Limestone, steel-gray, weathering tan, finely crystalline, the upper part weathers back along a probable thin parting.	1.0
Shale, brown, fissile to splintery.	0.4
Limestone, as above, but fossiliferous, containing a few fusulinids, and Myalina sp. and Neospirifer sp. fragments. The upper of two beds weathers back.	0.8
Shale, drab to brown, splintery, fossiliferous. . .	0.7
Limestone, same as the first limestone.	0.2
Shale, drab, fissile.	0.3
Limestone, steel-gray, weathering gray to tan, finely crystalline, moderately dense, one bed, fossiliferous, containing small to medium fusulinids.	0.4
Limestone, gray, marly, shaley bedded, extremely fossiliferous.	1.0
Limestone, steel-gray, weathering gray, finely crystalline, moderately dense, massive, fossiliferous, containing mostly fragments but fusulinids are numerous.	1.4
ADMIRE shale formation:	

18. Outside the area; measured just west of the center of the west section line of sec. 7, T. 25 N., R. 7 E.

Americus limestone member:	

	Feet
ADMIRE shale formation:	
Shale, brown, splintery, with several thin 1" limestones at the base	2.5
Limestone, steel-gray, weathering tan, extremely fine-crystalline, massive, slightly silty in the upper part, non-fossiliferous or sparingly so	0.9
Shale, brown, fissile	0.3
Limestone, as above	0.3
Shale, brown, fissile, with a few thin stringers of silty limestone	0.4
Limestone, steel-gray, weathering tan to cream, non-crystalline, moderately dense, massive, fossiliferous, containing abundant pelecypod fragments and numerous unidentifiable gastropods	0.8
Shale	4.0

19. Sec. 6, T. 25 N., R. 7 E.; measured from the south bank of the stream up the north facing escarpment near the west boundary of the NW¼.

Americus limestone member: The approximate base.	
ADMIRE shale formation:	
Covered interval	5.5
Limestone, gray, weathering tan, non-crystalline to finely crystalline, moderately dense, possibly slumped about 5'	0.3
Shale essentially, but this interval contains several soft, silty limestones whose respective positions are impossible to ascertain at this location. The shale varies from drab at the base through irregular zones of maroon and blue-gray upward and the entire interval is littered with small calcareous nodules	40.0
Note: Found a short distance east of this location is a gray, limonitic mottled, finely crystalline, moderately dense limestone, containing a few small fusulinids as well as other fossil fragments and it forms a small but prominent bench about 22' below the base of the Americus limestone.	
Limestone, yellowish, soft, silty, non-fossiliferous	N.M.
Covered interval, probably marly limestone and shale	3.0
WOOD SIDING formation:	
Brownville limestone member:	
Limestone, gray, weathering gray, finely	

	Feet
crystalline, dense, slightly argillaceous, massive, contains extremely abundant small to medium fusulinids and a few small horn corals. .	1.0
Covered interval.	4.5
Limestone, gray, weathering gray to brownish, non-crystalline to finely crystalline, soft, silty, irregularly bedded.	2.0
Pony Creek shale member:	
Siltstone, brown, calcareous, shaley bedded	1.2
Shale, brownish, fissile.	7.0
Coal, blocky, no underclay.	0.2
Shale, drab, fissile to platy, sandy and silty in the upper 3'.	5.5
Covered interval, probably shale.	20.0
Unnamed limestone:	
Limestone, gray, weathering gray with a faint maroon tinge, finely crystalline, moderately dense, possibly slumped a foot or so, though not overly fossiliferous it does contain a few brachiopods, crinoid radial plates and other fossil fragments	N.M.
Covered interval.	18.0
Limestone, gray, weathering light gray with some minor limonitic staining, non-crystalline to finely crystalline, forms a small bench and occurs as fragments.	N.M.
Covered interval, limestone fragments noted near the top of this interval that contain fossils replaced by calcite.	12.0
Limestone, gray, weathering gray with mottled limonitic staining, finely crystalline, weathers into irregular fragments and is fossiliferous, containing Crurithyris planoconvexa, Chonetes granulifer, Dictyoclostus americanus, Marginifera wabashensis, a few small fusulinids and large crinoid columnals	N.M.
Covered interval.	17.0
Grayhorse limestone member:	
Limestone, dark gray, weathering brown, coarsely crystalline, slightly conglomeratic, contains abundant small algal pellets, and weathers into thin slabby fragments.	N.M.

20. Sec. 18, T. 25 N., R. 7 E.; measured up the steep slope about 100 yards north of the farmhouse in the NW¼ SE¼.

ADMIRE shale formation:	
Covered interval, limestone debris at the top . . .	21.0
Sandstone, buff, weathering a dirty tan to brown,	

	Feet
fine-grained, massive, gently cross-bedded, about.	4.0
Shale essentially, maroon, upper part covered . . .	4.0
Siltstone, calcareous, greenish, sandy, with phosphatic shells.	N.M.
Limestone, dark gray, weathering brownish, fine to coarsely crystalline, conglomeratic, possibly algal, weathers into thin slabs which litter the slope	0.3
Shale, predominantly maroon, blocky to fissile. . .	22.0
Limestone, gray, weathering gray, finely crystalline, argillaceous, weathers thin bedded, appears algal on the upper surface, and contains numerous fossil remains.	0.5
Covered interval.	2.0
WOOD SIDING formation:	
Brownville limestone member:	
Limestone, gray, weathering gray, finely crystalline, dense, massive, and contains extremely abundant small to medium fusulinids.	1.0
Covered interval.	2.5
Limestone, gray, weathering light gray to cream, non-crystalline to finely crystalline, moderately dense, prominent vertical jointing, and contains numerous small fossil fragments	0.5

21. Sec. 28, T. 25 N., R. 7 E.; measured from the stream bed up the west bank in the NE¼.

WILLARD-STOTLER (Dry) shale formation:	
Sandstone, tan to buff, massive-to irregular-bedding, some prominent cross-bedding, fine- to medium-grained, resistant	7.5
Covered interval, probably shale.	26.0
EMPORIA limestone formation:	
Elmont limestone member: ??	
Limestone, gray to brownish-gray, weathering gray to brown, medium-crystalline, slightly conglomeratic, moderately dense, massive but weathers into thin slabs, although it contains an abundance of fossil fragments few are distinctive other than a few spiriferoid brachiopods and very few small fusulinids	1.0
Covered interval.	21.0
Reading limestone:	
Limestone, light gray, medium-crystalline, algal, weathers to a crumbly state, probably slumped several feet	1.5
Limestone, yellowish, soft, argillaceous.	1.0

	Feet
Shale, maroon, fissile.	4.5
Limestone, gray to brownish, weathering with definite limonitic stain but moderately so and locally stained red, non-crystalline to finely crystalline, dense, brittle, and contains abundant fusulinids and a few "Cryptozoon" . . .	2.0
Covered interval.	11.0
Limestone, gray, weathering yellowish, dense, finely crystalline, massive, contains no distinctive fossils but numerous fragments.	1.0
AUBURN shale formation:	
Covered interval.	15.0
Sandstone, buff to tan, fine- to medium-grained, massive to irregular-bedding, some cross-bedding, contains one foot lenses of drab gray, blocky, sandy, shale	6.0

22. Sec. 35, T. 25 N., R. 7 E.; measured along the east side of the road in the $SE\frac{1}{4}$ $SE\frac{1}{4}$.

AUBURN shale formation:	
Sandstone, tan to buff, weathering with minor limonitic stain, fine- to medium-grained, massive, irregular bedding, slightly micaceous locally, contains variegated shale lense near top of interval and at the base a few imprints of brachiopods and Aviculopecten sp.	17.0
Shale, chiefly maroon, blocky, with some clayey zones.	28.0
BERN limestone formation:	
Wakarusa limestone member:	
Limestone	N.M.

23. Sec. 34, T. 25 N., R. 7 E.; measured from the west bank of Hominy Creek along the western edge of the $SW\frac{1}{4}$ $SW\frac{1}{4}$ up a ravine in the $SE\frac{1}{4}$ $SE\frac{1}{4}$ of sec. 33.

Reading limestone member: Estimated base.	
AUBURN shale formation:	
Shale, olive drab to brown at the top, fissile, sandy.	5.0
Covered interval.	11.0
Shale, olive, fissile	3.0
Limestone, brownish, crystalline, coquinoid, essentially all brachiopod fragments but a few pelecypod fragments also	1.0
Shale, olive, fissile to blocky, sandy in the lower part	24.0

	Feet
Sandstone, tan, weathering tan to buff, fine-grained, massive, moderately cross-bedded	3.0
Covered interval, but it seems to consist of a sandy, silty, drab shale.	5.0
Shale, maroon, blocky	12.5
Shale, drab, blocky to nodular, calcareous, fossiliferous, containing Dictyoclostus americanus, and Chonetes granulifer in abundance and some fluted crinoid columnals	4.0
BERN limestone formation:	
Wakarusa limestone member:	
Limestone, steel blue-gray, weathering a pale limonitic brown, finely crystalline to non-crystalline, and contains numerous "Cryptozoon" and small fusulinids	0.6
Shale, drab to maroon, fissile.	0.5
Limestone, steel blue-gray, weathering the same to light tan, non-crystalline, extremely dense, sub-conchoidal fracture, massive, and contains a few small fusulinids, a few brachiopods and an occasional "Cryptozoon"	1.9

Township 24 North

24. Sec. 6, T. 24 N., R. 6 E.; measured up the steep slope in the NW¼.

FORAKER limestone formation:	
Long Creek limestone member:	
Limestone, gray, weathering gray with a brown tinge, medium-crystalline, moderately dense, probably medium-bedded, and contains a few small to medium fusulinids, about.	5.0
Covered interval essentially but contains abundant sandstone debris 5' from the base.	12.0
Hughes Creek limestone member:	
Covered interval essentially but considered to be largely limestone, gray, weathering brownish, medium-crystalline, dense, massive, shows some algal characteristics, and relatively non-fossiliferous.	2.0
Limestone, dark gray, weathering dirty gray to tan, finely crystalline, moderately dense, irregular-bedding, and contains extremely abundant medium to large fusulinids, some extremely large in the upper layer of this interval	2.0
Covered interval, upper 12' contains abundant limestone debris	24.0

	Feet
Americus limestone member: The top probably extends into the interval above about 5'.	
Limestone, gray, weathering tan, non-crystalline, silty, sparingly fossiliferous	0.5
Shale, drab	0.2
Limestone, gray, weathering tan, finely crystalline, massive, silty, weathering into irregular chips, few fossils evident	1.0
Covered interval.	4.0
Limestone, gray, weathering gray to tan, finely crystalline to non-crystalline, dense, massive, and contains abundant small to medium fusulinids	1.0
ADMIRE shale formation:	
Covered interval.	23.5
Limestone, gray, weathering gray, fine- to medium-crystalline, moderately dense, probably massive, forms a good bench and contains fossil fragments and a few small fusulinids, about.	2.0
Shale, drab with a maroon tinge	6.0
Covered interval, probably shale.	12.0
Limestone, dark gray, weathering gray to light gray, non-crystalline to finely crystalline, dense, probably massive, forms a small bench, and contains fragments of fossils and a few small fusulinids	N.M.
Covered interval.	11.0
WOOD SIDING formation:	
Brownville limestone member:	
Limestone, gray, weathering gray-brown, finely crystalline, dense, forms a good bench, and contains abundant small to medium fusulinids. The lower bed of the Brownville lies 7' below the bed here described and is also somewhat prominent.	N.M.

25. Sec. 30, T. 24 N., R. 6 E.; measured in the railroad cut in the NE¼.

WOOD SIDING formation:	
Pony Creek shale member:	
Limestone, limonitic brown, irregular bedding, coquinoid, fossil fragments generally unidentifiable	1.0
Shale, drab green, fissile with a few thin sandstone stringers in the approximate middle of the interval and an accumulation of limonitic material in the upper 3'	12.5
Grayhorse limestone member:	
Limestone, light brown, extremely conglomeratic,	

	Feet
crystalline, the lower 0.7' well packed with Myalina sp. remains.	1.2
Plumb shale member:	
Shale, maroon, ferruginous, fissile, becoming blocky and leached at the top.	4.0

26. Sec. 8, T. 24 N., R. 6 E.; measured on the east side of Salt Creek in the C S½.

WOOD SIDING formation:	
Grayhorse limestone member:	
Limestone	N.M.
Root shale formation - Wood Siding transition	
French Creek-Plum shale:	
Covered interval, probably shale.	8.0
Shale, maroon, fissile.	11.0
Covered interval, probably shale.	10.0
Shale, blue-gray, fissile	5.0
ROOT shale formation:	
Jim Creek limestone member:	
Limestone, reddish-brown, arenaceous, silty, the lower 0.6' is one bed, fossiliferous with rare fusulinids, the upper 0.6' is coquindoid and irregularly bedded	1.2
Friedrich shale member:	
Shale, brownish at the base grading into an olive green, non-fossiliferous but contains a few limonite or ironstone concretions up to several inches in diameter	5.5
Limestone, brownish, algal, fossiliferous	0.3
Shale, brownish-drab, firm, extremely fossiliferous, containing mostly Chonetes granulifer but some Dictyoclostus americanus, Myalina sp. as well as Bryozoa and crinoid columnals	3.0
Shale, predominantly gray-blue but locally variegated, limonitic brown, fissile to splintery and contains much carbonaceous plant material in the upper part.	5.0

27. Sec. 17, T. 24 N., R. 6 E.; measured in the railroad underpass in the C E¼.

WOOD SIDING formation:	
Pony Creek shale member:	
Sandstone, buff to brown, fine- to medium-grained, massive, irregularly bedded, cross-bedded locally with an unconformable base. Near the base of this interval there is a lensing bed of algal, conglomeratic limestone that contains	

	Feet
some streaks of pure sandstone, this limestone is gently cross-bedded	12.0
Shale, maroon, fissile.	3.0
Limestone, greenish-gray, weathering gray to brownish, non-crystalline to finely crystalline, thick to irregularly bedded, slightly algal and contains scab-like structures on the surface	2.0
Shale, maroon, nodular to splintery	4.0
Note: the algal, conglomeratic limestone mentioned above lies approximately 22' above the Grayhorse limestone.	

28. Sec. 33, T. 24 N., R. 6 E.; measured up the stream bed in the approximate center of the section to the outliers of Grayhorse limestone in the C S½.

WOOD SIDING formation:	
Grayhorse limestone member:	
Limestone	N.M.
Root shale - Wood Siding transition:	
French Creek-Plumb shale:	
Covered interval, probably shale.	31.0
Shale, drab brown, extremely fissile.	5.0
ROOT shale formation:	
Jim Creek limestone member:	
Limestone, yellow-brown, non-crystalline, soft, silty, medium to irregularly bedded, highly fossiliferous, mostly fragments, about	1.0
Friedrich shale member:	
Shale, drab, extremely fossiliferous, containing Myalina sp., Chonetes granulifer, large crinoid columnals and other fragments.	3.0
Essentially covered, assumed shale, brown to drab, blocky to fissile.	18.0
Shale, maroon to brown at the top, blocky	8.5
Grandhaven limestone member: ??	
Limestone, weathering yellowish to maroon, non-crystalline, soft, silty, weathering nodular. (In a drainage gully approximately 50' east of this location a 5' massive sandstone occupies the interval up to the approximate base of this unit.)	0.5
WILLARD-STOTLER (Dry) shale formation:	
Covered interval essentially but from observed patches exposed it is a drab, sandy, shale . . .	4.5
Sandstone, buff to orange, fine- to medium-grained, massive.	1.5
Sandstone and shale interbedded	1.0
Sandstone, buff to yellow, fine-grained and thin-	

	Feet
bedded in the upper part while locally conglomeratic and massive in the lower part	4.0
Covered interval, probably shale.	2.5
Sandstone, buff, fine- to medium-grained, medium- to thick-bedded but slightly irregular	4.5
Covered interval, probably shale.	3.0
Sandstone, light tan, fine- to medium-grained, massive.	3.0
Covered interval essentially, but limited exposures of an olive shale may be seen in this interval .	9.0
Shale, drab, fissile, containing a calcareous, fossiliferous zone about 5' from the base of this interval. This zone is believed to be the same one that occurs above the Elmont limestone in T. 27 N., R. 7 E. and the fossil representatives consist predominantly of brachiopod fragments. About 2' above this zone several fragments of a brownish, finely crystalline to non-crystalline, silty, moderately dense limestone containing a few brachiopod fragments occur. . .	11.0
EMPORIA limestone formation:	
Elmont limestone member: The approximate position.	
Covered interval.	6.0
Sandstone, cream, fine-grained, slightly silty, medium-bedded layer at the base, the remainder of this interval being massive, with gentle, ill-defined cross-bedding.	2.0
Shale, maroon, splintery, leached drab in the upper 4"	N.M.

29. Sec. 21, T. 24 N., R. 7 E.; measured along the road trending eastward from the Naval Reserve store in the C E$\frac{1}{2}$.

EMPORIA limestone formation:	
Elmont limestone member:	
Limestone, gray with a brownish tinge, weathering brownish, fine- to medium-crystalline, dense, slightly sandy, and contains some small fragments of fossils	1.0
Harveyville shale member:	
Shale, drab, highly sandy in the upper 2'	9.5
Sandstone, light gray, weathering tan to buff, fine-grained, calcareous, finely cross-bedded. .	1.0
Covered interval, probably shale.	2.5
Reading limestone member:	
Limestone, gray, weathering gray, fine- to medium-crystalline, dense, algal, the pellets being relatively small, weathers with a smooth but irregular surface and contains some locally	

	Feet
numerous fossil fragments.	1.5
Limestone, gray, the lower one foot weathering a deep limonitic brown to yellow, extremely fine-crystalline, dense, brittle, and contains abundant medium to large fusulinids, some zones are packed.	3.0
Covered interval.	3.0
Limestone, light gray, weathering gray, finely crystalline, slightly sandy, contains abundant gastropods that have been replaced by calcite, the bed weathers rapidly	N.M.
Covered interval.	1.0
Sandstone, light tan, weathering dark, fine-grained, medium-bedded	1.5
Covered interval, probably sandy shale.	5.5
Limestone, gray, weathering yellowish, non-crystalline, soft, silty and nodular	0.5
Covered interval, probably shale.	0.5
Limestone, light gray, weathering the same to darker, non-crystalline, extremely dense, conchoidal to sub-conchoidal fracture	0.2
Limestone, light gray, weathering brownish, crystalline, algal, massive, and fossiliferous, containing abundant pelecypod remains. The algal pellets are large and this unit weathers irregularly with a slight parting plane about the middle of the interval	2.0
AUBURN shale formation:	
Shale, brownish, fissile to blocky, with a few thin stringers of sandstone.	10.0

Township 23 North

30. Sec. 19, T. 23 N., R. 6 E.; measured at the upper part of the steep slope east of the road in the NE¼.

FORAKER limestone formation:	
Long Creek limestone member:	
Limestone, gray, weathering light gray with minor amounts of limonitic staining, medium to coarsely crystalline, dense, possibly algal, non-fossiliferous and forms the uppermost bench, about.	1.0
Covered interval, covered with small fragments of light tan limestone containing a few fossil fragments.	3.0
Limestone, dark gray, weathering light gray, with limonite stains, medium to coarsely crystalline,	

Feet

medium dense, thin-bedded, but weathers out in larger fragments than the underlying limestone, contains minor amout of chert float (probably from above), is a small bench former, and contains an abundance of long slender fusulinids, possibly slumped, about. 3.0

Covered interval. 9.0

Limestone, dark gray, weathering light gray with limonitic blotches, extremely fine-crystalline, dense to the point of being almost lithographic, thin but irregular bedding, forms small bench, and contains an abundance of large fusulinids, some zones are packed, about 1.0

Hughes Creek Limestone member:

Covered interval. 13.0

Sandstone, light buff to cream, fine-grained, thin-bedded. 1.0

Covered interval. 2.0

Sandstone, sugar brown, weathering dirty, fine-grained, base irregularly bedded but the upper 1.5' is thinly laminated 3.0

Covered interval, probably sandy shale. 3.0

Sandstone, tan to buff, weathering a mottled brown, fine- to medium-grained, massive, with some cross-bedding near the base, and forms the most prominent bench in the immediate area . 6.0

31. Sec. 8, T. 23 N., R. 6 E.; measured from a stream bed up slope in a southerly direction from the C N½ to the SE¼.

FORAKER limestone formation:

Hughes Creek limestone member:

Sandstone, buff to brown, massive, prominent. . . . N.M.

Covered interval, about 5.0

Americus limestone member:

Limestone, brownish, crystalline, and extremely fossiliferous, containing abundant Myalina sp. and brachiopods. . . . . N.M.

Covered interval. 3.0

Limestone, gray, weathering gray to brownish-gray, medium to coarsely crystalline, dense, good bench former, appears slightly algal, and contains highly abundant small fossil fragments . . 2.0

Covered interval, covered with limestone debris but probably shale 4.0

Limestone, gray, weathering gray, locally limonitic stained, finely crystalline, dense, massive, prominent vertical jointing, good bench former,

	Feet
and contains abundant small fossil fragments among which only numerous small fusulinids are identifiable, about.	1.0
ADMIRE shale formation:	
Covered interval, littered with limestone debris. .	17.0
Limestone, dark gray, weathering gray, finely crystalline to non-crystalline, thin-bedded, breaks irregularly as if slightly silty but actually is resistant to weathering forming a good bench and contains an abundance of fossil fragmental material	N.M.
Covered interval essentially but littered with considerable sandstone debris, probably predominantly maroon shale with sandstone beds about 11' and 20' from the base of this interval	37.0
WOOD SIDING formation:	
Brownville limestone member:	
Limestone, gray, weathering gray with some locally brownish zones, finely crystalline, medium-bedded, and contains abundant small to medium fusulinids and abundant crinoidal debris, resistant, forming a good bench	N.M.
Pony Creek shale member:	
Covered interval, littered with abundant limestone debris. This interval is measured to the top of the above described limestone.	15.0
Shale, maroon, fissile to blocky.	17.0
Covered interval.	6.0
Sandstone, pinkish, weathering a dark, mottled, dirty brown, fine- to medium-grained, massive, with a slight hint of cross-bedding, about . . .	2.0
Covered interval, probably shale.	12.0
Unnamed limestone: ??	
Limestone, brownish to reddish, medium-crystalline, algal appearing and contains numerous large fragments of Myalina sp. that have been replaced by calcite. This limestone's position is approximate due to its occurence merely as fragments about 50 yards west of the line of this section.	N.M.
Covered interval.	19.0
Limestone, light gray to off-white, weathering darker, finely crystalline, sandy, massive, slightly pitted, and grades into the sandstone below.	2.0
Sandstone, orange-buff, weathering darker buff to dirty brown, massive, weathering with a pitted, rough surface.	1.0
Covered interval with considerably numerous small	

	Feet
fragments of yellowish-brown, fine- to medium-crystalline, arenaceous limestone in the lower 11' of this interval	38.0
Grayhorse limestone member:	
Limestone, gray, weathering a drab brown, medium to coarsely crystalline, shows its conglomeratic nature well, contains numerous fossil fragments and occurs as large fragments.	N.M.
Covered interval.	30.0
ROOT shale formation:	
Jim Creek limestone member:	
Limestone, gray, weathering light brownish gray, finely crystalline, slightly argillaceous, massive, fossiliferous, becoming sandy at the base .	1.0
Friedrich shale member:	
Sandstone, buff, weathering buff, fine- to medium-grained, thin-bedded to massive, and has gently undulating bedding planes.	2.0
Shale, drab, fissile.	11.0
STOTLER limestone formation:	
Grandhaven limestone member: ??	
Limestone, gray-brown, weathering the same, non-crystalline, ferruginous, argillaceous and highly fossiliferous, though mostly fragments, of which almost exclusively brachiopods.	0.6
Shale, drab, sandy.	5.0

32. Sec. 8, T. 23 N., R. 6 E.; measured up the west side of the road in the NW¼.

WOOD SIDING formation:	
Grayhorse limestone member:	
Limestone, dark gray, weathering brownish, medium to coarsely crystalline, shows its conglomeratic nature by the presence of small light blue to off-white pebbles, and contains a few Myalina sp.	N.M.
Root shale - Wood Siding transition:	
French Creek-Plumb shale formation:	
Covered interval, probably shale.	10.0
Shale, maroon, fissile.	18.0
ROOT shale formation:	
Jim Creek limestone member: ??	
Limestone, yellow-brown, weathering brownish, non-crystalline, soft, silty to arenaceous, massive, most of the bed is sparingly fossiliferous but the upper 3" is extremely fossiliferous.	1.5
Friedrich shale member:	
Siltstone and shale interbedded, five well-defined 3" beds of siltstone with shale between.	2.0

	Feet
Shale, drab, platy	1.0
Sandstone, pale olive, fine-grained, silty, medium-bedded.	1.0
Shale, blue-gray to brown, fissile.	8.0
STOTLER limestone formation:	
Grandhaven limestone member: ??	
Limestone, drab brown, crystalline, silty, fossiliferous, the middle part of this interval is shaley and nodular and weathers back more readily than the remainder of the bed.	1.2
WILLARD-STOTLER (Dry) shale formation:	
Shale, brown, fissile, and highly fossiliferous at the base while the upper part is blue-gray to brown and fissile to splintery.	9.0
Siltstone, brown, arenaceous, thin-bedded	1.0
Shale, blue-gray, weathering brown, fissile, and contains a few fossil fragments, most of which are Myalina sp., possibly wash	8.5

33. Sec. 13, T. 23 N., R. 6 E.; measured from a pond by the south side of Oklahoma Highway 20 up to a road cut in the SW¼ SW¼.

WILLARD-STOTLER (Dry) shale formation:	
Sandstone, buff, with some limonitic spotting, fine-grained, medium-bedded, with a 3' to 4' massive bed that seems to be a channel filling at the base, causing this interval to vary as well as the shale below, about	5.0
Shale, drab brown, fissile, sandy . . . . . .2' to	5.0
EMPORIA limestone formation:	
Elmont limestone:	
Limestone, brownish-gray, weathering the same, finely crystalline, dense, massive, arenaceous, contains locally numerous small fusulinids . . .	2.0
Shale	0.2
Limestone, gray, weathering gray, finely crystalline, extremely dense, massive, and contains abundant small to large fusulinids	1.5
Limestone, gray, weathering drab brown, thin-bedded and contains abundant fossil fragments, the most noticeable being small to large fusulinids	1.0
Shale, drab brown, fissile, with a blue-gray zone overlying a definite sandstone stringer zone one foot from the base of this interval . .	5.5
Covered interval, probably shale.	21.5
Reading limestone member:	
Shale, maroon, predominantly the aforementioned but the surface is covered with abundant small	

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	Feet
fragments of the limestone described above . . .	11.0
Limestone, weathering yellowish at the base and purplish at the top, the upper portion is finely crystalline, dense, shows only one well defined 0.3' bed and contains an extreme abundance of fusulinids; the lower part is soft, silty, rather thin-bedded, due probably to rapid weathering, and is packed with small to large fusulinids . .	2.0
Shale, maroon, fissile and contains abundant small to large fusulinids, probably washed from above.	1.5
Limestone, gray with a purplish tinge, weathering drab brown, non-crystalline, dense, upper surface slightly pitted, and contains numerous extremely small fusulinids	0.5

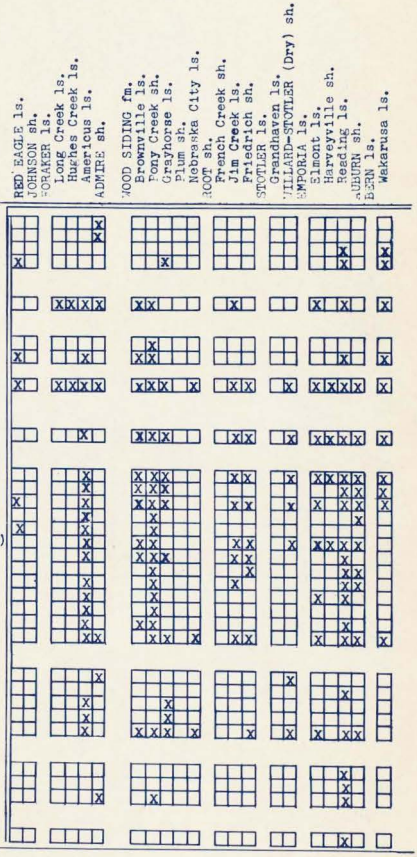
Township 22 North

34. Sec. 1, T. 22 N., R. 6 E.; measured in the bank of a small stream bed 10 yards east of an old trail along the western edge of the SW¼ NW¼ NW¼.

Approximately 62' to the base of the Reading limestone.	
BERN limestone formation:	
Wakarusa limestone member:	
Limestone, gray, weathering brownish with limonitic staining, non-crystalline to extremely fine-crystalline, dense, chalcopyrite or pyrite locally coating some fragments when broken, and fossiliferous, medium fusulinids predominantly	0.4
Shale, brownish	0.2
Limestone, gray, weathering brown with minor limonitic staining, non-crystalline to extremely fine-crystalline, dense, fractures irregularly, massive, and contains an abundance of small to medium fusulinids	1.6
Shale, blue-gray, fissile	0.1
Limestone, same as above.	0.6
Shale, gray-blue, fissile	0.6
Limestone, brownish-gray, weathering brownish, non-crystalline, dense, breaks into irregular, angular fragments, and contains an abundance of small fossil fragments.	0.7
Shale, blue-gray, weathering brown, fissile	0.3
Limestone, blue-gray, weathering brownish to off-white with limonitic staining on the upper surface, finely crystalline, extremely dense, sub-conchoidal fracture, massive, fossiliferous, containing medium fusulinids	1.0
Soldier Creek shale member:	
Shale, blue-gray, splintery to fissile.	2.0

APPENDIX B

PALEONTOLOGY



Plantae
- Calamites
- Sigillaria
- "Cryptozoon" (Osagia & Ottonosia)
- Other algal forms

Protozoa
- Triticites

Anthozoa
- Chaetetes sp.
- Lophophyllidium ? sp.

Crinoidal debris

Bryozoa
- Fenestrate and encrusting forms

Brachiopoda
- Chonetes granulifer Owen
- Composita subtilita (Hall)
- Crurithyris planoconvexa (Shumard)
- Derbyia crassa (Meek and Hayden)
- Derbyia sp.
- "Dictyoclostus" americanus (Dunbar and Condra)
- Hustedia mormoni (Marcou)
- Juresania nebrascensis (Owen)
- Marginifera sp.
- Neospirifer dunbari King
- Punctospirifer kentuckiensis (Shumard)
- Wellerella osagensis (Swallow)
- Other fragments

Pelecypoda
- Aviculopecten sp.
- Edmondia aspinwallensis Meek
- Myalina copei Whitfield
- Myalina perattenuata Meek and Hayden
- Myalina (Orthomyalina) subquadrata Shumard

Gastropoda
- Amphiscapha sp.
- Murchisonia gouldii Beede
- Unidentifiable spp.

Trilobita
- Ditomopyge decurtata Gheyselinck

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