

**KANSAS GEOLOGICAL SURVEY**  
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Pennsylvanian and Permian Stratigraphy  
of Elk County, Kansas

by

George J. Verville

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**KANSAS GEOLOGICAL SURVEY**

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PENNSYLVANIAN AND PERMIAN STRATIGRAPHY  
OF ELK COUNTY, KANSAS

by

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## INTRODUCTION

This stratigraphic report of Elk county, Kansas, embraces an area of 651 square miles and is based on field studies carried out during the summer months of 1949 and 1950. This particular county was selected for this study because it contains some of the best exposures of upper Pennsylvanian and lower Permian rocks in Kansas. It was hoped that a detailed study of the stratigraphy in Elk county would contribute additional information concerning lateral changes which occur in these ages of rocks southward along their strike from the dominantly marine Pennsylvanian and Permian rocks of the Kansas River Valley to the increasingly non-marine clastic section in Oklahoma.

Exposures throughout the county, embracing the entire thickness of rocks represented, were measured in detail and correlated with the better known Pennsylvanian and Permian rocks in central and northern Kansas. The group boundaries and the contacts of the more prominent limestones and shales were mapped on air photographs in the field. The accompanying areal geologic map was made by transferring the field data from the photographs to a base map by the use of a grid

system. Generalized sections of the groups and detailed cross-sections, with individual sections arranged from north to south along the strike, were drafted and are presented in the appropriate place throughout the text. Over 300 fossil collections, including both limestone and shale samples, were made. However, as the purpose of this investigation is stratigraphic in nature, nothing resembling an exhaustive paleontologic study was made. The faunal lists given in the text represent only the more common genera. The detailed locations, lithologies, and thicknesses of the measured sections are to be found at the end of this report.

## ACKNOWLEDGEMENTS

The field work for this report was financed by the Kansas State Geological Survey, as part of their program of compiling up to date reports on the stratigraphy, ground water, and economic geology of eastern Kansas counties. This paper constitutes the stratigraphic portion of such a report on Elk county.

Dr. J. M. Jewett of the Kansas State Geological Survey directed the field work and gave suggestions and constructive criticism throughout its progress.

Dr. M. L. Thompson not only gave constant aid during the preparation of this report, but was responsible for the undertaking of this project.

## GENERAL CONSIDERATIONS

Elk county is located in southeastern Kansas and is in the second tier of counties north of the Kansas-Oklahoma boundary and in the fourth tier of counties west of the Kansas-Missouri boundary. The accompanied index map (Fig. 1) shows the location of Elk county and the adjacent counties to which reference is made in the report. Elk county is rectangular in shape, with a north-south dimension of 21 miles and an east-west dimension of 31 miles, embracing an area of 651 square miles. Elk county comprises townships or parts of townships 28 to 31 south in ranges 8 to 13 east.

Elk county lies within the physiographic subdivisions known as the Osage Prairie and the Flint Hills Upland. The latter subdivision occupies the extreme western edge of the county and consists of a series of relatively high escarpments, the eastern edge of which is held up by the westerly dipping chert-bearing Foraker limestone. The remainder of the county lies within the Osage Prairie subdivision. The topography of this subdivision consists mainly of a series of low, north-northeast trending cuesta-like ridges, formed by the outcropping thin Pennsylvanian limestones. The interven-

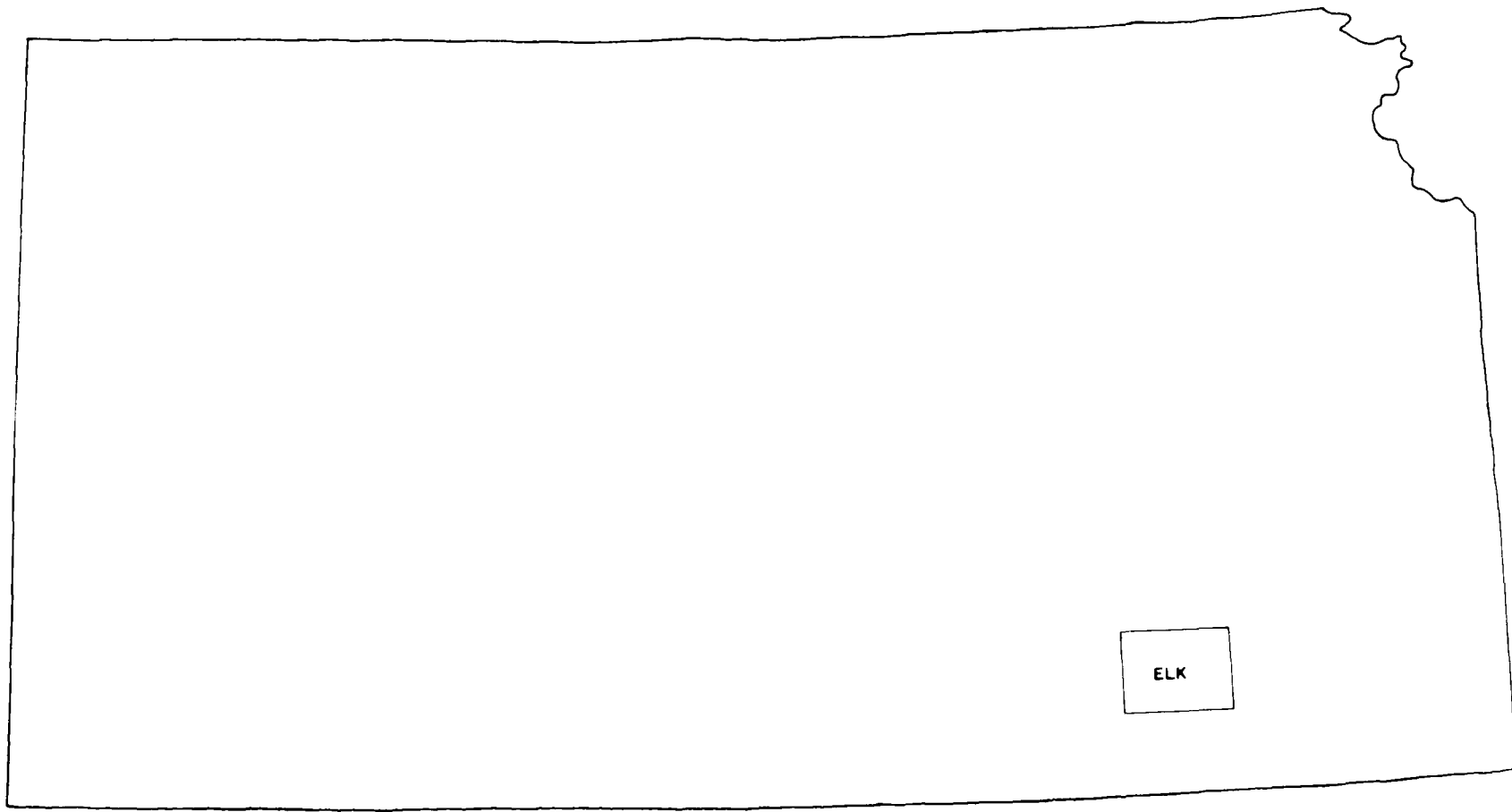


FIG. I. OUTLINE MAP OF KANSAS SHOWING THE LOCATION OF ELK COUNTY

ing valleys are somewhat asymmetrical in cross-section, their floor being defined by the dip slope of the gently dipping limestones for the most part, but being terminated rather abruptly on their western edge by the relatively steep shale slope underlying the next higher limestone. The outstanding topographic features of the Osage Prairie are the relatively high escarpments formed by the thick Plattsmouth and Ervine Creek limestones and the rounded hills and ridges formed by the massive sandstones in the Kanwaka and Lawrence shales.

The relief of Elk county is about 750 feet, the lowest point in the county being the surface of the Elk River, southeast of Oak Valley, which is somewhat less than 850 feet above sea level. The highest point in the county occurs in the extreme northwestern corner, where the chert capped Flint Hills have an elevation of slightly more than 1,600 feet. .

The two largest streams in Elk county are the Elk and Fall rivers, tributaries of the Verdigris River. The only extensive alluvial deposits are found in the valleys of the Elk and Fall rivers and along Indian Creek. The extent of the alluvium is shown on the accompanying areal geologic map (Plate 1).

## STRATIGRAPHIC SUMMARY

The exposed rocks in Elk county belong to the upper part of the Pennsylvanian and the lower part of the Permian Systems. These rocks, which have a combined thickness of about 1,600 feet, strike north - northeast across the county and dip gently to the west. The dip is slight, being only about 30 to 40 feet per mile. The only exposed rocks in the county which are not upper Paleozoic in age are the thin, scattered, high level chert gravels believed to be Pleistocene and the alluvial terraces and flood plain deposits in the major stream valleys. A stratigraphic table of the outcropping Paleozoic rocks of Elk county is given on page 27.

The Pennsylvanian System is represented by about 1,100 feet of rocks belonging to the Pedee group of the Missourian Series and to the Douglas, Shawnee, and Wabaunsee groups of the Virgilian Series.

The Missourian Series crops out in the extreme southeastern corner of the county and is represented only by the exposed upper part of the Weston shale. The Iatan limestone, which overlies the Weston shale and is the top formation of the Pedee group in other parts of Kansas, is not present in Elk county.

The Virgilian Series in Elk county is about 1,050 feet thick and comprises the outcropping rocks over the great majority of the area of the county. The base of the Virgilian Series, which is by definition, the disconformity occurring between the Stanton limestone and the Stranger formation, is not strikingly pronounced in Elk county. This disconformity, which is drawn at the base of the channel-filling Tonganoxie sandstone, is obscure, because the Tonganoxie sandstone thins to less than 2 feet in southeastern Elk county and is locally absent in the area just to the south. This thinning and local absence of the Tonganoxie sandstone is probably the result of a thinning of sandstone deposition over the divides between the channels cut into the underlying Weston shale. Although the base of the Tonganoxie sandstone is not exposed northward from T. 31 S., the member is known to thicken considerably to the north, where it is presumed to be a channel-filling deposit. Similar thickening is reported to occur locally in Chautauqua county to the south.

Similarly, the upper boundary of the Virgilian Series (also the top of the Pennsylvanian System) is defined as the disconformity at the base of the channel-filling Indian Cave sandstone member of the Towle shale. In Elk county, the beds immediately above and below the Brownville limestone appear to be conformable, with the only suggestion of a disconformity immediately above the Brownville limestone being a slightly discolored zone in the lower part of the Towle shale.

However, lower in the section, within the French Creek shale, a locally prominent channel-filling sandstone occurs. Elsewhere in Kansas, channel-filling sandstones have been reported in the Pony Creek shale, in a stratigraphic position which is intermediate between the Indian Cave sandstone and the sandstone in the French Creek shale. It would appear from this, that the upper Pennsylvanian, as now defined, was a time of local unrest during which channels were cut at several different stratigraphic positions in the upper Pennsylvanian rocks of Kansas. The upper Virgilian boundary is drawn at the top of the Brownville limestone, the persistent formation which underlies the Towle shale.

Rocks of the Douglas group in Elk county are between 225 and 250 feet thick. They crop out along the eastern edge of the county, and the entire outcrop belt of the group is present only in the southeastern corner of the county. The Stranger formation, the lower formation of the group, is characterized by lateral variations in thickness and lithology which make correlation from outcrop to outcrop somewhat difficult. Lithologically, the only persistent member is the Haskell limestone: a thin, massive, algal bearing limestone.

The lowest member, the Tonganoxie sandstone, thins southward across Elk county and is locally missing in the area immediately south of the county. The Westphalia limestone is also locally absent, being found only in the north-

eastern corner of Elk county and in the northeastern corner of Chautauqua county. In an excellent exposure of the lower part of the Douglas group in southeastern Elk county, the Westphalia limestone is missing. From the exposures of the Westphalia limestone in this area, it seems that the following generalization can be made; where the underlying Tonganoxie sandstone is thickest, and presumably represents a channel-filling deposit, the Westphalia limestone is present. This suggests that the marine invasion responsible for the deposition of the Westphalia limestone was relatively shallow and that the occurrence of the member, as seen on the outcrop in Elk and adjacent counties, represents limestone deposition in marine embayments that extended into the areas formerly occupied by the stream valleys. Evidently, the marine invasion was not sufficiently deep over the pre-existing divides between the stream channels to allow continuous limestone deposition over the entire area. This condition, however, was attained somewhat higher in the section when the thin but persistent Maskell limestone was deposited. The upper member of the Stranger formation, the Robbins shale, is a thick, sandy to clayey shale which locally contains deep channels in its upper part. These channels were cut prior to the deposition of the overlying Lawrence shale and are filled by the massive sandstones (Ireland sandstone) of the lower part of that formation.

The Lawrence shale is also variable in thickness, being up to about 170 feet thick where the basal Ireland sandstone fills deep channels cut into the underlying Robbins shale. The upper part of the Lawrence shale, above the fusulinid bearing Amazonia limestone, is a sandy to clayey shale which contains a persistent thin coal in the upper part. A generalization<sup>ed</sup> section of the rocks of the Douglas group is illustrated in Figure 2. The lateral variations found in the measured sections of the Douglas group are presented in the cross-sections of Figure 3.

The rocks of the Shawnee group in Elk county are about 400 feet thick and crop out in a belt averaging about 12 miles in width and trending north-northeast, with their westernmost boundary running approximately through the center of the county. Lithologically, the Shawnee group is unique, being composed of beds which display a distinctive type of cyclic deposition. This type of deposition, termed megacyclothem<sup>ic</sup> by Moore (1936a), is characterized by a repetition in which distinctive types of limestones are repeated in the same order in the four limestone formations of the group. The nature of the typical Shawnee megacyclothem is well known and should not require lengthy repetition at this time. However, a brief discussion of each of the formations as they exist in Elk county and their variations from the more nearly complete megacyclothems of north and central Kansas will be given. A generalized section of the rocks of the Shawnee

group is given in Figure 4.

The Oread limestone in Elk county contains the "lower", "middle", "upper", and "super" limestones which characterize the formation to the north in Kansas. However, the "lower" and "super" limestones vary considerably from their counterparts in northern Kansas.

The Toronto limestone member ("lower" limestone) thins markedly across Elk county, being reduced to two thin limestones separated by a thin shale in the southern part of the county. The thinning is accompanied by a pronounced faunal change. Fusulinids, which dominate the fauna of the member in its type area, are found in its limestone phase only in the most northerly outcrops in Elk county. In T. 30 S., the thin limestones and shales contain brachiopods, bryozoans, corals, and ostracods, with the fusulinids being restricted to the shale below the lower limestone bed of the member. Here, the fusulinids occur in great abundance only a foot or so above a coal and about a foot below the limestone. The Toronto limestone is reported to be represented by a single limestone bed in outcrops in Chautauqua county to the south.

The Snyderville shale member, above the Toronto limestone, is about 65 feet thick in Elk county, representing an increase of approximately 50 feet over the thickness reported for the member in northern Kansas.

The Leavenworth limestone ("middle" limestone) and overlying Heebner shale members are very persistent and maintain approximately the same thickness and lithology as is found in northern Kansas.

The "upper" limestone, the Plattsmouth limestone member maintains its lithologic and faunal development southward into Elk county; however, the member is slightly thinner in Elk county, being on the average about 15 feet thick. Southwest from Toronto, in Greenwood county, the Plattsmouth limestone is locally missing, with the interval immediately above the persistent Heebner shale being occupied by a fossiliferous shale which closely resembles the Heumader shale of northern Elk county.

The Heumader shale member can only be differentiated in the northern outcrops in Elk county, as the Kereford limestone member, which defines the top of the Heumader shale, is not persistent south of T. 29 S. The Kereford limestone ("super" limestone) was not found on the outcrop south of T. 29 S. In the southernmost exposure of the Kereford limestone studied in Elk county, the member is very thin and apparently represents the feathering edge of the limestone. However, channeling in the lower part of the Kanwaka shale was observed to cut down to the top of the Kereford limestone in Greenwood county and may be responsible for local cutting out of the Kereford limestone in parts of Elk county. Exposures in

T. 33 S., Chautauqua county, do not show evidence for the Kereford limestone having been removed by erosion, and it is assumed that the Kereford limestone was never deposited that far south. Lateral variations found in the measured sections of the Oread limestone are shown in the cross-sections in Figure 5.

The Kanwaka shale, which represents the terminus of the Oread megacyclothem and the beginning of the Lecompton megacyclothem, thickens southward, being about 40 feet thick in northern Kansas and about 140 feet in northern Chautauqua county. This thickness is of the combined Heumader-Kanwaka shale. The marine limestone member of the Kanwaka shale, the Clay Creek limestone, was not observed on the outcrop in southern Elk and northern Chautauqua counties. As the Kereford limestone is also missing south of T. 29 S., the entire interval from the top of the Plattsmouth limestone to the base of the Spring Branch limestone cannot be subdivided and is referred to as the Heumader-Kanwaka shale. In the parts of Elk county where the Clay Creek limestone is present, and where the Jackson Park and Stull shale members can be distinguished, the former is found to contain a massive, channel-filling sandstone deposit, the Elgin sandstone. The literature reports that the Elgin sandstone is found in southern Kansas within the Stull shale. This was not found to be the case in Elk and Chautauqua counties. As this sandstone has been regarded as the initial phase of the

Lecompton megacyclothem, it would seem that this cyclic event took place somewhat lower in the Kanwaka shale in southern Kansas than to the north, where a thick sandstone is reported to be present in the Stull shale in the vicinity of the lower Kansas River. The variations found in the measured sections of the Kanwaka shale are shown in the cross-sections shown in Figure 6.

The Lecompton limestone, which is about 50 feet thick in Elk county, clearly displays the same type of cyclic deposition encountered in the Oread limestone below. In general, the Lecompton limestone differs from the Oread limestone in being a considerably thinner formation in which the intervening limestones are thinner and more variable. The four major limestone types are found, but they display the typical lithologic features somewhat less perfectly and are more variable along the outcrop than are the limestones of the Oread limestone. In Elk county, the lower limestone member, the Spring Branch, is persistent but quite variable, often being a somewhat impure algal limestone which contains a sparse fusulinid fauna. Across Elk county and into Chautauqua county, the lower part of the Lecompton limestone is characterized by a southward thinning of the Doniphan shale and Big Springs limestone members and by a southward thickening of the Queen Hill shale member. The "upper" limestone of the Lecompton limestone, the Beil, is a persistent and fossiliferous limestone which clearly displays the wavy-bedded

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& thickens to  
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character of this member of the magacyclothem. The Avoca limestone member, which is algal in its upper part and fusulinid bearing below, thins southward from central Elk county into Chautauqua county. The variations found in the measured sections of the Lecompton limestone are shown in Figure 6.

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unnoticed PC* 16

The Tecumseh shale, which is about 70 feet thick in the vicinity of the Kansas River, averages about 45 feet in thickness in Elk and northern Chautauqua counties. Because the Ost limestone member of the Tecumseh shale is not persistent and may not even be present in Elk county, the formation is not divisible into the members recognized in northern Kansas and Nebraska. The Ost limestone may be represented by the thin ostracod bearing limestone which occurs in the middle of the Tecumseh shale in sec. 10, T. 30 S., R. 11 E. The sandstone in the upper part of the formation, which has been regarded as the initial deposit of the Deer Creek megacyclothem, is represented by 10 to 20 feet of sandstone in the upper part of the formation in Elk county.

The rocks of the Deer Creek limestone, which are about 60 feet thick in Elk county, also display the cyclic repetition found in the Oread and Lecompton limestones. With the exception of the relatively greater thickness of the Ervine Creek limestone member (up to about 35 feet), the members of this formation are very closely similar to their counterparts in the more northerly exposures in Kansas, indicating remarkable persistence of the members of this formation.

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The Calhoun shale, which is about 45 feet thick in the vicinity of the Kansas River, thins southward and is represented in Elk county by 2 to 10 feet of sandy to clayey shales.

The Topeka limestone, which is about 40<sup>to 50</sup> feet thick in Elk county, represents the last of the typical Shawnee megacyclothems. The members of this formation are less persistent across Kansas than the members of the formations below. The members of the Topeka limestone are correlated southward across central Kansas with some difficulty. The Hartford limestone, perhaps the most persistent member of the formation, displays some of the characteristics of the "lower" limestone unit of a megacyclothem. The Coal Creek limestone, as developed in Elk county, is clearly the equivalent of the "middle" limestones of the other Shawnee limestone formations. The intervening limestones and shales of the Topeka limestone in Elk county are less readily correlated with either the units of a typical megacycle or with the better known exposures of the Topeka limestone in the Kansas River area. In the cross-sections of the measured exposures of the Topeka limestone in Elk county (Fig. 8), I have suggested what seems to be the most plausible correlation between the Topeka limestone in northern Kansas and the formation as developed in Elk county.

The Wabaunsee group, which in Elk county is slightly less than 450 feet thick, crops out in a belt averaging about

9 miles in width. The eastern edge of the outcrop belt runs north-northeast approximately through the center of the county, with the western boundary being very irregular but terminating in the lower slopes of the eastern edge of the Flint Hills.

The group is characterized by the relative preponderance of shales, most of which are silty or sandy. The limestones are thin but very persistent, with little difficulty encountered in correlating most of them with their counterparts to the north in Kansas. The cyclic deposition displayed by the rocks of the Wabaunsee group is strikingly different from that of the underlying Shawnee group. In the Wabaunsee group, the rocks fit into an alternating pattern of marine and non-marine units which apparently do not conform to any larger megacyclic arrangement. The group has been divided into a number of shale and limestone formations, with the former including the shales, coals, and sandstones which are interpreted as representing the ending and beginning phases of adjacent cycles. The limestone formations include the limestones and intervening shales, which are regarded as representing the middle part of each cycle. A generalized section of the rocks of the Wabaunsee group is shown in Figure 9.

In Elk county, the rocks of the Wabaunsee group, up to the top of the Elmont limestone, are readily correlated with the rocks of the section in north Kansas. However, in Elk county, the interval between the top of the Elmont and the base of the Dover limestones is occupied by an average of

only 9 feet of rocks of variable lithology, including coals, underclays, shales, and thin somewhat unusual limestones. The comparable interval to the north, in the vicinity of Emporia, is occupied by three shale and two limestone formations, with a combined thickness of about 100 feet. Evidently, during this time, the general area of Elk county remained relatively close to sea level or at least received only minor amounts of sediments. The presence of three thin coals in the Willard-Langdon shale in sec. 2, T. 30 S., R. 9 E. suggests that the area, at least locally, was sufficiently above sea level at various times to allow coal forming vegetation to grow and accumulate. Northward, the area evidently was more deeply submerged for longer periods, as up to 100 feet of sediments, including two marine fusulinid-bearing limestones, were deposited in the area of Lyon county.

The Dover limestone in Elk county consists of three limestones separated by shales, with a combined thickness of about 20 feet. In northern Kansas, only the middle fusulinid bearing unit is present. To the south, the formation is expanded to include a higher algal limestone and a lower, massive, brachiopod-bryozoan limestone. The upper algal bed is reported to be first observed in the section south of the Kansas River, while the lower limestone bed is first observed still farther to the south in Greenwood county.

The interval between the Dover and Jim Creek limestones in Elk county contains several thin and rather undistinctive

limestones separated by shales in which one persistent and several apparently local coals are present. The interval is not well known as it is usually rather poorly exposed. The rocks of this interval are usually rather badly covered as they crop out at the base of the slope along the front of the Flint Hills. Small isolated outcrops are often seen; however, the rather similar and <sup>undistinctive</sup> ~~homogeneous~~ nature of the limestones does not favor the construction of entirely dependable composite sections. The correlations and variations of the rocks of this interval are shown in the cross-sections illustrated as Figure 11.

The French Creek shale in Elk county contains a rather prominent channel-filling sandstone in the upper part. This sandstone is the thickest and most prominent sandstone in the uppermost Pennsylvanian and lower Permian rocks in Elk county. The possible relationship of this sandstone to the Indian Cave and other slightly lower sandstones in the section in other parts of Kansas is discussed above.

The Caneyville limestone thickens slightly to the south across Elk county, with two or three thin limestones making their appearance in the extreme southern part of the county. Of these thin limestones, which appear between the Nebraska City and Grayhorse limestone members, evidently only the uppermost fusulinid bearing limestone bed persists southward across Chautauqua county.

The upper boundary boundary of the Wabaunsee group, corresponding also to the top of the Pennsylvanian System, is drawn at the top of the Brownville limestone. The channel filling-sandstone which occurs in the lower part of the Towle shale in other parts of Kansas is not present in Elk county.

The Permian System in Elk county is represented by about 525 feet of rocks belonging to the Admire, Council Grove, and Chase groups of the Wolfcampian Series. The Permian rocks crop out in a narrow belt along the western margin of the county. Because of the relatively thick limestones, some chert bearing, the Permian rocks crop out in a series of high escarpments known as the Flint Hills, and the dominant topographic feature of southeastern Kansas. The group boundaries and the lower contacts of the more prominent limestones are mapped on the accompanying areal geologic map. Generalized sections and cross-sections of the Permian rocks of Elk county are given in the text following these general stratigraphic considerations.

The Admire group in Elk county averages about 110 feet in thickness. The rocks of this group, which are predominately shaly, crop out as the upper part of the slope immediately below the first major escarpment of the Flint Hills. The group crops out in a very narrow belt, generally less than one-half mile in width. All of the named subdivisions of the group are recognized in Elk county. However,

the Aspinwall and Falls City limestones are not well developed. The Five Point limestone, occurring about in the middle of the group, is the only persistent mappable formation. A generalized section of the rocks of the Admire group is illustrated as Figure 12.

Rocks of the Council Grove group, averaging about 315 feet in thickness, occupy the great majority of the Permian outcrop belt in Elk county. The lower part of the group consists of thick limestone formations which crop out as the lower escarpments of the Flint Hills. Stratigraphically higher, the limestones of the group are thinner, but because of the increased thickness of the intervening shales, they are well exposed and form distinct, though minor, benches which can be traced across Elk county. The limestones of the upper part of the group are very well suited for mapping on areal photographs, as the slight but distinct benches are readily traced with the use of a stereoscope. A generalized section of the rocks of the Council Grove group is illustrated as Figure 14.

The Foraker limestone, which is about 55 feet thick in Elk county, is characterized by its abundant fusulinid fauna and by the presence of highly fossiliferous blue chert nodules. Southward from Wabaunsee county, the limestone element of the formation becomes increasingly more prominent, comprising over 55 per cent of the thickness of the formation in Elk county as contrasted to 20 or 25 per cent of the formation

farther to the north.

A similar southward increase in the limestone content is seen in the Red Eagle limestone. To the north, the formation consists of 2 limestone members separated by up to 14 feet of shale. In Elk county, the intervening shale, the Bennett, is missing, and the Glenrock and Howe limestone members occur together. However, the two limestone members can be distinguished on the basis of lithology.

The Roca shale and the somewhat higher Eskridge shale are very distinctive formations in Elk county. Being thick, reddish, clayey shales for the most part, they are readily identified on the outcrop. The middle part of the Eskridge shale contains a hard, dense, bluish-green, algal limestone which is very persistent across Elk county.

The Grenola limestone is about 40 feet thick in Elk county. As the formation is both overlain and underlain by relatively thick shales, it outcrops well and forms a distinctive bench across the county. Until recently, the Kansas Geological Survey considered the Sallyards limestone and the Legion shale as subdivisions of the Roca shale; however, Moore (1951) redefines the Grenola formation in accordance with the usage of the Nebraska Geological Survey and includes the Sallyards limestone and the Legion shale as the lower members of the Grenola limestone. The Neva limestone member of the Grenola limestone is almost completely a limestone unit in southwestern Elk county. The member is characterized

by its prolific fusulinid fauna. The Neva represents the lowest reported occurrence of Paraschwagerina in Kansas, a faunal occurrence which has been regarded by some as sufficiently significant to warrant considering the Neva limestone as the base of the Permian in Kansas.

The Beattie limestone is well represented in Elk county. The most significant variation occurring in the formation is the southward change in the character of the Cottonwood limestone, changing from a massive, white to light grey, fusulinid bearing, prominently outcropping limestone to the north in Kansas to a poorly outcropping unit consisting of thin to nodular limestones interbedded with shale in Elk county. The middle shale member of the Beattie limestone, the Florena shale, is the most highly fossiliferous interval of the Permian in Elk county, containing a large variety of excellently preserved fossils. The Morrill limestone, which is decidedly less conspicuous than the Cottonwood limestone to the north, thickens to about 8 feet in Elk county and is one of the most persistent outcropping limestones of the Council Grove group. Long slender specimens of Schwagerina occur in the Morrill limestone in Elk and Cowley counties.

The remainder of the Council Grove group, with the exceptions of the algal, thin-bedded but relatively thick Crouse and the variable Funston limestones, consists predominantly of varicolored shales with minor amounts of thin to nodular, sparingly fossiliferous limestones. The

Speiser shale, the uppermost formation of the group, consists of varicolored, clayey to sandy shales with local thin sandstones. The formation is highly fossiliferous in the upper part, possessing a persistent zone containing abundant large specimens of Derbya, Juresania, and Aviculopinna.

The rocks of the Chase group are found only in scattered outliers along the western margin of Elk county. The group is represented by about 100 feet of rocks comprising the Wreford limestone, Matfield shale, and the lower part of the Florence limestone. Because of the high chert content and massive character, the thick limestones of the lower part of the Chase group are very resistant and form some of the more prominent escarpments of the Flint Hills in southern Kansas. A generalized section of the rocks of the Chase group in Elk county is illustrated as Figure 16.

The Wreford limestone is by far the most widespread of the lower Chase group formations in Elk county. The formation caps about a dozen small outliers along the western margin of Elk county. In most instances in Elk county, only the lower few feet of the formation are bedded, with the upper part being reduced by weathering to a chert rubble. The total thickness of the formation, about 30 feet, is present only in the extreme northwestern corner of the county. In general, the Wreford limestone consists of massive to thin beds of cherty limestone and bedded chert, with only minor thick-

nesses of shale. Because of the southward liming up of the formation, the members which have been recognized to the north in Kansas are not clearly distinguishable in Elk and Cowley counties.

The Matfield shale and the lower part of the Florence limestone are found to occur only in the extreme northwestern corner of Elk county, where the highly cherty rubble of the lower part of the Florence limestone caps two small outliers. These outliers represent the highest topographic points in Elk county, being slightly higher than 1,600 feet above sea level. The Florence limestone, like the lower occurring Wreford limestone, is a very cherty, massive limestone which is characterized by very abundant fusulinids. The Florence represents the lowest reported stratigraphic horizon in Kansas to contain Pseudoschwagerina.

The following table gives the names and stratigraphic positions of all the Pennsylvanian and Permian rocks found to outcrop in Elk county:

TABLE I

Stratigraphic section of the outcropping Pennsylvanian  
and Permian rocks in Elk county,  
Kansas

PERMIAN SYSTEM

Wolfcampian Series

Chase group

- Barneston limestone
- Florence limestone member
- Matfield shale
- Blue Springs shale member
- Kinney limestone member
- Wymore shale member
- Wreford limestone

Council Grove group

- Speiser shale
- Funston limestone
- Blue Rapids shale
- Crouse limestone
- Easley Creek shale
- Bader limestone
- Middlebury limestone member
- Hooser shale member
- Eiss limestone member
- Stearns shale
- Beattie limestone
- Morrill limestone member
- Florena shale member
- Cottonwood limestone member
- Eskridge shale
- Grenola limestone
- Neva limestone member
- Salem Point shale member
- Burr limestone member
- Legion shale member
- Sallyards limestone member
- Roca shale
- Red Eagle limestone
- Howe limestone member
- Glenrock limestone member
- Johnson shale
- Foraker limestone
- Long Creek limestone member
- Hughes Creek shale member
- Americus limestone member

**Admire group**

Hamlin shale  
     Oaks shale member  
     Houchen Creek limestone member  
     Stine shale member  
 Five Point limestone  
 West Branch shale  
 Falls City limestone  
 Hawxby shale  
 Aspinwall limestone  
 Towle shale

**PENNSYLVANIAN SYSTEM****Virgilian Series****Wabaunsee group**

Brownville limestone  
 Pony Creek shale  
 Caneyville limestone  
     Grayhorse limestone member  
     Nebraska City limestone member  
 French Creek shale  
 Jim Creek limestone  
 Friedrich shale  
 Grandhaven limestone  
 Dry shale  
 Dover limestone  
 Willard-Langdon shale  
 Elmont limestone  
 Harveyville shale  
 Reading limestone  
 Auburn shale  
 Wakarusa limestone  
 Soldier Creek shale  
 Burlingame limestone  
 Silver Lake shale  
 Rulo limestone  
 Cedar Vale shale  
 Happy Hollow limestone  
 White Cloud shale  
 Howard limestone  
     Utopia limestone member  
     Winzeler shale member  
     Church limestone member  
     Aarde shale member  
     Bachelor Creek limestone member  
 Severy shale

## Shawnee group

## Topeka limestone

Coal Creek limestone member

Holt shale member ?

Du Bois limestone member ?

Turner Creek shale member ?

Sheldon limestone member

Jones Point shale member

Curzon limestone member

Hartford limestone member

## Calhoun shale

## Deer Creek limestone

Ervine Creek limestone member

Larsh-Burroak shale member

Rock Bluff limestone member

Oskaloosa shale member

Ozawkie limestone member

## Tecumseh shale

## Lecompton limestone

Avoca limestone member

King Hill shale member

Beil limestone member

Queen Hill shale member

Big Springs limestone member

Doniphan shale member

Spring Branch limestone member

## Kanwaka shale

Stull shale member

Clay Creek limestone member

Jackson Park shale member

Elgin sandstone

## Oread limestone

Kereford limestone member

Heumader shale member

Plattsburgh limestone member

Heebner shale member

Leavenworth limestone member

Snyderville shale member

Toronto limestone member

## Douglas group

## Lawrence shale

Amazonia limestone member

Ireland sandstone member

## Stranger formation

Robbins shale member

Haskell limestone member

Vinland shale member

Westphalia limestone member

Tonganoxie sandstone member

*delete**undifferentiated*

Missourian series

Pedee group  
Weston shale

## PENNSYLVANIAN SYSTEM

The Pennsylvanian System in Elk county is represented by about 1,100 feet of rocks belonging to the Missourian and Virgilian Series. The Missourian Series crops out in the extreme southeastern corner of the county and is represented only by the single formation, the Weston shale of the Pedee group. The outcrop belt of the Virgilian Series, averaging only slightly less than 30 miles in width, includes approximately five-sixths of the total area of Elk county. The Virgilian Series is about 1,050 feet thick and contains the following groups, in ascending order: Douglas, Shawnee, and Wabaunsee.

The areal extent of the outcropping rocks of the recognized groups of the Pennsylvanian System is shown on the accompanying areal geologic map (Plate 1). The names and stratigraphic positions of the outcropping rocks of the Pennsylvanian System in Elk county are given in the stratigraphic table of the outcropping rocks of Elk county, page 27.

### Missourian Series

The name Missouri stage was proposed by Keyes (1894) to replace the term "Upper Coal Measures" and included the beds between the "great limestone" at Winterset, Iowa, and the base of the Cottonwood limestone. Although the Missouri or Missourian was at various times given the rank of series, formation, stage, division, or group, the approximate stratigraphic usage of Keyes was generally adhered to for many years. Moore (1932) redefined the base of the Missourian Series to coincide with the regional disconformity which occurs from 5 to 100 feet below the Hertha limestone, and lowered the upper boundary of the series to coincide with the widespread disconformity which occurs between the Stanton limestone and the Stranger formation of the Douglas group.

The rocks of the Missourian Series in Kansas have been divided into the following groups, in ascending order: Pleasanton, Kansas City, Lansing, and Pedee.

In Elk county, the only Missourian rocks exposed belong to the upper part of the Pedee group. The approximate top of the Missourian Series in Elk county is mapped on the accompanying areal geologic map (Plate 1) and its position is indicated by the dashed line identified by the symbol We.

### Pedee group

The Pedee group was defined by Moore (1932) to include the beds between the top of the Stanton limestone and the disconformity which defines the base of the Virgilian Series. The group includes only two formations, the Weston shale and the Iatan limestone. The thickness of the group across Kansas averages about 90 feet (Moore, 1951).

In Elk county, the Pedee group is represented by the exposed upper part of the Weston shale. The Iatan limestone was not found to outcrop in southeastern Elk county.

### Weston shale

The Weston shale was named by Keyes (1899) from exposures near Weston, Platte county, Missouri. The name was applied to the shaly beds occupying the interval between the Stanton and Iatan limestones. Locally, where the Iatan limestone is missing, as in southeastern Elk county, the top of the Weston shale is defined by the disconformity at the top of the Missouri Series.

Across Kansas, the Weston shale is a dark-bluish to bluish-grey shale which locally contains thin fossiliferous limestones and sandstones. The shale commonly contains numerous concretions. The formation varies in thickness from a featheredge up to about 200 feet (Moore, 1951).

Lithologic character and thickness.--- The maximum thickness of the Weston shale found to be exposed in Elk county was located in sec. 21, T. 31 S., R. 13 E. Here, the exposed upper part of the Weston shale measures about 22 feet in thickness and consists of grey to greenish, clayey to silty shale which contains numerous small limonitic concretions. In T. 32 S., R. 13 E., southeast of Elk City, the Weston shale consists of about 55 feet of grey clayey shale. The approximate position of the top of the Weston shale is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol We.

Fauna.--- No fossils were found in the exposures of the Weston shale that were measured.

For measured sections of the Weston shale, see section 5 at the end of this report.

#### Virgilian Series

The Virgil Series was originally named by Moore (1931) to include beds from the base of the Americus limestone to the top of the shale overlying the Iatan limestone. Moore (1936a) redefined the Virgil Series and included the beds from the unconformity which occurs between the Stanton limestone and the Stranger formation up to the unconformity marked by the channel sandstones above the Brownville limestone. The series is subdivided into the following groups, in ascending order; Douglas, Shawnee, and Wabaunsee. The type exposures

are along the Verdigris River in Greenwood and Wilson counties, Kansas. The name was derived from the town of Virgil, Greenwood county, Kansas. The ending -ian is used in this report in accordance with the policy of the Geological Survey of Kansas.

### Douglas Group

The Douglas formation, named for Douglas county, Kansas, was defined by Haworth (1898) to include the Lawrence shales and the Oread limestone. The Lawrence shale was then defined as including all beds from the top of the "Garnett limestone" to the base of the Oread limestone. Moore (1932) restricted the Douglas group to the beds between the unconformity at the top of the Missourian Series and the base of the Oread limestone.

In Elk county, the Douglas group is 225 to 250 feet thick and consists mainly of thick sandstones and micaceous, sandy shales with two or three thin algal or fusulinid bearing limestones. The group outcrops in eastern Elk county and its line of outcrop is characterized by steep sided, scrub oak covered sandstone hills which are held up by the massive Ireland sandstone. The outcrop belt of the Douglas group is shown on the accompanying areal geologic map. The top of the group is very well defined; however, the base of the group is exposed only in the extreme southeastern part of the county and is mapped with difficulty as it is defined

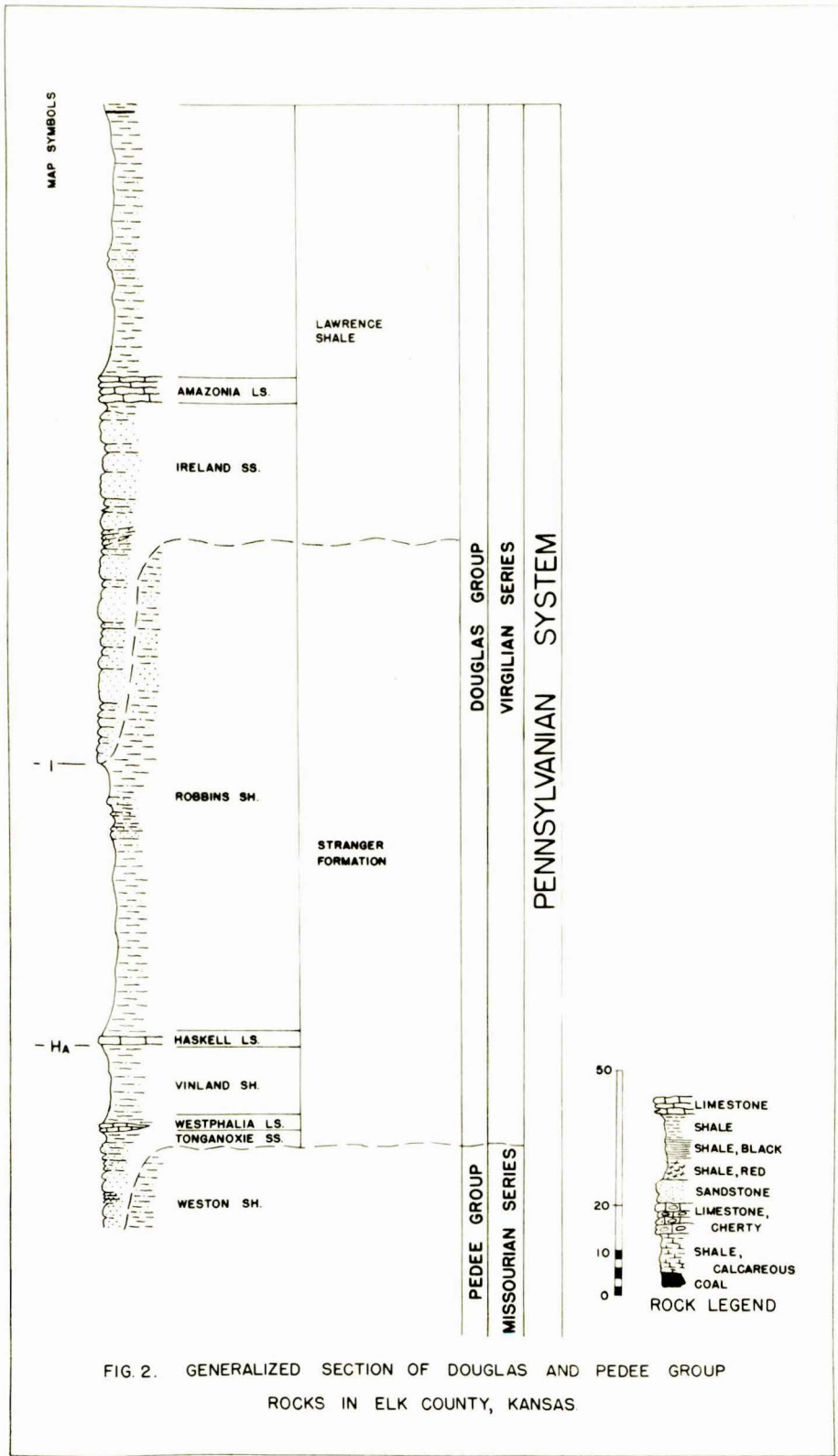


FIG. 2. GENERALIZED SECTION OF DOUGLAS AND PEDEE GROUP ROCKS IN ELK COUNTY, KANSAS

by a sandstone of variable thickness. A generalized section of the rocks of the group is illustrated as in Figure 2.

#### Stranger formation

Although the name Stranger formation had been used previously, it was formally described by Newell (1936) as including the beds between the unconformity at the top of the Pedee group and the base of the Haskell limestone. Moore (1936a) redefined the formation and raised the upper boundary to the disconformity at the base of the Ireland sandstone member of the Lawrence shale.

In Elk county, the formation varies from 65 to about 130 feet in thickness.

#### Tonganoxie sandstone member

The Tonganoxie sandstone was named by Moore, Elias, and Newell (1934). The type area is located east of Tonganoxie, Leavenworth county, Kansas. Throughout Kansas, the Tonganoxie sandstone is highly variable in thickness, ranging from a featheredge to almost 100 feet (Moore, 1936a). In the more northerly outcrop area, the Tonganoxie sandstone contains several thin, discontinuous coal beds. The disconformity at the base of the sandstone has been reported from many localities throughout eastern Kansas and is the major criterion for placing the Missourian-Virgilian boundary at this stratigraphic position.

Lithologic character and thickness.---- In Elk and immediately adjacent counties, the Tonganoxie sandstone varies from a minimum of slightly less than 2 feet to over 40 feet in thickness. In sec. 21, T. 31, S., R. 31 E., the Tonganoxie sandstone consists of a 1.6 foot massive bed of grey to greenish, calcareous, brown weathering sandstone which possesses many worm borings and castings. In west-central Wilson county, sec. 11, T. 29 S., R. 13 E., the Tonganoxie sandstone consists of over 40 feet of grey to light brown, fine grained micaceous, massive to cross-bedded or thin-bedded sandstone which contains scattered concretions, ironstone, bands, and plant fragments (H. C. Wagner, personal communication).

The thin Tonganoxie sandstone in southeastern Elk county possibly represents a thin veneer of sandstone which was deposited over a divide between channels, as was suggested by Moore (1936a) for a similar occurrence a few miles west of Elk City. In the latter instance, Moore reports that in sec. 15, T. 32 S., R. 13 E., the lower Stranger formation does not contain a basal sandstone and that shales of Stranger age rest directly upon shales believed to be the Weston shale of upper Missourian age.

In southeastern Elk county, where the thin Tonganoxie sandstone is exposed, the disconformity below the member is obscure but may be represented by the somewhat irregular base shown by the member in this area.

The Tonganoxie sandstone is exposed in the extreme southeastern and northeastern corners of the county; however, the base of the member is exposed only in the southeastern outcrops where the sandstone is very thin. The base of the Tonganoxie sandstone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop marks the position of the Missourian-Virgilian boundary in Elk county.

For measured sections of the Tonganoxie sandstone, see sections 2, 4, and 5 at the rear of this report.

#### Westphalia limestone member

The Westphalia limestone was named by Moore and Newell (1936a) from exposures near the town of Westphalia, Anderson county, Kansas. The limestone has not been recognized north of T. 19 S. but is reported by Moore (1944) to be fairly persistent throughout southern Kansas. Newell (1934) described Triticites secalicus var. oryziformis from the limestone in Anderson county. Comparison of the original description and illustrations with thin sections of the fusulinids collected in Elk and Chautauqua counties show them to be very closely similar.

Lithologic character and thickness.--- In Elk county and immediately adjacent areas, the Westphalia limestone is a discontinuous, shaly to sandy, fusulinid bearing algal limestone which averages slightly less than 3 feet in thickness.

In sec. 3, T. 32 S., R. 13 E., the member is just over 2 feet thick and consists of 1 foot of dark grey, sandy to silty, dirty, irregular platy limestone underlain by a 0.9 foot, more massive, dark grey, mottled, red to brownish weathering limestone which contains abundant Osagia, Triticites, and a few coaly fragments. The lower 2 to 3 inches consist of grey, shaly, calcareous plates. In the outcrops in the northwestern corner of the county, the member is a little thicker, ranging from 3.1 to about 4.8 feet. In a well exposed section of the lower Stranger formation in sec. 21, T. 31 S., R. 13 E., the Westphalia limestone is missing; however, about 3 miles to the south, the member is well exposed along an east-west county road in the extreme north east corner of Chautauqua county. The discontinuous nature of the member in Chautauqua county was noted by Moore (1937).

Although the Westphalia limestone is fusulinid bearing and seemingly represents the maximum marine invasion of the lowermost cycle in the Stranger formation, it is interesting to note the relatively great abundance of clastic material present (coaly fragments, mica flakes, silt, and fine sand) which seems to suggest an environment of deposition in shallow waters relatively near shore.

Fauna.--- The following fossils were collected from the limestone in sec. 3, T. 32 S., R. 13 E.; Triticites, Neospirifer, Juresania, Osagia, crinoid stems, and many small shell fragments.

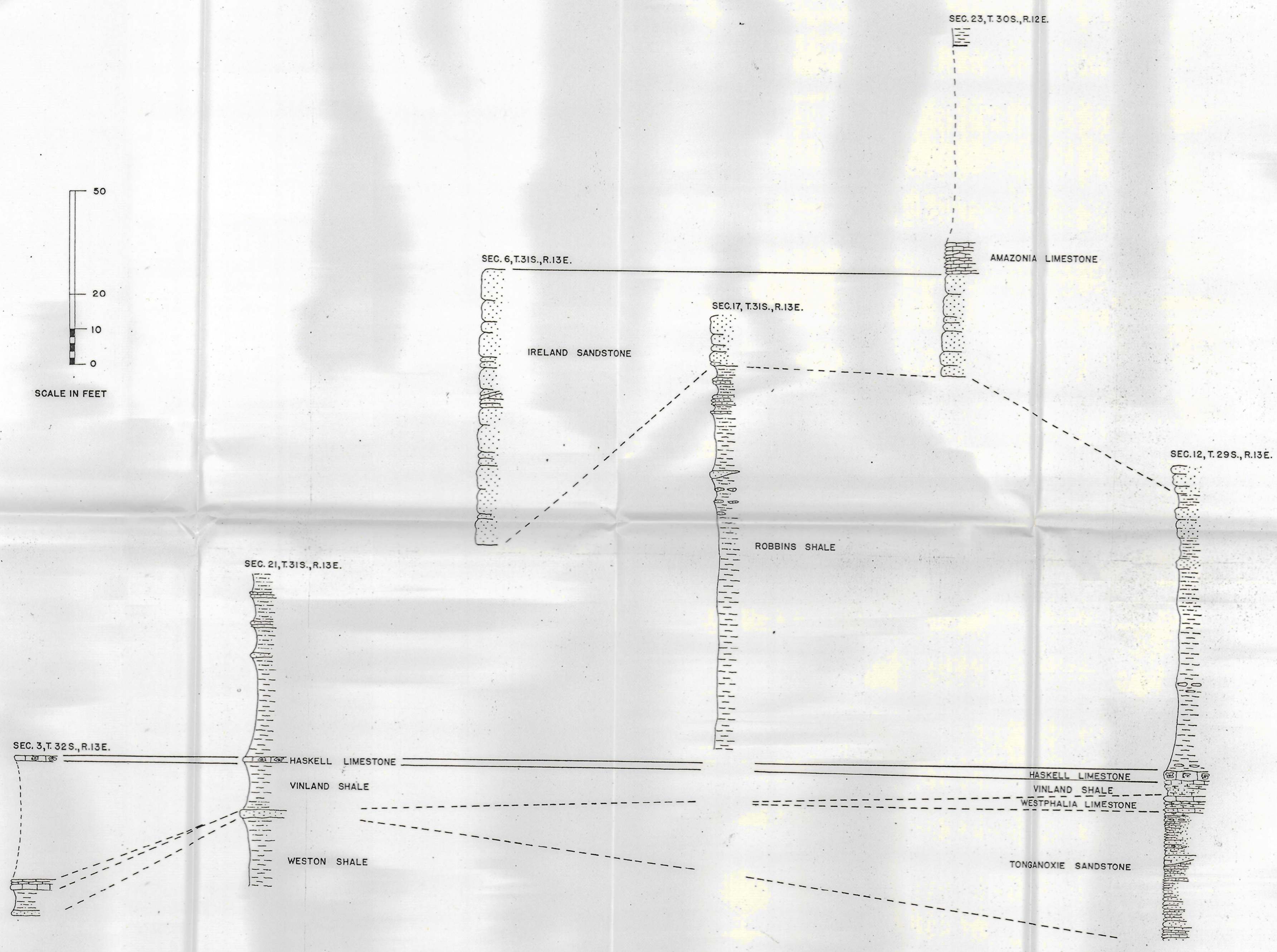


FIG. 3. CORRELATION OF MEASURED SECTIONS OF DOUGLAS AND PEDEE ROCKS.

The lateral variations found within the Westphalia limestone are shown in the cross-sections illustrated in Figure 3. For measured sections of the Westphalia limestone, see sections 2, 4, and 8 at the end of this report.

#### Vinland shale member

The Vinland shale was named by Patterson (1933) in his Master's Thesis at the University of Kansas. Moore, Elias, and Newell (1934) published a stratigraphic chart in which the position and stratigraphic relationships of the Vinland shale were shown. Originally, the Vinland shale included the beds between the Sibley coal and the Haskell limestone; however, Moore and Newell (1936a) restricted the member to the beds between the Westphalia limestone and the base of the Haskell limestone. Throughout Kansas, the member is a grey, clayey, to calcareous, sandy shale which locally contains sandstones and which varies from 9 to 50 feet in thickness (Moore, 1951).

Lithologic character and thickness.--- In Elk county and adjacent areas, the Vinland shale averages about 18 feet in thickness, ranging from about 4 feet in west-central Wilson county (H. C. Wagner, personal communication) to about 35 feet in northeastern Chautauqua county. In sec. 21, T. 31 S., R. 13 E., the Vinland shale is 15 feet thick and consists of yellowish to grey shales in its upper part to greenish-grey.

clayey shales in its lower part. There is a thin zone of pelecypods in the upper few inches in this locality. In a measured section furnished by H. C. Wagner, in sec. 11, T. 29 S., R. 13 E., the Vinland shale consists of a little over 4 feet of thin, variable, shaly to carbonaceous limestones and a thin sandstone.

Fauna.--- The upper part of the shale in southeastern Elk county contains numerous poorly preserved specimens of Myalina. In northeastern Elk county, the member is more calcareous and is somewhat more fossiliferous, with Myalina, fenestellid bryozoans, crinoid stems, and a few small brachiopods being present.

The lateral variations found within the Vinland shale are shown in the crosssections illustrated as Figure 3. For measured sections of the Vinland shale, see sections 2, 4, and 5 at the end of this report.

#### Haskell limestone member

The Haskell limestone was named by Moore (1932) from exposures on the eastern edge of Lawrence, Kansas. The name was derived from the Haskell Institute, Lawrence, Kansas. In the more northerly outcrops, the member consists in general of a main algal bearing unit which possesses an upper and a lower oolitic phase (Moore, 1936a). The member, which varies in thickness throughout Kansas from a featheredge to about 10 feet, is reported to be cut out and overlapped by

the Ireland sandstone in some localities (Moore, 1944).

Lithologic character and thickness.--- In Elk county and adjacent areas, the Haskell limestone is a persistent, massive limestone bed which averages about 1.5 feet in thickness. The member thins southward from about 2.6 feet in west-central Wilson county (H. C. Wagner, personal communication) to about 0.8 feet in the northeastern corner of Chautauqua county. In sec. 21, T. 31 S., R. 13 E., the Haskell limestone is well exposed and is a dark blue-grey, hard, brownish to buff weathering, massive limestone bed which is 1.4 feet thick and which contains abundant black to dark grey, irregular banded algae referred to as <sup>Cryptozoon</sup> Ottensia.

The Haskell limestone crops out only in the northeastern and southeastern corners of the county and is the only consistent stratigraphic horizon in the Douglas group. The base of the member is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol Ha. Although only the main massive unit of the Haskell limestone is present in Elk county, the oolitic upper phase was present in limestones believed to be the Haskell limestone in northwestern Wilson county.

Fauna.--- The Haskell limestone, in sec. 21, T. 31 S., R. 13 E., contains the following fossils; abundant <sup>Cryptozoon</sup> Ottensia, Crurithyris, Lophophyllid corals, and crinoid stems.

The lateral variations found within the Haskell limestone are shown in the cross-sections illustrated in Figure 3. For measured sections of the Haskell limestone, see sections 2, 4, and 5 at the end of this report.

#### Robbins shale member

The Robbins shale was named by Moore and Newell (1936a) from exposures on the Robbins farm, southwest of Yates Center, Kansas. In Kansas, the Robbins shale is essentially restricted to the area south of Woodson county, where the member appears as a southward thickening shale wedge (up to over 100 feet) between the Ireland sandstone and the Haskell limestone (Moore, 1936a).

Lithologic character and thickness.--- In Elk county, the base of the Robbins shale is readily defined, being placed at the top of the persistent Haskell limestone; however, the top of the member is very irregular, being defined by the pronounced disconformity at the base of the channel-filling Ireland sandstone. In the localities where the Ireland sandstone is relatively thin and seemingly represents a more or less sheet phase sand deposited over the divides between channels, the Robbins shale is very thick and the contact between the Ireland sandstone and the Robbins shale can not be sharply defined. The above situation is shown in an exposure in sec. 17, T. 31 S., R. 13 E., where the Robbins shale is about 112 feet thick. At this locality, the

upper part of the member becomes increasingly more sandy and finally grades into the massive sandstones considered to be the base of the Ireland sandstone. Although the Ireland sandstone caps a belt of steep sided hills across eastern Elk county, good exposures of the Ireland-Robbins contact are rare and accurate measurements of the thickness of the two units are difficult to obtain. In the sections studied, the Robbins shale varies from a maximum thickness of about 112 feet to a minimum of about 65 feet or less. In a particularly deep channel, exposed along US Highway 160 between Oak Valley and Longton, the Ireland sandstone has a measurable thickness of about 80 feet; however, the base of the sandstone was not observed at this locality and it is possible that it occurs 10 or 20 feet lower in the section, giving the channel-filling sandstone a possible thickness of about 100 feet. Although individually the two units vary considerably in thickness from place to place, it is believed that the position of the top of the Ireland sandstone in Elk county is relatively uniform and that in any one place the total Ireland-Robbins interval averages about 150 feet in thickness. Following this reasoning further, it seems very possible that underneath some of the deeper channels, such as the one above, the Robbins shale has a thickness of 50 feet or less. In more northerly outcrops, the Robbins shale and Haskell limestone are reported to be cut out in some localities by the Ireland sandstone; however, in Elk county

no such occurrence was observed and in all instances where the Haskell limestone was observed it was overlain by the Robbins shale.

Lithologically, the Robbins shale consists of grey to blue-grey, clayey to silty, blocky shale in its lower part which grades upward into sandy to silty shales and finally into sandstones. In sec. 17, T. 31 S., R. 13 E., the upper 25 feet consist of interbedded reddish to grey, clayey to silty or sandy shale and grey to yellowish or reddish thin sandstones. The next lower 25 feet consist of blue-grey silty shale streaked with orange and yellow and interbedded with thin sandstone plates. This part of the member contains many, small to fairly large, grey to yellowish ironstained concretions in which plant remains are common. The lower 60 feet of the member consists of grey to bluish, less silty, blocky shale.

Fauna.--- With the exception of the plant remains in the concretions discussed above, and a zone of poorly preserved gastropods and brachiopods about 10 feet above the base of the shale in sec. 21, T. 31 S., R. 13 E., the Robbins shale is unfossiliferous.

Lateral changes found within the Robbins shale are shown in the cross-sections illustrated in Figure 3. For measured sections of the Robbins shale, see sections 1, 4, and 5 at the end of this report.

## Lawrence Shale

The name Lawrence shale was first used by Haworth (1894) for exposures near Lawrence, Kansas, which included beds from the top of the Ottawa limestone (Stanton) to the base of the Oread limestone. In a classification of the rocks of the Pennsylvanian and "Permian" published by Moore (1934), the Lawrence shale is regarded as including all beds from the top of the Haskell limestone to the base of the Oread limestone. Moore and Newell (1936a), recognizing the regional importance of the disconformity below the Ireland sandstone, restricted the Lawrence shale to the beds between the disconformity and the base of the Oread limestone. This coincides with the present usage of the term.

The Lawrence shale, with the exception of the Ireland sandstone and Amazonia limestone members, is undivided. In Elk county, the Lawrence shale varies in thickness from about 90 feet to a maximum of about 170 feet, being thickest where the lower sandstone member fills deep channels cut into the top of the underlying Stranger formation.

### Ireland sandstone member

The Ireland sandstone was named by Moore (1932) from exposures on the Ireland farm, 5 miles southwest of Yates Center, Woodson county, Kansas.

Lithologic character and thickness.---- In Elk county, the Ireland sandstone is represented by about 30 to 100 feet of massive sandstone. The sandstone was deposited over an irregular erosion surface and represents a series of channel-fillings which grade laterally into more extensive but thinner sands which seem to represent a sheet phase deposited over the divides between the channels. In the deeper channels, as described above under the Robbins shale, the Ireland sandstone has a measurable thickness of about 80 feet; however, the base of the sandstone was not seen in this particular locality and it is estimated that the sand has a total thickness of about 100 feet in this particular channel. As the sandstone does not possess characteristic subzones which can be identified from one outcrop to another, accurate thickness measurements are difficult to obtain as exposures which possess the entire thickness in one measurable outcrop sequence are not common.

Where the sandstone fills a channel, the contact between the member and the underlying Robbins shale is sharp and well-defined as one would expect; however, where the sandstone appears to represent a more or less sheet phase, the contact is much less well marked. In the latter case, the gradational appearance may be due to reworking of the upper part of the Robbins shale.

In sec. 6, T. 31 S., R. 13 E., the member is well exposed and consists mainly of massive, grey to reddish or buff, fine

to medium angular grained sandstone. Although the member is cross-bedded throughout to some extent, the cross-bedding seems to be most common about 30 to 40 feet below the top.

The outcrop belt of the member, across the eastern edge of the county, is characterized by steep sided bluffs and isolated hills or outliers which invariably are covered by a dense growth of scrub oak.

Elsewhere in Kansas, the Ireland sandstone is separated from the overlying Amazonia limestone by shales of varying thickness (Moore, 1944). In Elk county, in most instances where the Amazonia limestone was present, the massive sandstones of the Ireland occur immediately below it with little or no intervening shale. This is especially well shown in sec. 23, T. 30 S., R. 12 E. and in sec. 35, T. 31 S., R. 12 E.

Although the base of the Ireland sandstone is variable and presents a difficult mapping problem, an attempt was made to map the base of the member as accurately as possible. The approximate line of its outcrop is indicated on the accompanying areal geologic map (Plate 1) by a dashed line identified by the symbol I. Some of the lateral variations in thickness found within the member are shown in the cross-sections illustrated in Figure 3. For measured sections of the Ireland sandstone, see sections 1, 3, 4, and 6 at the end of this report.

### Amazonia limestone member

The Amazonia limestone was named by Hinds and Greene (1915) from exposures near Amazonia, Andrew county, Missouri. In the type area, the Amazonia limestone is 9 feet thick and occurs about 24 feet below the top of the Lawrence shale. The overlying shale is reported to thicken southward from the type area to somewhat over 60 feet near Atchison, Kansas (Moore, 1936a) and up to 100 feet between Rushville and St. Joseph, Missouri (Hinds and Greene, 1915).

Lithologic character and thickness.--- In Elk county, the Amazonia limestone averages slightly less than 5 feet in thickness. In sec. 23, T. 30 S., R. 12 E., the member occurs immediately above the massive sandstones of the Ireland sandstone member and 60 to 65 feet below the lower limestone bed of the Oread limestone. In this locality, the limestone is about 9 feet thick and consists of thin, slabby, irregular beds of dark grey to bluish, light grey to buff or whitish weathering, very fossiliferous limestone. In sec. 24, T. 31 S., R. 12 E., the member is slightly less than 4 feet in thickness and consists of blue, hard, irregular thin beds of highly fossiliferous limestone separated from a lower 0.5 foot sandy, light grey, unfossiliferous limestone by a 0.3 foot blue-grey, clayey, shale. In an exposure just north of the Chautauqua county line, in sec. 35, T. 31 S., R. 12 E., the member is represented by a fusulinid bearing limestone slightly less than 2 feet in thickness.

Fauna.--- In Elk county, the Amazonia limestone is highly fossiliferous. The following fossils were collected from the outcrops discussed above: Neospirifer, Derbya, Punctospirifer, Chonetes, Dictyoclostus, Composita, Crurithyris, Triticites, Osagia, Rhombopora, crinoid stems, and many shell fragments.

For measured sections of the Amazonia limestone, see sections 6 and 7 at the end of this report.

Outcrops of the upper undivided portion of the Lawrence shale are poor, as the unit forms a covered shale slope between the lower limestone units of the Oread limestone and the bench held up by the massive sandstone of the Ireland sandstone member. In one of the few outcrops where a reasonably accurate measurement could be made, in sec. 23 T. 30 S., R. 12 E., the interval from the base of the Toronto limestone to the top of the Amazonia limestone is about 65 feet thick. The interval consists of grey to buff, silty to sandy shales with minor amounts of grey, buff, and greenish sandstone. A persistent, thin coal is found about 2 feet below the top of the shale. The interval between the coal and the lower Oread limestone bed contains an upper grey, calcareous shale crowded with fusulinids and a lower more sandy shale which contains a prolific pelecypod fauna. The following fossils were collected from the shales above the coal in sec. 27, T. 30 S., R. 12 E.: Chonetes, Triticites, Myalina, Dictyoclostus, Rhombopora, Bairdia, Amphissites, echinoid spines, crinoid stems, and fenestellid bryozoans.

### Shawnee group

The Shawnee formation was named by Haworth (1898) to include all beds from the top of the Oread limestone to the top of the Osage (Scranton) shale. The Scranton shale, now a discarded term, was originally defined by Haworth and Bennett (1908) to include the beds between what is now known as the Howard limestone and the Burlingame limestone (Moore, 1936a). The above usage for the Shawnee group was accepted until Moore (1932) redefined the group to include the beds from the base of the Oread limestone to the top of the Topeka limestone. The group contains the following formations, in ascending order: Oread limestone, Kanwaka shale, Lecompton limestone, Tecumseh shale, Deer Creek limestone, Calhoun shale, and Topeka limestone. The group is named from Shawnee county, Kansas. A generalized section of the rocks of the Shawnee group, as developed in Elk county, is shown in Figure 4.

### Oread limestone

The Oread limestone was named by Haworth (1894), at which time, he included only the beds which later were known as the "lower Oread" (Moore, 1936a). Haworth (1895) expanded the formation and included two 15 foot limestones which were separated by about 20 feet of shale in the Oread limestone. The upper of the two limestones corresponds to the Plattsmouth limestone of Condra (1927). Bennett (1896) further expanded

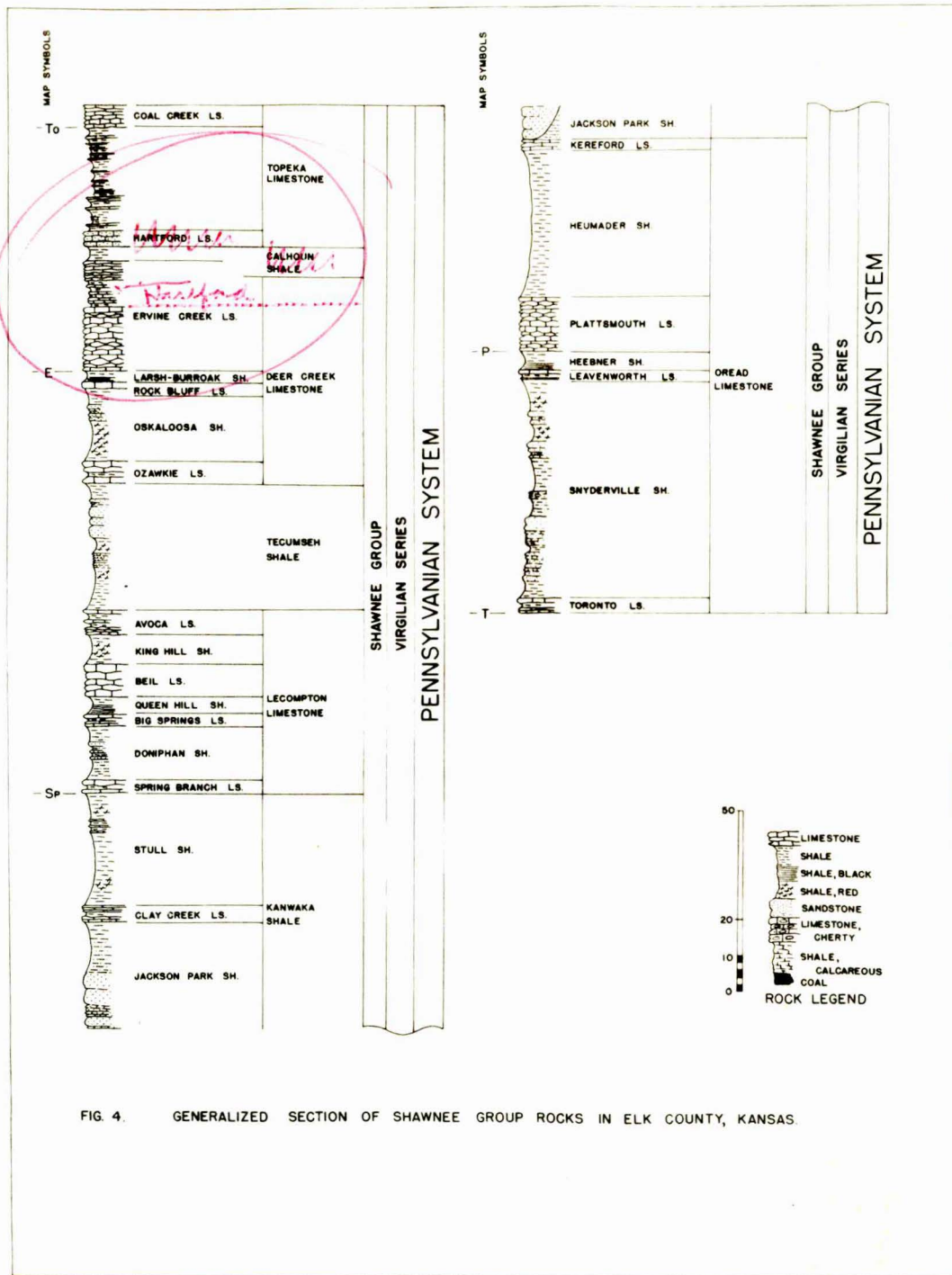


FIG. 4. GENERALIZED SECTION OF SHAWNEE GROUP ROCKS IN ELK COUNTY, KANSAS.

the Oread limestone to include several feet of shelly limestone (Kereford limestone) above the heavy-bedded (Plattsmouth) limestone. The formation includes the following members, in ascending order: Toronto limestone, Snyderville shale, Leavenworth limestone, Heebner shale, Plattsmouth limestone, Heumader shale, and Kereford limestone. In the type locality, Lawrence, Kansas, the formation has a thickness of about 45 feet; however, the formation thickens to the south, giving the formation an overall average thickness of about 70 feet for the state as a whole (Moore, 1944).

In Elk and immediately adjacent counties, the Oread limestone averages about 120 feet in thickness. All of the members, with the exception of the Heumader shale and the Kereford limestone, are well represented.

#### Toronto limestone member

The Toronto limestone was named by Haworth and Fiatt (1894) from exposures near Toronto, Woodson county, Kansas. The original description of the Oread limestone (Haworth, 1894) was of this lower member of the formation; however, the formation was later expanded to include overlying limestones and shales. Condra and Bengston (1915) applied the name Weeping Water to a limestone in Nebraska which occurs at the stratigraphic horizon of the Toronto limestone. Moore (1936a) states that the correlation of the Weeping Water limestone with the lower Oread of Kansas is somewhat doubtful and

that it possibly was more a correlative of the Amazonia limestone member of the Lawrence shale.

Lithologic character and thickness.--- In Elk and adjacent counties, the Toronto limestone varies in thickness from slightly over 10 feet in exposures near Toronto, Woodson county, to 1.7 feet in southeastern Elk county. The faunal and lithologic changes which accompany the southward thinning of the member are marked. In the type area, the member is about 10 feet thick and consists of an upper wavy bedded, grey to dark grey, principally mollusoid limestone with a few fusulinids, separated from a lower more massive, blue, dense, fusulinid bearing limestone by a thin grey, clayey shale. The base of the member in this locality is underlain by a very thin, unfossiliferous dark grey shale followed below by a 0.5 foot coal.

In sec. 5, T. 29 S., R. 13 E., the Toronto limestone consists of about 6 feet of thin bedded limestones<sup>s</sup> most of which are separated by thin shale partings. All of the limestones, with the exception of a silty to sandy molluscan limestone just below the uppermost bed, contain abundant fusulinids. At this locality, the shale between the coal and the nodular basal unit of the Toronto limestone is crowded with fusulinids.

In sec. 27, T. 30 S., R. 12 E., the member is represented by two thin, non-fusulinid bearing, mollusoid limestones separated by a thin blue-grey shale, with a total thickness

of 1.7 feet. Fusulinds are extremely abundant in the shale between the lower limestone bed and the underlying coal. In a section illustrated by Moore (1951) from sec. 33, T. 33 S., R. 11 E., Chautauqua county, the member is represented by a single thin limestone bed. *delete*

Fauna.--- The thin limestones and shale in sec. 27, T. 30 S., R. 12 E. contain the following fossils: Neospirifer, Chonetes, Chonetina, Rhipidomella, Crurithyris, Hustedia, Derbya, Lophophyllum, Rhombopora, Amphissites, Hollinella, Bairdia, fenestellid bryozoans, crinoid stems, and many shell fragments. In sec. 5, T. 29 S., R. 13 E., the following fossils were collected: Triticites, Neospirifer, Composita, Dictyoclostus, Hustedia, Chonetes, Crurithyris, and small gastropods. The silty limestone bed just below the top of the member contains Myalina, Aviculopecten, and Juresania.

The base of the Toronto limestone was mapped and its line of outcrop is indicated on the accompanying areal geologic map (Plate 1) by the symbol T. The lateral variations found within the member are shown in the cross-sections illustrated in Figure 5. For measured sections of the Toronto limestone, see sections 6, 9, 10, and 18 at the end of this report.

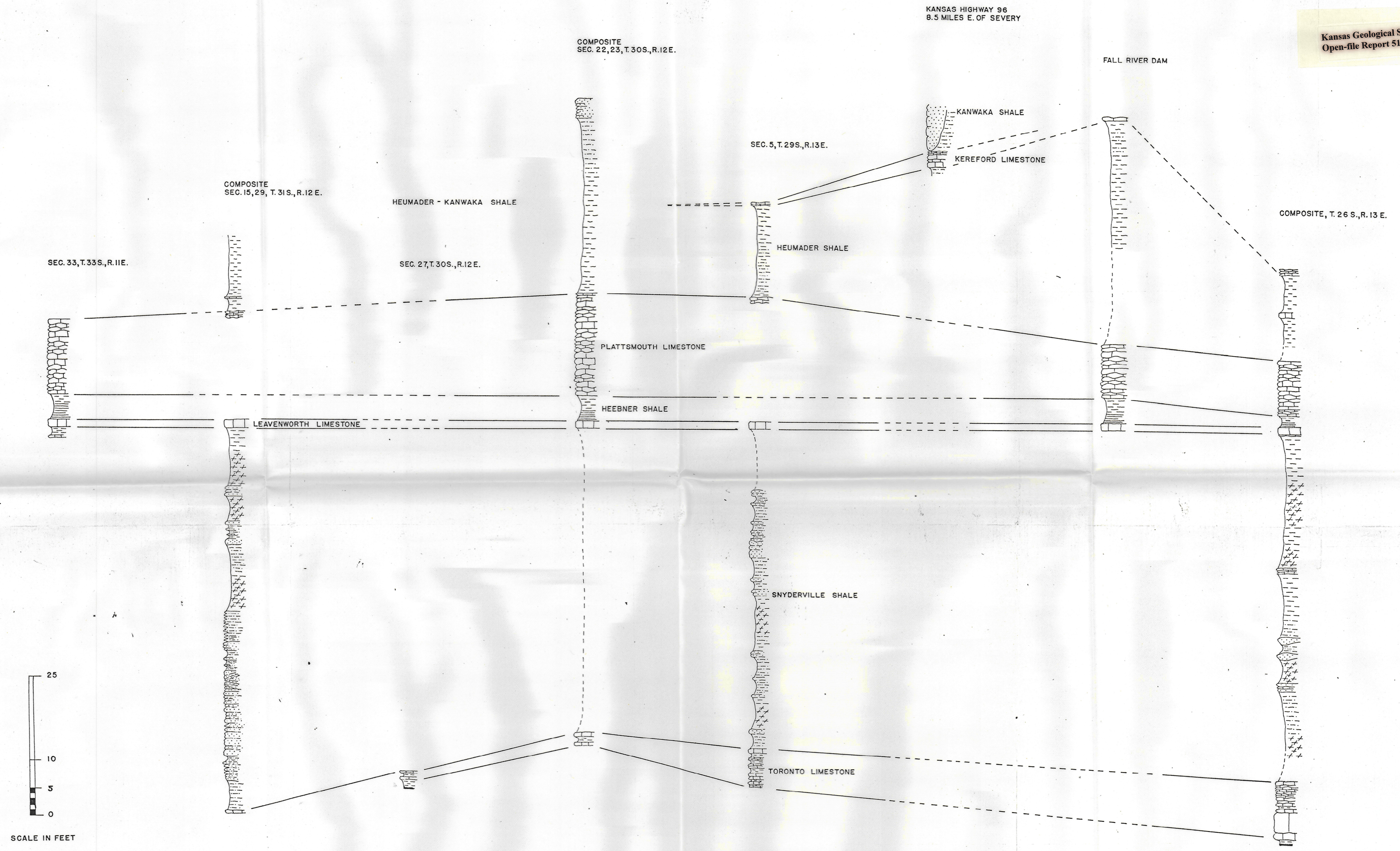


FIG. 5. CORRELATION OF MEASURED SECTIONS OF THE OREAD LIMESTONE.

## Snyderville shale member

The Snyderville shale was named as a member of the Oread limestone by Condra (1927) from exposures in the Snyderville quarry, 3 to 4 miles west of Nehawka, Nebraska. The name was proposed to include the shales between the Leavenworth and Weeping Water limestones. Although Moore (1936a) considered the correlation of the Weeping Water and Toronto limestones to be questionable, he states that there is no doubt about the identity of the Leavenworth limestone which overlies the Snyderville shale in the type locality. In general, the member is reported to be about 12 feet thick in the more northerly outcrops in Kansas and to thicken southward to a maximum of about 75 feet in the extreme southern part of the state.

Lithologic character and thickness.--- In Elk county, the Snyderville shale averages about 65 feet in thickness. In a complete exposure in sec. 15, T. 31 S., R. 12 E., the Snyderville shale is 68 feet thick. The upper 30 feet consist mainly of red shales which contain several thin greenish-grey siltstones and sandstones and minor amounts of blue-green and buff shales. The lower half of the member is made up mainly of thin to cross-bedded, fine grained, micaceous, grey to greenish sandstones with minor amounts of sandy shale. In sec. 5, T. 29 S., R. 13 E., the member is slightly less than 60 feet thick and consists largely of red, buff, and light grey clayey to sandy shales. In this exposure, the content

of sandstone is less than in the more southerly exposures and is essentially limited to 12 to 13 feet of buff to dirty yellow and orange colored sandstones, the top of which occurs about 10 feet below the top of the member. Scattered throughout the lower 45 feet of the member are a few thin sandstone plates and a few iron stone concretions. In Chautauqua county, in sec. 33, T. 33 S., R. 11 E., the upper 2 feet of the member are characterized by dark bluish to black shales and thin fossiliferous limestones. In Greenwood county, in an exposure about 11 miles northeast of the Fall River Dam, the Snyderville shale is about 63 feet thick. In this exposure, the member is largely green, grey, buff, and red clayey to sandy shales which contain a thin, greyish-green, algal, fossiliferous limestone about 25 feet below the top and a zone of lenticular sandstone lenses about 20 feet above the base. The upper few inches of the member contain abundant free specimens of fusulinids.

Fauna.--- With the exception of the upper few feet of the member and a thin algal limestone which occurs in the middle of the member, as discussed above, the Snyderville shale is unfossiliferous.

The following fossils were collected from the upper 2 feet of the member in sec. 33, T. 33 S., R. 11 E.: Chonetes, Dictyoclostus, Astartella, Hollinella, Pairdia, Cavellina, Amphissites, Osagia, echinoid spines, and crinoid stems and plates. The upper few inches of the shale in the exposure

in Greenwood county (described above) contains Triticites, Tetrataxis, Bairdia, Amphissites, conodonts, and many shell fragments. The thin algal limestone in the same outcrop contains Triticites, Osagia, trilobite fragments, Rhombopora, gastropods, echinoid spines, and crinoid stems.

The lateral variations found within the Snyderville shale are shown in the cross-sections illustrated in Figure 5. For measured sections of the member, see sections 6, 13, 18, 24, and 28 at the end of this report.

#### Leavenworth limestone member

The Leavenworth limestone was named by Condra (1927) from roadcut exposures, northwest of the federal penitentiary, Leavenworth, Kansas. In the type area, the member is a dark grey, vertical jointed, fossiliferous limestone about 2 feet thick. This member is very persistent, both in lithology and distribution. From Iowa into Oklahoma it is a single massive bed of dark-blue, fine grained, dense, vertical jointed limestone between 1 and 2 feet thick (Moore, 1936a).

Lithologic character and thickness,--- In Elk, ~~Chautauqua~~, <sup>delete</sup> <sub>Rea</sub> and Greenwood counties, the Leavenworth limestone varies from 1.0 to 1.8 feet, averaging 1.3 feet. Everywhere the member was studied, it consisted of dark-blue, dense, brittle, hard, vertically jointed, fossiliferous limestone which weathers with a buff to orange veneer. The only exception to the single massive bed, which characterizes the member, was found

in an exposure in Greenwood county, about 11 miles northeast of the Fall River Dam. In this exposure, the lower 4 inches of the member consist of a dark-blue, nodular, almost coquina of small fusulinids.

Fauna.--- The Leavenworth limestone is fossiliferous; however, due to its hard brittle character it is very difficult to free the fossils from the limestone. In Elk county, the most numerous element of the fauna are the small Triticites; however, a few small brachiopods, crinoid stems, and echinoid spines are usually present.

For measured sections of the Leavenworth limestone, see sections 6, 11, 13, 18, 24, 28, and 29 at the end of this report.

#### Heebner shale member

The Heebner shale was named as a member of the Oread limestone by Condra (1927) from exposures on Heebner Creek, on the Heebner farm, west of Newhawka, Nebraska. In the type area, the member is about 5 feet thick and consists of an upper bluish argillaceous shale underlain by black, finely-bedded, carbonaceous shale.

Lithologic character and thickness.--- In Elk and adjacent counties, the Heebner shale averages about 4.6 feet in thickness. The member characteristically consists of an upper grey to brownish shale underlain by black, carbonaceous, fissile shale. In a typical exposure in sec. 22, T. 30 S.,

R. 12 E., the member is 4.7 feet thick and contains an upper grey clayey shale about 1.7 feet thick and a lower black, fissle shale about 3.0 feet thick. The only section studied, in which the thickness was at variance with the majority of the other measured sections, was in an exposure in Greenwood county, about 11 miles northeast of the Fall River Dam. In this exposure, the Heebner shale is only 1.9 feet thick. The lower fissle and upper non-fissle units are approximately equal in thickness.

The Heebner shale is a useful stratigraphic horizon, as the distinctive lithology of the lower black fissle shale does not occur elsewhere in the Oread limestone. One does not again encounter this particular lithologic development in the Shawnee group until reaching the stratigraphically higher Queen Hill shale member of the Lecompton limestone.

Fauna.--- Conodonts are the most common fossils found in the black fissle shale unit of the member. ~~The following fossils were collected from the contact zone between the grey-brown shale and the black fissle shale in sec. 33, T. 33 S., R. 11 E.:~~ Chonetes, Chonetina, Punctospirifer, Hustedia, Enteletes, Crurithyris, Amphiscapha, Tetrataxis, Conuspira, Bairdia, Cavellina, Trichognathus, Hindeodella, Cavusgnathus, and crinoid plates and stems.

The lateral changes found within the Heebner shale are shown in the cross-sections illustrated in Figure 5. For measured sections of the Heebner shale, see sections 11, 13, 24, and 29 at the end of this report.

### Plattsmouth limestone member

The name Plattsmouth was used by Meek (1871) for the fossiliferous limestones within the "Platte division", a sequence of limestone and shales which he reported were about 200 feet thick in the Platte River valley. Keyes (1898) briefly discussed the distribution of the Plattsmouth limestone and stated that in Missouri and Nebraska it was about 30 feet thick. Condra (1927) restricted the name Plattsmouth to the "top" and thickest limestone above the Heebner shale at Plattsmouth, Nebraska. Moore (1936a) states that the above designation by Condra included several limestones above the "upper" Oread limestone of Kansas and since it apparently was Condra's intention to designate only the "upper" Oread limestone as the Plattsmouth, he suggests restricting the Plattsmouth to the limestone between the Heebner shale and the Kereford limestone (Heumader shale is missing at Plattsmouth, Nebraska) in the type area.

In Kansas, the Plattsmouth limestone varies from 2 to 25 feet, commonly being 15 to 20 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Plattsmouth limestone averages about 15 feet in thickness. In sec. 22, T. 30 S., R. 12 E., the member is 18 feet thick and consists of characteristically thin, irregular or wavy bedded, light grey to buff or whitish weathering limestone. The upper few feet are made up of rather soft to almost earthy, light buff, wavy bedded limestones separated by thin

shales. The middle part of the member is bluish-grey, dense, brittle, wavy bedded limestone, which lower becomes more coarsely crystalline and light grey to almost white in color. The lower 4 or 5 feet consist of dense, brittle, buff to brown or mottled weathering limestone. The above lithologic variations are by no means sharply defined and all represent gradational changes.

In southeastern Greenwood county, the Plattsmouth limestone thins and is locally missing. Along U.S. Highway 54, northwest of Toronto, the stratigraphic position of the Plattsmouth limestone above well developed Heebner shale, is occupied by sandy to silty shales which contain many small ironstone concretions. However, a few miles to the south, the <sup>member</sup> number is about 10 feet thick and possesses what is considered to be the normal lithology for the Plattsmouth limestone in southeern Kansas: wavy bedded, white to greyish color, and relatively coarse crystalline texture.

Across eastern Elk county, the Plattsmouth limestone forms a pronounced scarp, the base of which is mapped on the accompanying areal geologic map (Plate 1). The line of outcrop of the base of the Plattsmouth limestone is indicated on the above map by the symbol P.

Fauna.-- The following fossils were collected from the Plattsmouth limestone in ~~sec. 33, T. 33 S., R. 11 E. and~~ sec. 22, T. 30 S., R. 12 E.: Triticites, Composita, Meekella, Phricodothyris, Dictyoclostus, Neospirifer, Lophophyllum,

Delete extra-Elk stuff  
RCM

bryozoans, small gastropods, crinoid stems, and echinoid spines.

The lateral changes found within the Plattsmouth limestone are shown in the cross-sections illustrated in Figure 5. For measured sections of the Plattsmouth limestone, see sections 11, 13, 19, 24, 25, 26, and 29 at the end of this report.

#### Heumader shale member

The Heumader shale was named by Moore (1932) from exposures in the Heumader quarry, in the bluffs of the Missouri River, north of St. Joseph, Missouri. In northern Kansas, the Heumader shale is dark grey, bluish or greenish, clayey to silty shale from 2 to 5 feet thick (Moore, 1944).

Lithologic character and thickness.---- The Heumader shale, where it can be distinguished in Elk county from the overlying Kanwaka shale, is about 16 feet thick. The lower 2 to 8 feet of the member is grey, clayey, highly fossiliferous shale which locally contains a thin fusulinid bearing limestone. The upper part of the member is lighter in color, silty to sandy, containing numerous well preserved specimens of Astartella.

In exposures south of T. 29 S., in Elk and ~~Chautauque~~ <sup>Chautauque</sup> Counties, the Heumader shale cannot be clearly differentiated, as the overlying Kereford limestone, which defines the top of the Heumader shale, is not present. In these more southerly exposures, where differntiation is impossible, the interval

between the top of the Plattsmouth limestone and the base of the Spring Branch limestone is referred to as the Heumader-Kanwaka shale.

The absence of the Kereford limestone in the exposures south of T. 29S. is seemingly due to non-deposition; however, removal by subsequent erosion seems a distinct possibility in some localities. Supporting evidence for non-deposition is shown in several well exposed sections in Elk and Chautauqua counties. In sec. 22, T. 30 S., R. 12 E., the interval between the Plattsmouth limestone and the massive sandstones of the Jackson Park shale consists of about 31 feet of clayey to silty and sandy shales in which no limestones are present. In sec. 17, T. 33 S., R. 11 E., the same interval is slightly over 60 feet thick and consists of 8 feet of grey, fossiliferous, clayey shales overlain by progressively more sandy shales and thin sandstones.

Removal by erosion, which cut channels in the lower Kanwaka or Heumader-Kanwaka shales, is suggested by several exposures. Although actually cutting out of the Kereford limestone was not observed, channel-filling sandstones were observed to cut down through the shales of the lower Kanwaka to the top of the Kereford limestone. One such occurrence is well shown in an exposure about 1 mile east of the west entrance to the Fall River Dam. In several exposures in T. 31 S., south of Longton, the massive lower Kanwaka sandstone occur only 12 to 14 feet above the top of the Platts-

mouth limestone, making removal of the Kereford by erosion a distinct possibility.

Fusulinids studied from the thin limestone which occurs about 17 feet above the top of the Plattsmouth limestone in sec. 5, T. 29 S., R. 13 E. compare favorably with specimens collected from the Kereford limestone near Lecompton, Kansas, and suggest correlation with the Kereford limestone of northern Kansas. Because of the minor thickness reported in the literature for the Heumader shale (from almost nothing to about 10 feet, Moore, 1949), I was tempted to regard only the lower highly fossiliferous grey shales as Heumader and to consider the thin fusulinid bearing limestones in or just above them as a possible equivalent of the Kereford limestone of northern Kansas. However, the fusulinids from these thin lower limestones in Elk county are not closely similar to the northern Kansas Kereford limestone forms. I now regard these thin limestones as local, more calcareous phases within the lower Heumader-Kanwaka shale.

The following 2 sections were studied in Greenwood county and although I made no attempt to work out the stratigraphy of that county, I am presenting them there as they do not entirely bear out my conclusions in Elk county.

In an exposure about 11 miles northeast of the Fall River Dam, the interval between the Plattsmouth and the Kereford (?) limestones is about 15 feet thick and consists of grey to brownish shales in which a 1 foot molluscan lime-

stone occurs about 6.5 feet below the top. The upper limestone (Kereford?) carries fusulinids and seemingly is to be correlated with the beds considered to be the Kereford limestone in Elk county.

In an exposure just below the Fall River Dam, the interval between the top of the Plattsmouth and the next higher limestone (Kereford?) is about 40 feet thick. The lower part of the interval is covered, but the upper part consists of grey, clayey to sandy shales and thin sandstone plates. The shale carries a fauna of Astartella and gastropods, not unlike that of the upper part of the Heumader shale in northern Elk county. If the capping limestone in this exposure is the Kereford, the Heumader shale is abnormally thick in this exposure, being about 40 feet.

Fauna.--- The following fossils were collected from the lower, grey fossiliferous shales at the base of the Heumader-Kanwaka shale in sec. 22, T. 30 S., R. 12 E. and in sec. 21 and 29, T. 31 S., R. 12 E.: Triticites, Astartella, Euphemites, Glyphostomella, Punctospirifer, Ditomopyge, Chonetina, Worthenia, Deckerella, Rhipidomella, Hollinella, Pseudozygopleura, Donaldina, Chonetes, Hustedia, Bairdia, Crurithyris, Nuculana, Conuspira, Tetrataxis, Bellerophon, Amphiscapha, Nucula, Hindeodella, Delocrinus, Ethelocrinus, Amphissites, Rhombopora, holothurian wheels, and sponge spicules. The above list of genera is not exhaustive, but represents only the most common elements of the fauna.

The lateral changes found within the Heumader and Heumader-Kanwaka shales are shown in the cross-sections illustrated in Figures 5 and 6. For measured sections of the above shale units, see sections 11, 13, 19, 25, 26, and 29 at the end of this report.

#### Kereford limestone member

The name Kereford was applied by Condra (1927) to the arenaceous, partially oolitic, fossiliferous, more or less lenticular limestones previously known as the "Waverly flagging". At the time the name was proposed, Condra considered the Kereford limestone as the base of the Kanwaka shale. Moore (1932) placed the Kereford limestone at the top of the Oread limestone. The Kereford limestone, unlike most of the upper Pennsylvanian limestones in Kansas, is characterized by lateral variations in thickness and lithology (Moore, 1949). Moore (1951) states that the Kereford limestone is not recognized in southern Kansas. The type section of the Kereford limestone is in the Kereford quarry, just south of Atchison, Kansas.

Lithologic character and thickness.--- In Elk county, the limestone beds occurring about 17 feet above the top of the Plattsmouth limestone in sec. 5, T. 29 S., R. 13 E. are correlated with the Kereford limestone of northern Kansas. At this locality, the member is slightly less than 1 foot thick and consists of dark grey, shelly, buff to grey

weathering limestone in two thin beds separated by grey shale. The entire unit is fusulinid bearing. In an exposure along Kansas Highway 96, about 1 mile east of the west entrance to the Fall River Dam, the Kereford limestone is 2.6 feet thick, consisting of an upper 0.6 foot, grey, nodular phase underlain by more massive, dark grey, algal, fusulinid bearing limestone. In this exposure, the channel-filling sandstone in the lower part of the Kanwaka shale rests directly on the top of the Kereford limestone. About 11 miles northeast of the Fall River Dam, the Kereford (?) limestone is slightly over 1 foot thick and consists of dense, blue-grey, wavy bedded, buff to grey weathering, algal, fusulinid bearing limestone. *RCM*

The member has not been previously recognized in southern Kansas; however, because of its stratigraphic position and because of the similarity of the fusulinids collected from Elk county and from the member near Lecompton, Douglas county, correlation of the two limestones seems warranted.

The limestone in Elk county which is considered to be the Kereford, was not found south of T. 29 S. Its absence south of T. 29 S. seemingly is due to non-deposition; however, removal during the erosion interval which produced channels in the lower part of the Kanwaka shale is also a possibility. For further information in regards the occurrence of the Kereford limestone, see the discussion of the Heumader shale above.

Fauna.--- The Kereford limestone, in northern Elk county, contains Triticites, Rhombopora, rare Astartella, and crinoid stems. In southeastern Greenwood county, the limestones considered to be the Kereford contain Ottonosia, Osagia, Triticites, Enteleles, Derbya, Amblysiphonella, and many shell fragments.

Lateral changes found within the beds considered to be the Kereford limestone are shown in the cross-sections illustrated in Figure 5. For measured sections of the Kereford limestone, see sections 12, 13, and 25 at the end of this report.

#### Kanwaka shale

The name Kanwaka was proposed by Adams, Girty, and White (1903) for the beds lying between the top of the Oread limestone and the base of the Lecompton limestone.

Throughout Kansas the formation varies from 40 to about 145 feet in thickness. In northern and central Kansas, the formation is subdivided into 3 members, which in ascending order are: Jackson Park shale, Clay Creek limestone, and Stull shale. In southern Kansas, where the Clay Creek limestone feathers out, the members cannot be differentiated and the entire shale and sandstone unit is referred to as the Kanwaka shale. Further, where the underlying Kereford limestone is absent in southern Kansas, the entire interval from

the top of the Plattsmouth limestone to the base of the Lecompton limestone is referred to as the Heumader-Kanwaka shale.

Lithologic character and thickness.--- The Heumader-Kanwaka shale in ~~Chautauque~~ and southern Elk counties averages about 125 feet in thickness. In T. 33 S., R. 11 E., the interval between the top of the Plattsmouth and the base of the Lecompton limestones is about 135 feet thick. In this area, the members of the Kanwaka shale and upper part of the Cread limestone can not be differentiated, as the limiting marine units, the Kereford and Clay Creek limestones are not present. In general, the lithology of the Heumader-Kanwaka shale consists of grey to bluish-grey, blocky shale which becomes increasingly more silty and sandy upward. The middle of the interval is marked by a massive sandstone, which in some localities fills channels cut into the lower shales of the Heumader-Kanwaka interval. The upper part of the interval is mainly grey to buff or yellowish sandy shales, with occasional thin limestones.

In exposures studied in northeastern Elk county, the Clay Creek limestone is present and the following discussion of the members of the Kanwaka shale is based on sections studied from this part of the county.

### Jackson Park shale member

The Jackson Park shale was named by Moore (1932) from exposures in the southern part of Atchison, Kansas. The member, which is 24 feet thick in the type locality, is reported to be over 50 feet thick in the exposures along the Kansas River (Moore, 1936a).

Lithologic character and thickness.--- In Elk county, the Jackson Park shale is about 40 to 50 feet thick. The upper part of the member, consisting of blue-grey to buff or reddish clayey shale is underlain by buff to yellowish or grey massive to cross-bedded sandstones, the lower part of which represents channel fillings. In some exposures, the channels were observed to cut down to the top of the Kereford limestone. In others, where the Kereford limestone is missing, the base of the sandstone occurs only a few feet above the top of the Plattsmouth limestone, making the cutting out of the Kereford limestone in such exposures a definite possibility. In exposure where the channels are not so deeply cut, the lower part of the Jackson Park shale consists of grey to tan sandy to silty shales and thin sandstones. In T. 31 S., where the massive sandstones occur shortly above the Plattsmouth limestone, the sandstone is considerably thicker than in northeastern Elk county, being estimated to have a thickness of 50 to 75 feet or more.

This massive sandstone has been named the Elgin sandstone by Haworth (1898). Moore (1944, 1951) considers the Elgin sandstone of southern Kansas to occur mainly within the Stull shale member of the Kanwaka shale. However, in the few exposures in Elk county where the Clay Creek limestone was identified, the massive sandstones occur lower in the section, within the Jackson Park shale. In a good exposure in sec. 17, T. 33 S., R. 11 E., the massive sandstone occurs about 50 feet below the Spring Branch limestone, where it is in an approximately equivalent position to the Jackson Park shale of northern Elk county. The position of the Elgin sandstone is shown in the cross-sections illustrated in Figure 6.

For measured sections of the Jackson Park shale, see sections 12, 14, and 17 at the end of this report.

#### Clay Creek limestone member

The name Clay Creek was proposed by Moore (1932) for the thin, blue to bluish-grey limestone which occurs in the middle of the Kanwaka shale. In the type section, on Clay Creek, about one mile west of Atchison, Kansas, the member is about 2 feet thick. In some unweathered exposures the member is vertically jointed and uniform, not unlike the Leavenworth or Rock Bluff limestones. However, the member more typically weathers into small, irregular, shelly chips (Moore, 1936a).

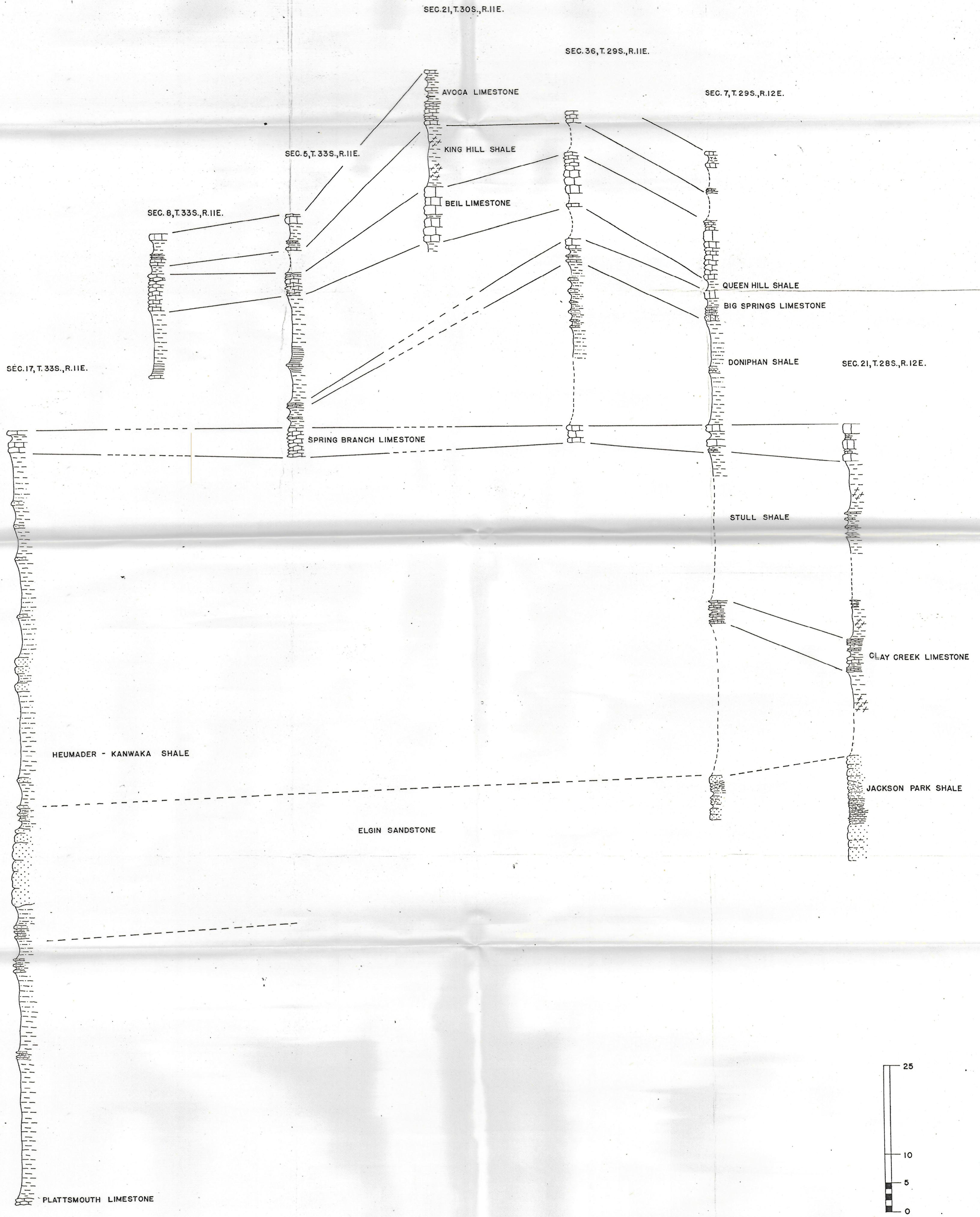


FIG. 6. CORRELATION OF MEASURED SECTIONS OF LECOMPTON LIMESTONE AND KANWAKA SHALE.

Lithologic character and thickness.---- In northeastern Elk county, the Clay Creek limestone averages about 4.5 feet in thickness. In an excellent exposure in sec. 21, T. 28 S., R. 12 E., the member consists of 3 feet of thin, grey, slabby, almost coquinoid limestones interbedded with grey shale which is underlain by 2.9 feet of thin-bedded, buff to orange, fusulinid bearing limestones interbedded with grey to buff shales. The lowermost limestone bed is brownish-grey and somewhat sandy. In sec. 7, T. 29 S., R. 12 E., the member is slightly less than 4 feet thick and consists of thin, grey, pelecypod bearing limestones and shales. The lower two thin limestones are sandy.

The member evidently feathers out in southern Elk or northern Chautauqua counties, as the member was not recognized south of T. 30 S. At any rate, in a well exposed section in sec. 17, T. 33 S., R. 11 E., the Clay Creek limestone is absent. As the lower beds of the Clay Creek limestone, in the sections described above, are becoming more sandy southward, it is possible that the Clay Creek limestone in southern Elk and Chautauqua counties is represented by one of the thin sandstones which occur about 30 feet below the Spring Branch limestone.

Moore (1951) states that the Clay Creek limestone has been tentatively identified in Elk and Greenwood counties. Fusulinids collected from the beds in Elk county compare favorably with specimens collected from the member in nor-

thern Kansas and seemingly suggest that a positive correlation between the two areas is possible.

Fauna.--- The Clay Creek limestone is highly fossiliferous in northeastern Elk county, with the upper beds in sec. 21, T. 28 S., R. 12 E. being almost coquinoid. The following fossils were collected from the member in Elk county: Triticites, Derbya, Myalina, Ethelocrinus, Composita, Crurithyris, Rhombopora, Linoproductus, Aviculopecten, Juresania, crinoid stems, and echinoid spines.

Lateral variations found within the Clay Creek limestone are shown in the cross-sections illustrated in Figure 6. For measured sections of the Clay Creek limestone, see sections 14 and 17 at the end of this report.

#### Stull shale member

The name Stull shale was proposed by Moore (1932) for the beds between the top of the Clay Creek limestone and the base of the Lecompton limestone. In the type locality, near Stull, Douglas county, the member is about 30 feet thick (Moore, 1936a). In northern Kansas, the member is a yellow-brown sandy shale which locally contains one or more coal beds (Moore, 1951).

Lithologic character and thickness.--- In northeastern Elk county, the thickness of the Stull shale is about 30 feet. In a good exposure in sec. 21, T. 28 S., R. 12 E., the member is about 35 feet thick and contains the following lithologies, in descending order: shale, 8 feet, green-grey, clayey, red-

dish in the middle; limestone and shale, 6 feet, thin; buff, fossiliferous limestones interbedded with grey shales, the latter contain plant remains; shale, 21 feet, orange to buff in upper part, grades downward through bluish-grey, Myalina bearing shale into mottled green to red or bluish and buff shales. A few thin, buff, Chonetes bearing limestone plates occur 7 to 8 feet above the base.

The occurrence of the Elgin sandstone, reported by Moore (1944, 1951) to occur mainly within the Stull shale, is discussed above under the Jackson Park shale. However, in repetition, it will suffice to say that wherever the Stull shale could be differentiated in Elk county, the massive sandstone (Elgin) was found to occur below the Clay Creek limestone and to lie within the Jackson Park shale.

As is the case with all the members of the Kanwaka shale, the Stull shale could be differentiated with certainty only in the northeastern part of Elk county, as the lower limiting marine unit, the Clay Creek limestone thins and disappears to the south in Chautauqua county.

Fauna.--- (In Chautauqua county, the upper part of the Kanwaka-Hemader shale, corresponding approximately to the Stull shale of northeastern Elk county, is unfossiliferous, consisting of sandy shales and sandstones. In more northerly outcrops, in T. 28 and 29 S., the member becomes increasingly more fossiliferous as thin limestones and calcareous shales appear.

The following fossils were collected from the member in sec. 21, T. 28 S., R. 12 E.: Triticites, Chonetes, Crurithyris, Neospirifer, Derbya, Linoproductus, Amphiscapha, Rhombopora, Amphissites, and crinoid stems. A few plant remains are present in the shale about 10 feet below the top.

The lateral variations found within the Stull shale are shown in the cross-sections illustrated in Figure 6. For measured sections of the Stull shale, see sections 14 and 17 at the end of this report.

#### Lecompton limestone

The Lecompton limestone was named by Bennett (1896) to include a "triple system of limestones" separated by shales which cap the hills near Lecompton, Kansas. Condra (1927) named the members of the Lecompton limestone and raised the upper boundary to include the next higher limestone, the Avoca. The names he proposed for the members are, in ascending order: Spring Branch limestone, Doniphan shale, Big Springs limestone, Queen Hill shale, Cullom limestone (later abandoned and replaced by the Beil), King Hill shale, and Avoca limestone. In the type locality, Lecompton, Douglas county, Kansas, the formation has a thickness of 35 to 40 feet (Moore, 1936a).

All of the recognized members of the Lecompton limestone have been identified in Elk county, where the formation has an average thickness of about 55 feet. The base of the

formation is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol Sp.

#### Spring Branch limestone member

The Spring Branch limestone was named by Condra (1927) from exposures of yellowish to brown weathering, massive, somewhat chalky limestone on Spring Branch, north of Big Springs, Kansas. This lower member of the Lecompton limestone was originally referred to by Bennett (1896) as the "Fusulina" limestone. Moore (1949) states that the member averages about 5 feet in thickness in northern Kansas and is represented in southern Kansas by 2 to 3 feet of impure, sandy limestone which may be nodular and algal in the upper part.

Lithologic character and thickness.--- In Elk county, the Spring Branch limestone averages about 4.3 feet in thickness. In sec. 7, T. 29 S., R. 12 E., the member is well exposed and consists of two limestones separated by shale with a total thickness of 4.8 feet. The upper 1.7 foot limestone bed which is massive, light grey, mottled, with abundant Osagia, is separated from the lower 1.6 foot massive, blue-grey, sandy limestone by a 1.5 foot grey shale. The member is 6.4 feet thick in sec. 21, T. 28 S., R. 12 E., where it consists of 3 massive limestones separated by thin slabby to nodular limestones. In this exposure, the upper limestone

is dense, blue-grey, algal, and fusulinid bearing. The middle limestone bed is impure, sandy, mottled, brown to orange weathering. The lower limestone bed is very algal and massive, but weathers to irregular slabs.

In general, the member thins southward from northeastern Elk county, ~~being about 3 feet or less in thickness in T. 33 S.~~ however, where the member is highly algal throughout, thicknesses of up to 5 feet were observed in Chautauqua county.

The member outcrops well, being the first persistent limestone bed above the Blattsouth limestone, it forms a bench which is usually recognizable across Elk county. The base of the Spring Branch limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol Sp.

Fauna.--- The Spring Branch limestone is characterized throughout its line of outcrop in Elk and ~~Chautauqua counties~~ by the presence of abundant Osagia. Generally, other fossils are only common locally. The following genera were collected from several outcrops in Elk and ~~Chautauqua counties~~: Myalina, Triticites, Neospirifer, Composita, Chonetes, echinoid spines, and crinoid stems.

Lateral variations found within the Spring Branch limestone are shown in the cross-sections illustrated in Figure 6. For measured sections of the Spring Branch limestone, see sections 14, 17, 19, 20, 23, and 32 at the end of this report.

## Doniphan shale member

The Doniphan shale was named by Condra (1927) from exposures in northern Doniphan county, Kansas. Moore (1936a) states that the beds which Condra evidently intended to designate as the Doniphan shale consist largely of impure thin bedded limestones and shales and that the more calcareous beds are equivalent to part of the Spring Branch limestone farther to the south. Across Kansas, the member is reported to vary in thickness from 5 to about 34 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Doniphan shale averages about 23 feet in thickness. In sec. 7, T. 29 S., R. 12 E., the member is slightly less than 18 feet thick and consists of grey to light buff sandy to silty shales, which in its middle part, contain several thin, greenish-grey sandstones. In sec. 36, T. 29 S., R. 11 E., the member is about 28 feet thick. The upper half of the member in this locality is mainly greenish-grey, somewhat cross-bedded, dirty sandstones interbedded with sandy to silty grey shales. The lower half consists of grey to greenish-grey, sandy to silty shales.

Southward, in Chautauqua county, the Doniphan shale thins markedly. Measurements of the member of 2 to 3 feet were obtained in several exposures in T. 33 S., R. 11 E. It is interesting to note, that in the areas in Chautauqua county where the Doniphan shale is thin, the next higher shale, the Queen Hill, is abnormally thick, being almost 18 feet in some

*No  
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exposures. In the exposures of the Doniphan shale studied in Chautauqua county, the member lacks the sandy character displayed in the more northerly exposures in Elk county and it consists of blue-grey, clayey shale which in some places contains a thin, dirty brown limestone which is crowded with Osagia.

Fauna.--- With the exception of Osagia, no fossils were collected from the member.

The lateral variations found within the Doniphan shale are shown in the cross-sections illustrated in Figure 6. For measured sections of the Doniphan shale, see sections 17, 20, 23, and 32 at the end of this report.

#### Big Springs limestone member

The Big Springs limestone was named by Condra (1927) from exposures near Big Springs, Kansas. The member possesses the lithologic development typical of the "middle" limestone bed of a Shawnee megacyclothem, being a dark blue, dense, vertically jointed, massive limestone bed commonly 1 to 3 feet thick. However, in some exposures, the member consists of 2 or 3 limestones separated by shale partings (Moore, 1936a).

Lithologic character and thickness.--- In Elk county, the Big Springs limestone averages about 4.5 feet in thickness. The upper limestone bed is typically a massive, dense, vertically jointed fusulinid bearing limestone. The remainder

of the member is made up of one or more thin bedded limestones separated by thin shales. The lowermost limestone of the member is always impure and sandy; in fact, in some of the exposures in Chautauqua county, the lower part of the member is a calcareous sandstone.

In sec. 7, T.29 S., R. 12 E., the Big Springs limestone is 5.5 feet thick and consists of an upper 1.5 foot dark blue-grey, massive, dense, vertically jointed, fusulinid bearing limestone bed separated from a lower 2.5 foot bluish, sandy limestone by a 1.5 foot grey clayey shale. In sec. 36, T. 29 S., R. 11 E., the member is slightly over 4 feet thick and contains the following lithologic units, in descending order: limestone, dense, blue-grey, massive, fusulinid bearing, weathers with a brownish crust, 1.4 feet; shale, grey, calcareous with abundant fusulinids, 1.0 feet; limestone, blue-grey, 0.2 feet; shale, grey, clayey, 0.7 feet; limestone, dirty grey, sandy, impure, dirty yellow to brownish weathering, 0.8 feet.

Southward, in Chautauqua county, the Big Springs limestone thins to an average of about 2.0 feet. In sec. 8, T. 33 S., R. 11 E., the member is represented by 2.5 feet of thin, slabby, fusulinid bearing limestones interbedded with thin shales which are underlain by a massive, 1.0 foot, brownish limestone. This is in turn underlain by 0.5 feet of thin-bedded calcareous sandstone.

Fauna.--- Throughout its outcrop in Elk and Chautauqua counties, the Big Springs limestone is characterized by the abundant occurrence of the fusulinid genus Triticites. Although fusulinids have been found to occur throughout the member, they are by far more abundant in the upper part. The lower, more impure sandy limestones contain a molluscan fauna.

The following fossils were collected from outcrops in sec. 36, T. 29 S., R. 11 E.: Triticites, Chonetes, Crurithyris, echinoid spines, and crinoid stems from the upper massive limestone bed and Hollinella, Bairdia, Cavellina, Myalina, Leda, Astartella, Pseudozygopleura, Anomphalus, Donaldina, Bellerophon, Baylia, Streptacis, Goniasma, Rhombopora, fenestellid bryozoans, and many shell fragments from the lower sandy to silty limestone and immediately overlying shale.

The lateral variations found within the Big Springs limestone are shown in the cross-sections illustrated in Figure 6. For measured sections of the Big Springs limestone, see sections 17, 20, 23, and 32 at the end of this report.

#### Queen Hill shale member

The Queen Hill shale was named by Condra (1927) from exposures at Queen Hill, northeast of Rock Bluff, Nebraska. In the type area, where the member is about 5.5 feet thick, it consists of an upper bluish argillaceous shale underlain

by black fissile shale. Although the black fissile part is not commonly found in southern Kansas (Moore, 1949), the two-fold lithologic subdivision is marked throughout the more northerly outcrops of the member. Across Kansas, the member varies in thickness from 3 to about 6 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Queen Hill shale averages about 3.5 feet in thickness. In sec. 36, T. 29, S., R. 11 E., the Queen Hill shale is 5.3 feet thick and consists of dark grey, clayey shale. Southward, in Chautauqua county, the Queen Hill shale thickens considerably, with the maximum thickness measured being just slightly under 18 feet. In sec. 5, T. 33 S., R. 11 E., the member is well exposed and consists of the following lithologic units, in descending order: shale, gray-blue, blocky, 8.3 feet; shale, black, fissile, 3.0 feet; limestone, black, shiny, with abundant Crurithyris, 0.2 feet; shale, black, fissile, grading downward into grey, blocky shale, 6.4 feet.

As was mentioned above, the Queen Hill shale thickens to the south, with the maximum thickness being recorded in the localities where the underlying Big Springs limestone and Doniphan shale are abnormally thin.

Fauna.--- The only fossils collected from the Queen Hill shale were a few conodonts from the black shale and Crurithyris from the black limestone in Chautauqua county.

The lateral variations found within the Queen Hill shale are shown in the cross-sections illustrated in Figure 6. For measured sections of the Queen Hill shale, see sections 17, 20, 21, 23, and 32 at the end of this report.

#### Beil limestone member

The name Beil was proposed by Condra (1930) for the limestone which Condra and Bengston (1915) had previously named the Cullom. The substitution was necessary, as the type section of the Cullem, which had been correlated as a subdivision of the Lecompton limestone, was discovered to be equivalent to the Westerville limestone of the Kansas City group. The type locality of the Beil limestone is the Beil farm, south of Rock Bluff, Nebraska.

The Beil limestone represents the wavy bedded "upper" limestone of a typical Shawnee megacyclothem as interpreted by Moore (1936a). Across Kansas, the member varies in thickness from about 4 to 15 feet.

Lithologic character and thickness.--- In Elk county, the Beil limestone averages about 9 feet in thickness. In sec. 36, T. 29 S., R. 11 E., the Beil limestone is 9.3 feet thick. The upper 7 feet are massive to wavy bedded, grey to cream yellow weathering, fossiliferous limestone of which the upper foot is algal. A lower 0.8 foot, blue-grey, dense limestone is separated from the upper massive part by a 1.5

foot grey shale. In sec. 7, T. 29 S., R. 12 E., the member is 10.7 feet thick and consists of 2 feet of thin, irregular bedded, rich yellow weathering limestone underlain by 8.7 feet of light grey, cream yellow weathering, fossiliferous limestone which is especially massive in the upper part.

Southward, in Chautauqua county, the Beil limestone thins to an average of about 5 feet. In sec. 5, T. 33 S., R. 11 E., the member is 4.2 feet thick. In this exposure, the upper 0.5 feet are mottled, light gray, coarsely crystalline limestone which weathers to a light buff and contains Osagia and a few large productid brachiopods. The remainder of the member is thin, wavy bedded, yellow to buff weathering limestone in which Caninia and Syringopora are very common. Fusulinids, which are fairly common throughout the lower part of the member, make their appearance about 1 foot below the top.

Fauna.--- Caninia and Syringopora, reported to characterize the Beil limestone across Kansas, were not found to be particularly abundant in the exposures studied in Elk county; however, these genera were extremely abundant in several outcrops of the member in Chautauqua county. The following genera were collected from the member in Elk and Chautauqua counties: Caninia, Syringopora, Triticites, Dunbartonella, Osagia, Crurithyris, Neospirifer, Dictyoclostus, Derbya, Chonetes, Punctospirifer, and Rhombopora.

The lateral variations found within the Beil limestone are shown in the cross-sections illustrated in Figure 6. For measured sections of the Beil limestone, see sections 17, 21, 23, 32, and 33 at the end of this report.

#### King Hill shale member

The King Hill shale was named by Condra (1927) from exposures in King Hill, southeast of the Rock Bluff, Nebraska. In the type area, the member is blue-green and reddish argillaceous shales with a thickness of about 7 feet. In Kansas, the member varies from about 5 feet in northern outcrops to a maximum of about 16 feet in southern Kansas (Moore, 1949).

Lithologic character and thickness.--- In Elk county, the King Hill shale varies in thickness from slightly less than 5 feet to slightly over 10 feet. In sec. 21, T. 30 S., R. 11 E., the member is 10.6 feet thick and consists of gray to greenish and red clayey shale. The red shale occurs in two 2 to 3 foot zones in the middle of the member. In sec. 36, T. 29 S., R. 11 E., the member is represented by 5 feet of blue to greyish shale. In sec. 5, T. 33 S., R. 11 E., in Chautauqua county, the King Hill shale is only slightly over 3 feet thick.

Fauna.--- With the exception of a few small irregular algal bodies in the member in Chautauqua county, no fossils were seen in the King Hill shale.

The lateral variations found within the King Hill shale are shown in the cross-sections illustrated in Figure 6. For measured sections of the King Hill shale, see sections, 17, 22, 23, 32, and 33 at the end of this report.

#### Avoca limestone member

The Avoca limestone was named by Condra (1927) from an exposure on the south fork of Weeping Water Creek, 3 miles east of Avoca, Otoe county, Nebraska. The Avoca limestone is a dense, bluish, earthy limestone usually occurring in one or two beds which average about 4 feet in thickness. Throughout its outcrop belt, the member contains abundant fusulinids.

Lithologic character and thickness.---- In Elk county, the Avoca limestone averages about 8.5 feet in thickness. In sec. 21, T. 30 S., R. 11 E., the Avoca limestone is completely exposed and consists of the following lithologic units, in descending order; limestone, 0.7 feet, shelly, dark grey, one bed; shale, 0.8 feet, grey-brown, clayey, fossiliferous; shale, 1.1 feet, grey, clayey, fossiliferous; limestone, 0.9 feet, hard, dense, brittle, vertically jointed, with abundant <sup>Cryptogon</sup> ~~Otostrophia~~; shale, 1.6 feet, grey to brown, clayey above to calcareous below, highly fossiliferous; limestone, 4.1 feet, blue-grey, weathers buff to brownish, wavy bedded, fusulinds abundant. The most persistent and characteristic element of the Avoca limestone in

Cryptozoon

Elk county is the dense, hard, Ottonosia bearing limestone bed. Although the lower unit of the member is often more massive, it tends to weather more readily and is often quite difficult to distinguish from the other fusulinid bearing limestones of the Lecompton limestone.

Southward, in Chautauqua county, the member thins to an average of about 5.5 feet. In sec. 8, T. 33 S., R. 11 E., the Avoca limestone is 5.4 feet thick and consists of an upper 1.0 foot, massive, dirty dark grey limestone bed, with abundant Cryptozoon Ottonosia, separated from a lower 1.7 foot slabby to massive bedded, dark grey, fusulinid limestone by a 2.7 foot grey, clayey, fossiliferous shale.

Fauna.--- In Elk and ~~Chautauqua~~ counties, the Avoca limestone is highly fossiliferous, with abundant Triticites and Ottonosia being the most characteristic genera. The following fossils were collected from the Avoca limestone in sec. 21, T. 30 S., R. 11 E. and ~~sec. 8, T. 33 S., R. 11 E.:~~ Triticites, Cryptozoon Ottonosia, Hustedia, Punctospirifer, Chonetes, Juresania, Crurithyris, Rhombopora, Bairdia, Hollinella, Amphissites, Ammodiscus, Glyphostomella, Amphiscapha, Astartella, Anematina, fenestellid bryozoans, echinoid spines, and crinoid stems and plates.

The lateral variations found within the Avoca limestone are shown in the crosssections illustrated in Figure 6. For measured sections of the Avoca limestone, see sections 17, 22, 23, 27, 31, 32 and 33 at the end of this report.

### Tecumseh shale

The name Tecumseh was proposed by Beede (1898) for about 75 feet of shale underlying the Calhoun (Deer Creek) limestone. The type section is located near the village of Tecumseh, Shawnee county, Kansas. Across Kansas, the formation ranges in thickness from about 70 feet in the north to about 50 feet in the southern part of the state (Moore, 1949). In general, the formation consists of clayey to sandy shales which locally may contain sandstone or a thin limestone. The subdivisions of the formation, as employed by the Nebraska Geological Survey, are not persistent enough in Kansas to be recognized as members.

Lithologic character and thickness.--- In Elk county, the Tecumseh shale averages about 45 feet in thickness. In sec. 10, T. 30 S., R. 11 E., the formation is about 55 feet thick and consists mainly of sandy to silty grey shales, red to green and bluish-grey clayey shales and sandstones. The upper 15 to 20 feet are made up of thin to fairly massive, cross-bedded, grey sandstones which weather to buff or reddish. A thin 0.4 foot limestone (Ost?) occurs about 12 feet above the base of the formation. The shale below the (Ost?) limestone is more clayey than above and contains occasional calcareous nodules and plates. Pelecypods are common in the upper part of this shale, in a zone just below the (Ost?) limestone.

In sec. 5, T. 33 S., R. 11 E., in Chautauqua county, the Tecumseh shale is well exposed and consists of 9 feet of

red to greenish clayey shale separated below from about 23 feet of yellow to buff blocky shale, which is fossiliferous in the upper few feet, by about 10.5 feet of grey sandstone and grey to yellowish sandy shale.

Fauna.--- For the most part, the Tecumseh shale is unfossiliferous; however, Chonetes, Juresania, and Myalina were found about 20 feet above the base of the formation in the exposure described above from Chautauqua county. Myalina was found in considerable abundance below the (Ost?) limestone in sec. 10, T. 30 S., R. 11 E. The (Ost?) limestone contains Bairdia, Jonesina, small gastropods, productid spines, crinoid stems, and many small shell fragments.

The lateral variations found within the Tecumseh shale are shown in the cross-sections illustrated in Figure 7. For measured sections of the Tecumseh shale, see sections 15, 16, 23, 27, 30 and 31 at the end of this report.

#### Deer Creek limestone

The Deer Creek system was named by Bennett (1896) from 26.5 feet of limestones and shales exposed on Deer Creek, east of Topeka, Kansas. Haworth (1898), in a stratigraphic table of the Coal Measures of Kansas, listed the Deer Creek limestone as a member of the Shawnee formation. The Deer Creek limestone is very persistent, having been traced from Iowa southward into Oklahoma. Across Kansas, the formation

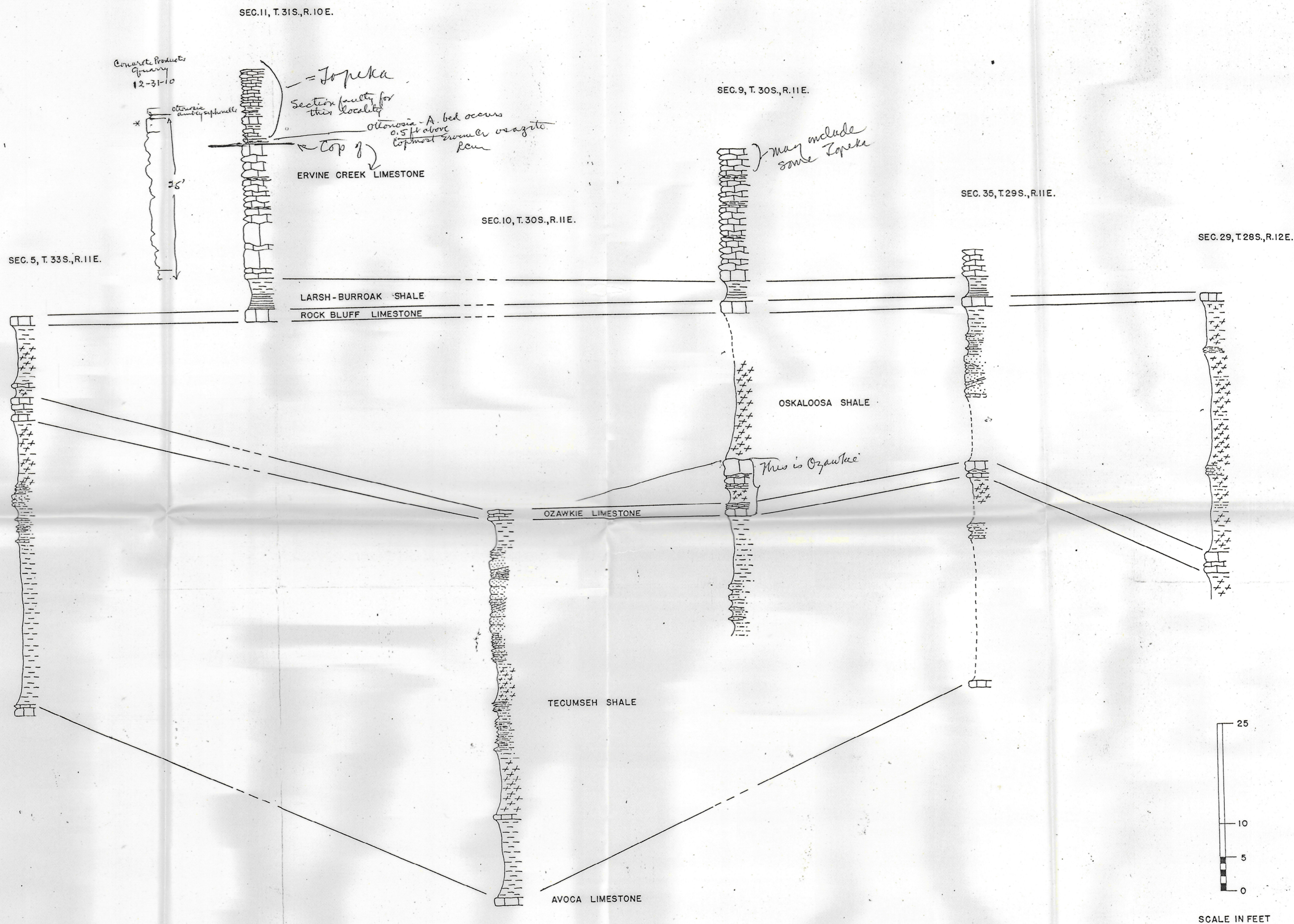


FIG. 7. CORRELATION OF MEASURED SECTIONS OF THE TECUMSEH SHALE AND DEER CREEK LIMESTONE.

varies in thickness from 20 to about 80 feet, averaging about 40 feet (Moore, 1944).

In Elk county, the Deer Creek limestone, with all the members present, is 55 to 60 feet thick. The formation is well exposed and the upper massive Ervine Creek limestone member forms a very pronounced scarp which trends northeast across east-central Elk county. The base of the Ervine Creek limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol E.

The members of the Deer Creek limestone recognized in Kansas are, in ascending order: Ozawkie limestone, Oskaloosa shale, Rock Bluff limestone, Larsh-Burroak shale, and Ervine Creek limestone.

#### Ozawkie limestone member

The Ozawkie limestone was named by Moore (1936a) from exposures near Ozawkie, Jefferson county, Kansas. This "lower Deer Creek" limestone was named the Rock Bluff limestone by Condra (1927). Moore (1936a) states that in the type locality, the Rock Bluff limestone possesses the lithology of a "middle" limestone of a typical Shawnee megacyclothem and that the limestone is equivalent to the "middle Deer Creek" limestone of Kansas. Therefore, Moore concluded that the lower limestone was unnamed and proposed the name Ozawkie for it.

Across Kansas, the Ozawkie is a massive bedded, somewhat impure, sandy, locally fossiliferous limestone averaging about 5 feet in thickness.

Lithologic character and thickness.--- In Elk county, the Ozawkie limestone averages about 2.5 feet in thickness. In sec. 35, T. 29 S., R. 11 E., the member is 2.2 feet thick and consists of two limestones separated by a thin grey-brown shale. The upper bed is a dark grey, massive, algal, fusulinid bearing limestone which possesses an irregular base. The lower bed is a blue-grey to mottled, buff weathering, fusulinid bearing limestone. In sec. 29, T. 28 S., R. 12 E., the member is 3.1 feet thick and consists of three massive beds of light grey, mottled, orange to buff weathering, algal, fusulinid bearing limestone. ~~In exposure in~~ sec. 5, T. 33 S., R. 11 E., in Chautauqua county, the member is 3.5 feet thick and is made up of three thin limestones separated by red, green, and yellowish shales.

Fauna.---Triticites and Osagia are the most common fossils found in the Ozawkie limestone in Elk county. The following fossils were collected from the member in Chautauqua and Elk counties: Triticites, Osagia, Tetrataxis, Cavellina, Bairdia, Juresania, Composita, Rhombopora, Aviculopinna, echinoid spines and bases, crinoid stems and plates, and small gastropods.

The lateral variations found within the Ozawkie limestone are shown in the cross-sections illustrated in Figure 7.

For measured sections of the Ozawkie limestone, see sections 15, 16, 23, 27, 30 and 31 at the end of this report.

#### Oskaloosa shale member

The shales, immediately above the limestone (Rock Bluff) which Condra considered to be the "lower Deer Creek" limestone in Nebraska, were named the Larsh shale by Condra (1927). However, as stated above, the Rock Bluff limestone of Condra is actually the "middle" limestone of the Deer Creek megacyclothem; therefore, the name Larsh shale is applicable only to the shale interval between the "middle" (Rock Bluff) and the "upper" (Ervin Creek) limestones. Moore (1936a) proposed the term Oskaloosa shale for the interval between the "lower Deer Creek" limestone (Ozawkie) and the "middle Deer Creek" limestone (Rock Bluff of Condra). The type section is located near Oskaloosa, Jefferson county, Kansas.

The member is bluish-grey to yellowish clayey shale, which contains minor amounts of siltstone in northern Kansas. In southern Kansas, the member becomes a sandy, micaceous shale in which occasional thin nodular limestones are present. Across Kansas, the Oskaloosa shale varies from 5 to 10 feet in the north to about 25 feet in the south (Moore, 1949).

Lithologic character and thickness.--- In Elk county, the Oskaloosa shale averages about 28 feet in thickness. The

member is composed mainly of reddish clayey shales in which minor amounts of green clayey shale, sandstones and local limestones occur. In some of the outcrops studied, in the upper part of the member sandstones and sandy shales are the dominant lithology. In sec. 29, T. 28 S., R. 12 E., the Oskaloosa shale is 34 feet thick and contains the following lithologic units, in ascending order: shale, 29 feet, red to green or purple, clayey to sandy, with thin greenish-grey sandstone plates occurring 12 and 28 feet above the base; shale, 5 feet, grey-brown, algal, with a few calcareous streaks in which fusulinids are present near the top. In sec. 35, T. 29 S., R. 11 E., the member is 23 feet thick. In this exposure, the top and bottom of the member are not exposed; however, starting about 6 feet below the top, 7 to 8 feet of buff, micaceous, fine grained, cross-bedded sandstones and buff sandy shales are exposed. In sec. 9, T. 30 S., R. 11 E., the member is 28 feet thick, containing an 8 foot covered interval, probably shale, followed downward by 20 feet of reddish clayey shale in which a 4 foot limestone occurs about 2.5 feet above the base. The limestone is highly algal, very irregular, greenish to dark grey, and weathers light grey to almost white. A similar occurrence of algal limestone in the lower part of the Oskaloosa shale was observed in sec. 5, T. 33 S., R. 11 E., Chautauque county. Here, a 0.5 foot dense, algal, greenish-grey limestone occurs about 1.2 feet above the base of the member.

Fauna.--- In general, with the exception of Osagia, the Oskaloosa shale is unfossiliferous; however, the following fossils were collected from the upper 2 to 3 feet of the member in sec. 29, T. 28 S., R. 12 E.: Triticites, Bairdia, echinoid spines and bases, and small, irregular, buff to white algal bodies.

The lateral variations found within the Oskaloosa shale are shown in the cross-sections illustrated in Figure 7. For measured sections of the Oskaloosa shale, see sections 15, 16, 23, 27, and 30 at the end of this report.

#### Rock Bluff limestone member

The Rock Bluff limestone was named by Condra (1927) from exposures in the Missouri River bluffs, northeast of Rock Bluff, Nebraska. In Nebraska, Condra applied the term Rock Bluff to the lower beds of the Deer Creek limestone. Moore (1936a) studied the type section of the Rock Bluff limestone and concluded that the Rock Bluff limestone of Condra was equivalent to the "middle Deer Creek" limestone of Kansas. It is in this stratigraphic sense that the name is employed in Kansas.

The member possesses the lithologic development that has come to be regarded as that of a typical "middle" limestone of a Shawnee megacyclothem; a single, blue, dense, hard, vertically jointed limestone bed. Across Kansas, the member is remarkably uniform, varying from 1 to 2 feet in thickness.

Lithologic character and thickness.--- In Elk county, the Rock Bluff limestone varies from 1.5 to 2.0 feet in thickness. In sec. 35, T. 29 S., R. 11 E., the member is 1.5 feet thick and is a dark blue, dense, hard, brittle, vertically jointed, massive, fusulinid bearing limestone bed. In sec. 9, T. 30 S., R. 11 E., the member is 2 feet thick, dense, blue, brittle, vertically jointed limestone which has a tendency to split about in the middle. The limestone weathers into sharp, angular blocks.

Fauna.--- Triticites is the most numerous and characteristic fossil of the Rock Bluff limestone; however, in most exposures Crurithyris, Juresania, and other shell fragments are present.

The lateral variations found within the Rock Bluff limestone are shown in the cross-sections illustrated in Figure 8. For measured sections of the Rock Bluff limestone, see sections 15, 27, and 30 at the end of this report.

#### Larsh-Burroak shale member

The term Larsh shale was introduced by Condra (1927) for exposures on the Larsh farm, northeast of Union, Nebraska. The member consists of argillaceous, bedded shale which is black and fissile in the lower part. The term Burroak was proposed by Condra and Reed (1937) to replace "Mission Creek" (Condra, 1927), as the latter was found to be equivalent to the Larsh shale of Nebraska. The Burroack shale is bluish-

grey, argillaceous, and fossiliferous. In Nebraska the Larsh shale is separated above from the Burroak shale by the Haynies limestone (Condra, 1927).

Apparently, southward from Nebraska, the Burroak shale thins and finally wedges out entirely as the Haynies limestone coalesces with and becomes the lower part of the Ervine Creek limestone (Condra and Reed, 1937). Moore (1949) states that the shale interval between the Rock Bluff and Ervine Creek limestones in central and southern Kansas seems to be the exact equivalent of the Larsh shale, Haynies limestone, and Burroack shale of Nebraska and refers to it as the Larsh-Burroak shale.

There is some question in the mind of the writer in regards the appropriateness of the use of the name Larsh-Burroak shale in Kansas. If, as Condra and Reed (1937) suggest, that the Haynies limestone, in northern Kansas, coalesces with the lower Ervine Creek limestone and can not be distinguished south of the point where the Burroak shale wedges out, the Haynies limestone and the Burroak shale should be considered as a northward equivalent of the lower part of the Ervine Creek limestone. If this is the case, the black fissile and bluish argillaceous shales which underlie the Haynies limestone in Nebraska, the Larsh shale, in more southerly areas simply underlies the Ervine Creek limestone, the base of which contains limestones equivalent to the Haynies limestone farther north which are overlain directly by the

main body of the Ervine Creek limestone. With the Burroak shale having wedged out, differentiation of the two limestones apparently becomes impossible. Following this, <sup>tenet</sup> further, it would seem that the Larsh-Burroak is a misnomer for the shale in southern and central Kansas and that the name Larsh shale would be more appropriate.

The use of the name Larsh-Burroak for the shale between the Rock Bluff and Ervine Creek limestones in southern and central Kansas suggests that the Haynies limestone is a more or less lenticular limestone which wedges out and disappears southward from Nebraska, allowing the two distinct shales, the Burroak and the Larsh, to come together and form a mutual but non-divisible shale south of the point where it (the Haynies limestone) disappears. This, however, was apparently not borne out by the field studies of Condra and Reed (1937, 1943).

Lithologic character and thickness.--- In Elk county, the shale between the Ervine Creek and Rock Bluff limestones averages about 3 feet in thickness. In a typical exposure of the member, in sec. 9, T. 30 S., R. 11 E., it is 2.8 feet thick, containing an upper grey to bluish-grey, clayey shale which is 1.6 feet thick and a lower 1.2 foot interval of black fissile shale.

Fauna.--- The only fossils collected from the member were the following conodont genera: Hindeodella, Lonchodina, Streptognathodus, and Cavusgnathus. The above genera were

collected from the black fissle part of the member in sec. 9, T. 30 S., R. 11 E.

For measured sections of the member, see sections 27 and 30 at the end of this report.

#### Ervine Creek limestone member

The Ervine Creek limestone was named by Condra (1927) from exposures on Ervine Creek, northeast of Union, Cass county, Nebraska. In Kansas, the member is composed mainly of massive, wavy bedded, light grey to whitish or bluish-grey, fossiliferous limestone from 5 to 32 feet thick. A less persistent, variable unit often overlies the main wavy bedded part of the member. This upper unit ranges from a featheredge to about 6 feet in thickness and varies locally, being either algal, coquinoid, nodular, fine grained, or sandy (Moore, 1951). The relationship of the Haynie limestone of Nebraska to the basal part of the Ervine Creek limestone of Kansas is discussed under the Larsh-Burroak shale.

Lithologic character and thickness.--- In Elk county, the Ervine Creek limestone has a thickness of up to ~~32~~ feet. In an excellent exposure in the quarry just northeast of Moline, the Ervine Creek limestone contains the following lithologic units, in ascending order: limestone, 21 feet, fossiliferous, lower part light grey, coarsely crystalline, very massive, with occasional wavy, thin, dark shale partings, upper 4 to

5 feet are darker grey, dense, with more pronounced wavy bedding and more prominent shale partings; limestone and shale, 3.4 feet, alternating beds of dark blue limestone and blue shales, upper limestone bed contains <sup>Cyrtosma</sup> Ottonosia; shale, 1.2 feet, bluish-grey, clayey, contains a thin, bluish-grey, nodular limestone in the middle; limestone, 5.5 feet, light grey, dense, weathers light buff, fine grained, thin wavy beds separated by thin grey-brown shales.

Across Elk county, the Ervine Creek limestone holds up a wide bench which is terminated along its eastern margin by one of the most pronounced scarps in the county. The base of the Ervine Creek limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol E.

The member is quarried northeast of Moline, where one of the largest quarries in southeastern Kansas is located. Fauna.--- The Ervine Creek limestone is highly fossiliferous and is characterized in the lower part by robust specimens of Triticites and in the upper part by small slender Triticites, numerous well preserved fenestellid bryozoans, and Phricodothyris.

The following fossils were collected from exposures of the member in sec. 12, T. 31 S., R. 10 E. and sec. 12, T. 30 S., R. 10 E.: Triticites, <sup>Dunbarinella,</sup> Caninia, Lophophyllum, Syringopora, Punctospirifer, Neospirifer, Crurithyris, Composita, Hustedia, Phricodothyris, Marginifera, Derbya, Bairdia,

Hollinella, Jonesina, Cavellina, Amphisites, Kirkbya,  
Cavusgnathus, Streptognathodus, Textularia, Ammodiscus,  
Glyphostomella, Tetrataxis, Pharkidonotus, Shansiella,  
Stegocoelia, Rhombopora, fenestellid bryozoans, fish teeth,  
echinoid spines and bases, trilobite pygidia, and crinoid  
stems.

For measured sections in which the Ervine Creek lime-  
stone is present, see sections 27, 30, 34, 35, and 64 at the  
end of this report.

#### Calhoun shale

The Calhoun shale was named by Beede (1896) from ex-  
posures at Calhoun Bluffs, about three miles northeast of  
Topeka, Kansas. In the type area, the formation attains a  
thickness of about 45 feet. In northern Kansas, the Cal-  
houn shale is mainly sandy to clayey shales and sandstones  
in which minor amounts of limestone and coal occur. South-  
ward from the type area, the formation thins until it is  
locally absent near the Oklahoma boundary (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the  
Calhoun shale is represented by a variable thickness of  
sandy to silty and clayey, finely laminated shales in which  
thin limestones are locally present. The Calhoun shale is  
fossiliferous locally, especially in the lower part. In the  
sections of the formation studied, the Calhoun shale was

found to vary from about 1.5 feet up to a maximum of about 9.5 feet. In sec. 12, T. 30 S., R. 10 E., the formation is 2.4 feet thick and consists of silty, blue, finely laminated shales which are streaked with red and orange and in which several thin, grey, calcareous sandstones are present.

In sec. 2, T. 31 S., R. 10 E., the formation consists of 1.4 feet of grey, blocky, clayey shale.

Fauna.--- The following fossils were collected from the lower part of the formation in sec. 12, T. 31 S., R. 10 E.:

Chonetes, Rhombopora, Amphiscapha, fenestellid bryozoans, and crinoid stems.

The lateral variations found within the Calhoun shale are shown in the cross-sections illustrated in Figure 8. For measured sections of the Calhoun shale, see sections 34, 35, 64, and 66 at the end of this report.

#### Topeka limestone

The Topeka limestone was named by Bennett (1896) from outcrops in the vicinity of Topeka, Kansas. Where the formation is completely developed, it contains nine distinctive members, of which the lowest is the thickest and the most persistent (Moore, 1951). Across Kansas, the formation varies from about 33 feet in the northern part of the state to about 55 feet in the south.

The members of the Topeka limestone, in ascending order are: Hartford limestone, Iowa Point shale, Curzon limestone,

Jones Point shale, Sheldon limestone, Turner Creek shale, DuBois limestone, Holt shale, and Coal Creek limestone.

In Elk county, the Topeka limestone averages about 40<sup>?</sup> feet in thickness. In the exposures of the formation in Elk county, only the Coal Creek and Hartford limestone members were considered to be definitely recognizable. However, possible correlations of the other members are discussed in the following description of the formation in Elk county.

The base of the Coal Creek limestone member is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol To.

Hartford limestone member

*Author is describing*  
The Hartford limestone was named by Kirk (1896) from exposures near Hartford, Coffey county, Kansas. The member is a massive, *Wrong field!* light blue-grey, brown weathering limestone varying from almost nothing to about 12 feet in thickness which is characterized by Amblysiphonella (Moore, 1949).

*thin field!*  
Lithologic character and thickness.--- In Elk county, the Hartford limestone is about 4 feet thick and consists of massive, dark grey, *RAM* sandy limestone which becomes very sandy in the more southerly part of the county. In sec. 12, T. 30 S., R. 10 E., the member is 4.0 feet thick and is a massive, sandy, dark grey, mottled limestone in which brachiopods, especially Neospirifer, are fairly common. In sec. 2, T.

31 S., R. 10 E., the Hartford limestone is represented by 4.1 feet of buff to grey, mottled, very sandy limestone which in the middle and lower parts contain sandstone and sandy shale.

Fauna.--- The following fossils were identified in the member in sec. 12, T. 30 S., R. 10 E.: abundant Neospirifer, Composita, Echinochonus, and rare Triticites.

The lateral variations found within the Hartford limestone are shown in the cross-sections illustrated in Figure 8. For measured sections of the Hartford limestone, see sections 35 and 66 at the end of this report.

#### Iowa Point shale member

The Iowa Point shale member was named by Condra (1927) from exposures in the Missouri River bluffs immediately southeast of the abandoned Iowa Point railway station, Doniphan county, Kansas. The member is a yellowish-grey to bluish-grey shale which contains local sandstones and coal. The member thins and disappears south of Topeka (Moore, 1951).

In Elk county, the Curzon limestone directly overlies the Hartford limestone and the Iowa Point shale is missing.

## Curzon limestone member

The "Curzen" limestone was named by Gallaher (1898) from exposures southeast of Forest City, Missouri. Condra (1927) named the "Curzen" limestone as the lower member of the Topeka limestone, stating that it had been previously used by the Missouri Survey. Moore (1936a) credits Condra as the author of the name as the limestone referred to by Gallaher was unidentifiable. He further states that the type locality of the "Curzen" limestone was presumably near Curzon (not Curzen), Missouri.

Across Kansas, the Curzon limestone consists of bluish-grey, brown weathering, massive limestone which varies from 5 to about 12 feet in thickness (Moore, 1949).

Lithologic character and thickness.--- In Elk county, the Curzon limestone is about 1 foot thick. The member directly overlies the Hartford limestone as the Iowa Point shale is missing in Elk county. In sec. 2, T. 31 S., R. 10 E., the member is 1.1 feet thick, massive, dark blue-grey, grey weathering, fossiliferous limestone.

Fauna.--- The Curzon limestone contains numerous large Triticites, Rhombopora, fenestellid bryozoans, echinoid spines and plates, and trilobite fragments.

The lateral variations found within the member are shown in the cross-sections illustrated in figure 8. For measured sections of the Curzon limestone, see sections 35 and 66 at the end of this report.

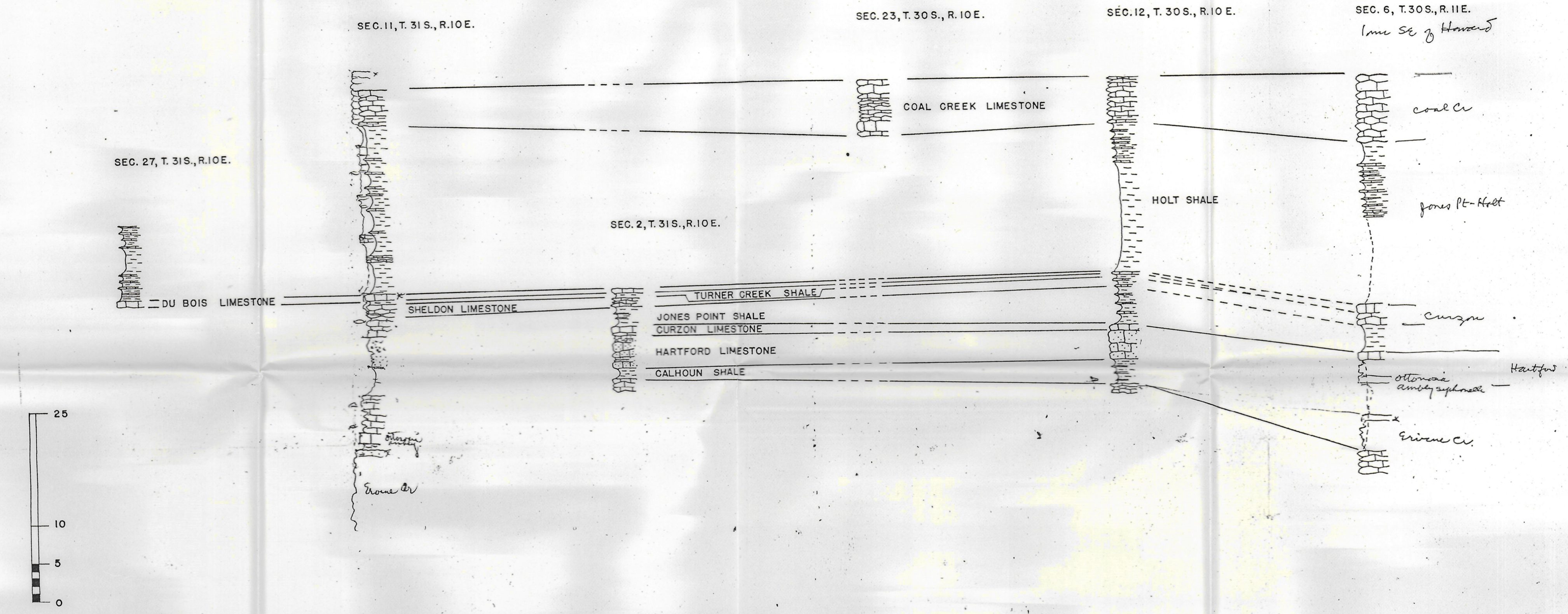


FIG. 8. POSSIBLE CORRELATION OF MEASURED SECTIONS OF THE TOPEKA LIMESTONE AND CALHOUN SHALE.

*Fig 8 - 1/10 - 5'*

### Jones Point shale member

The Jones Point shale was named by Condra (1927) from exposures at Jones Point, 4 miles east of Union, Cass county, Nebraska. In Nebraska, the member is a bluish-grey, argillaceous to calcareous, fossiliferous shale in which thin fossiliferous limestones occur. Across Kansas, the member averages about 5 feet in thickness and is a calcareous to silty or clayey shale which locally contains nodular or platy limestones (Moore, 1949).

Lithologic character and thickness.--- In Elk county, the shale above the Curzon limestone which is here tentatively correlated with the Jones Point shale varies from 2.6 to about 5 feet in thickness. The interval is well exposed in sec. 12, T. 30 S., R. 10 E., where it is 5 feet thick and consists of blue to grey or greenish and brown clayey shale, in which thin, platy, impure limestones occur. In sec. 2, T. 31 S., R. 10 E., the interval is a buff to grey calcareous shale which is 2.6 feet thick and in which thin, platy, impure, brown weathering limestones are present.

Moore (1949) correlates 10 to 15 feet of shale in Elk county with the Jones Point shale of northern and central Kansas. However, the only part of the Topeka limestone which contains such a great thickness of shale is found above the Osagia bearing limestones, here tentatively correlated with the Sheldon limestone.

Fauna.---- The following fossils were collected from the beds here correlated with the Jones Point shale, in sec. 2, T. 31 S., R. 10 E.: Jonesina, Hollinella, Triticites, Composita, Derbya, Juresania, Anomphalus, Astartella, trilobite fragments, and crinoid stems.

For measured sections of the Jones Point shale, see sections 35 and 66 at the end of this report.

#### Sheldon limestone member

The Sheldon limestone was named by Condra (1930) from quarry exposures east of Newhawka, Nebraska.

In Kansas, the Sheldon limestone is a massive, light grey to whitish, fine grained, dense, Osagia bearing limestone which is definitely known north of the Kansas River. In southern Kansas, there is an algal limestone at the Sheldon horizon (Moore, 1949).

Lithologic character and thickness.---- The limestone in Elk county which is here referred to as the Sheldon limestone averages slightly less than 2 feet in thickness. The unit consists of three or four irregular to thin beds of mottled grey to buff or bluish, dense, somewhat algal limestone. In sec. 6, T. 30 S., R. 11 E., the Sheldon limestone is 3 feet thick and consists of bluish, grey to buff weathering, Osagia bearing limestone. In sec. 11, T. 31 S., R. 10 E., the unit is 2.9 feet thick and consists of thin, irregular bedded, dirty grey, brownish weathering limestone.

Fauna.--- The limestones here tentatively correlated with the Sheldon limestone of northern Kansas contain Juresania, Myalina, Composita, rare Triticites, Osagia, Rhombopora, Aviculopecten, fenestellid bryozoans, trilobite parts, and echinoid spines and plates.

The cross-sections illustrated in Figure 8 show the lithologic variations found within the Topeka limestone in Elk county and a possible correlation of the members between Elk county and northern Kansas. For measured sections of the Sheldon limestone, see sections 35, 65, and 66 at the end of this report.

#### Turner Creek- Holt shale member

The Turner Creek shale was named by Condra (1927) from exposures on Turner Creek, southeast of Du Bois, Pawnee county, Nebraska. In Kansas, it is a blue to grey, clayey to calcareous shale which is mainly unfossiliferous. The member is 1 to 5 feet thick in northern Kansas and beds in southern Kansas which have been correlated with the Turner Creek shale are 12 to 15 feet thick (Moore, 1949).

The Du Bois limestone was named by Condra (1927) from the same locality as the Turner Creek shale. In Kansas, the member is dark grey or greenish-blue, fine grained, vertically jointed limestone which in northern Kansas is 0.5 to 2 feet thick. The member has not been recognized south of Topeka (Moore, 1949).

The Holt shale was named by Condra (1927) from exposures near Forest City, Holt county, Missouri, where it is 2-3 feet thick and consists of bluish-grey, argillaceous shale in the upper part and black, fissile shale below.

The relationship of the upper named members of the Topeka limestone in northern Kansas to the rocks occupying a comparable interval in Elk county are not clearly understood. Seemingly, southward from Topeka, the identity of these members is lost due to the non-persistent character of the limiting or bounding limestones. Accordingly, I refer to these undifferentiated beds in Elk county as Turner Creek - Holt shale to indicate that they occupy the same relative stratigraphic position as the defined members to the north. Although I have never studied the exposures of the Topeka limestone between Elk county and Topeka, the literature reports that there is a southward disappearance of the diagnostic characteristics which are used in distinguishing the nine members of the formation farther to the north. The above lateral change, seemingly, would make precise correlations between the two areas a dubious proposition. However, a somewhat detailed study of the Topeka limestone in Elk county has revealed that although thicknesses of the members vary considerably from those in northern Kansas, the lithologic development is similar enough to warrant making a suggested correlation of these upper Topeka beds. A suggested correlation between the members in northern Kansas with comparable

beds in Elk county is shown in the cross-sections illustrated in Figure 8.

Lithologic character and thickness.--- In Elk county, the interval between the Sheldon and Coal Creek limestone averages about 23 feet in thickness. In T. 31 S., R. 10 E., the interval consists of the following lithologic units, in ascending order: shale (Turner Creek shale ?), up to 0.5 feet, blue-grey, clayey to silty; limestone (Du Bois limestone ?), 0.4 to 0.8 feet, dark blue to dark grey, dense, tough, hard, vertically jointed, locally it resembles the "middle" limestone of a Shawnee megacyclothem, Lingula and Jonesina common; shale (Holt shale ?), 17 to 22 feet, greenish-grey to dark blue or almost black, locally coaly in lower part, upward the shale becomes blue-grey to buff or yellowish, highly fossiliferous, with thin, platy, fossiliferous limestones becoming numerous in the upper part.

Fauna.--- The shale here referred to with question as the Turner Creek shale contains Bairdia, Jonesina, Rhombopora, Triticites, and many shell fragments. The Du Bois limestone (?) contains abundant Lingula and Jonesina. The Holt shale (?) is extremely fossiliferous, with the upper part being characterized by abundant slender, small Triticites,

Rhombopora, and many productid brachiopods. The following fossils were collected from the upper part of the Holt shale (?) in sec. 11 and 12, T. 31 S., R. 10 E., sec. 12, T. 30 S., R. 10 E., and sec. 6, T. 30 S., R. 11 E., and represent only

the most common genera: Triticites, Chonetes, Rhombopora, Marginifera, Hustedia, Echinochonchus, Dictyoclostus, Chonetina, Dialasma, Composita, Astartella, Myalina, Septimyalina, Yoldia, Bellerophon, Worthenia, Amphiscapha, Euphemites, Bairdia, Erisocrinus, and Paradelocrinus.

The lateral variations found in this interval are shown in the cross-sections illustrated in Figure 8.

For measured sections of this interval, see sections 35, 55, 64, 65, 66, and 67 at the end of this report.

#### Coal Creek limestone member

The Coal Creek limestone was named by Condra (1927) from exposures on Coal Creek, north of Union, Cass county, Nebraska. In northern Kansas, the member is a blue-grey limestone and nodular shale or dark blue, massive, brown to blue-grey weathering limestone which varies from 2 to 5 feet in thickness (Moore, 1951). The Coal Creek limestone shows a tendency to thin wavy beds, which characterize the "upper" limestone of a typical Shawnee megacyclothem.

Lithologic character and thickness.--- In Elk county, the Coal Creek limestone varies from about 5.0 to 8.5 feet in thickness. The member consists mainly of dark grey to brownish, buff to grey weathering, fusulinid bearing limestone which is usually wavy bedded. In sec. 12, T. 30 S., R. 10 E., the Coal Creek limestone is 5 feet thick. The

upper few beds are rather thin, grey to light grey, and contain numerous Triticites and Osagia. Lower, the member is blue-grey, buff to grey weathering, wavy bedded, fusulinid bearing limestone. The basal few feet are more massive than beds above and contain numerous brachiopods. Fauna.--- The Coal Creek limestone is characterized by abundant, large Triticites. The following fossils were collected from the member in sec. 12, T. 30 S., R. 10 E.: Triticites, Osagia, Derbya, Chonetes, Hustedia, Juresania, Rhombopora, echinoid spines, and crinoid stems.

The lowermost bed in sec. 11, T. 31 S., R. 10 E., contains Amphiscapha, Myalina, Euphemites, Pharkidonotus, and many small high-spined gastropods.

The Coal Creek limestone outcrops well and forms a recognizable bench across most of Elk county. The base of the Coal Creek limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol To.

The lateral variations found within the Coal Creek limestone are shown in the cross-sections illustrated in Figure 8. For measured sections of the Coal Creek limestone, see sections 35, 64, and 65 at the end of this report.

### Wabaunsee group

The Wabaunsee formation was named by Prosser (1895) to include about 575 feet of rocks from the "Osage coal" (Nodaway coal in Aarde shale) to the base of the Cottonwood limestone. Haworth (1898) redefined the base of the formation by raising it to the base of the Burlingame limestones. Moore (1932) redefined the Wabaunsee group to include the beds between the top of the Topeka limestone to the base of the Americus limestone. Condra (1935) further restricted the Wabaunsee group by lowering the top of the group to the top of the Brownville limestone. Moore (1936a) defined the group as comprising the beds between the top of the Topeka limestone and the base of the unconformity at the base of the Towle shale.

Across Kansas, the Wabaunsee group consists of alternating limestone and shale formations which have a combined thickness of about 500 feet. Where the Indian Cave sandstone cuts out the upper beds of the group, the thickness is somewhat reduced.

In Elk county, the Wabaunsee group is slightly less than 450 feet thick. With the exception of the formations which occur between the Elmont and Dover limestones in other parts of Kansas, here represented by a relatively thin shaly interval, all of the recognized formations of the group are present in Elk county. The group outcrops in a broad belt covering approximately one fourth of Elk county. The eastern

margin of the outcrop belt runs north-northeast through the center of the county. The western margin is more irregular, terminating in the lower slopes of the Flint Hills. The base and top of the group are mapped on the accompanying areal geologic map (Plate 1). The base is mapped at the base of the Severy shale and its line of outcrop is indicated by a dashed line identified by the symbol S. The top of the group is mapped at the top of the Brownville limestone and its line of outcrop is indicated by the symbol Bv. A generalized section of the rocks of the Wabaunsee group is illustrated in Figure 9.

#### Severy shale

The Severy shale was named by Haworth (1898) from exposures at Severy, Greenwood county, Kansas, which consist of 50 to 75 feet of shale occurring between the Howard and "Elk Falls" (Topeka) limestones.

Across Kansas, the Severy shale is 70 to 80 feet thick and consists mainly of yellow-brown to bluish-grey sandy shale. Lithologic character and thickness.--- In Elk county, the Severy shale is about 70 feet thick and is composed of grey to buff, silty to sandy, micaceous shales, which locally, in the upper part, contain nodules and lenses of hard, bluish siltstone and thin sandstones. The lower part of the shale is usually finely laminated grey silty to sandy shale which contains occasional yellowish or bluish streaks. Vertical

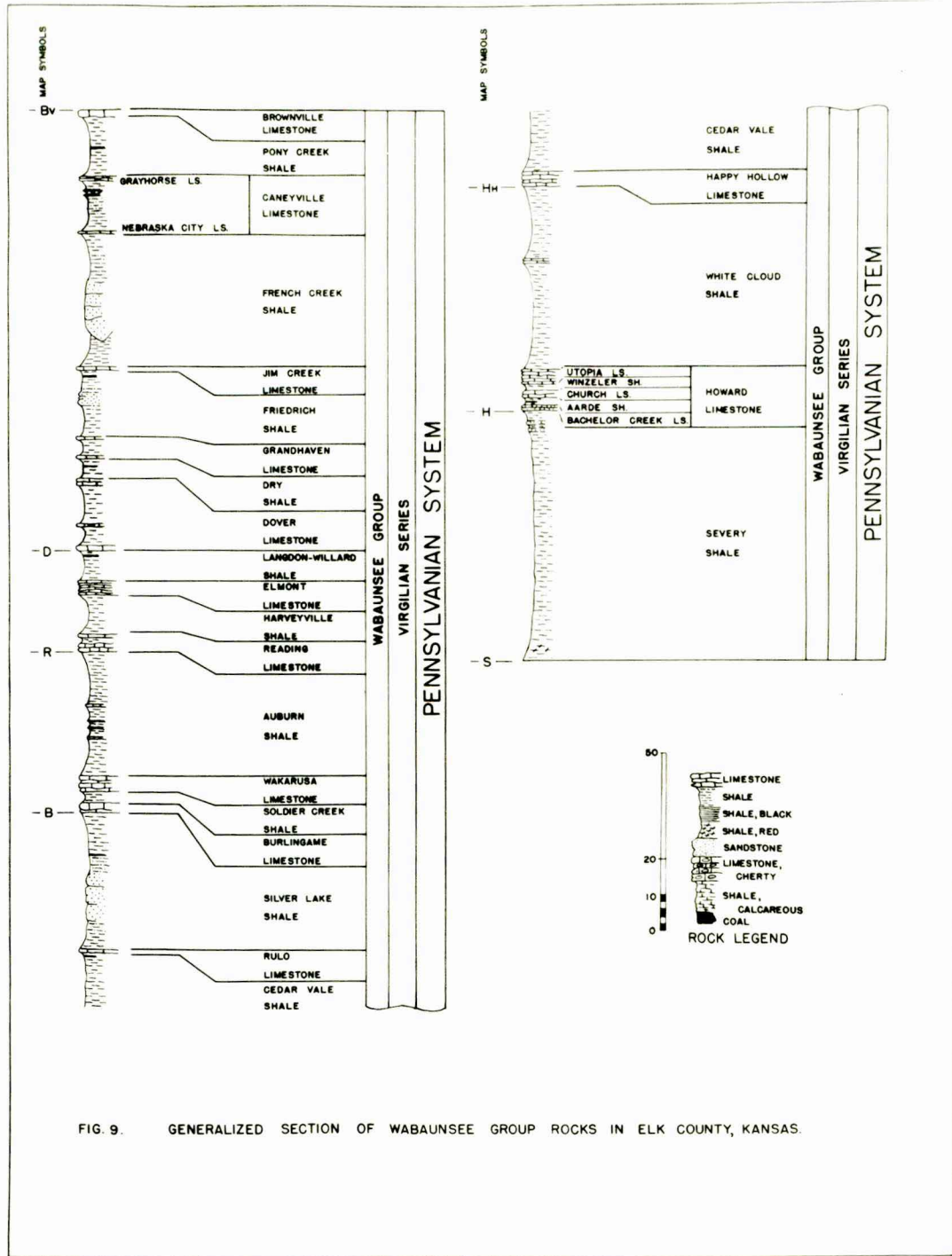


FIG. 9. GENERALIZED SECTION OF WABAUNSEE GROUP ROCKS IN ELK COUNTY, KANSAS.

jointing is fairly common in the lower half of the formation. In sec. 11, T. 30 S., R. 11 E., the lower 5 to 10 feet are red to grey clayey shale. Southward from Howard, the upper part of the Severy shale contains bluish, mottled siltstones which are sufficiently resistant to form the cap rock for several hills lying out beyond the outcropping edge of the Howard limestone. Generally, however, the Severy shale forms a slope, the upper part of which is held up by the resistant limestones of the Howard limestone formation. The lower part of the Severy slope merges gently with the soil covered dip slope of the Topeka limestone and ~~is~~ usually obscure and difficult to define precisely. However, as it was deemed advisable to map the group boundaries, the base of the Severy shale was mapped and its approximate line of outcrop is shown by a dashed line on the accompanying areal geologic map (Plate 1) which is identified by the symbol S. Fauna.--- No fossils were seen or collected from the formation.

For <sup>a</sup> measured sections of the Severy shale, see section 41 at the end of this report.

#### Howard limestone

The Howard limestone was named by Haworth (1898) from exposures of a thin limestone near Howard, Elk county, Kansas.

Where the formation is completely developed, it consists of three limestone and two shale members, ranging in

thickness from 8 to 30 feet (Moore, 1951). The formation represents cyclic deposition, which is considered by Moore (1936a) to be intermediate between the typical megacyclothem of the Shawnee group and the simpler cyclothem of the Wabaunsee group.

The recognized members of the Howard limestone are, in ascending order: Bachelor Creek limestone, Aarde shale, Church limestone, Winzeler shale, and Utopia limestone.

In Elk county, all of the members of the Howard limestone are present and the formation has an average thickness of between 11 and 12 feet. Across the county, the formation holds up a rather prominent scarp, due to its resistance to erosion and its position directly above the thick and more readily weathered Severy shale. The base of the Howard limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol H.

#### Bachelor Creek limestone member

The Bachelor Creek limestone was named by Moore (1932) from exposures on Bachelor Creek, about 5 miles east of Eureka, Kansas. In southern Kansas, where the member is best known, it is a hard, bluish-grey, somewhat sandy limestone usually less than 4 feet thick.

Lithologic character and thickness.--- In Elk county, the Bachelor Creek limestone averages slightly less than 3.5 feet

in thickness. In sec. 25, T. 29 S., R. 10 E., the member is 3.4 feet thick and is composed of light to dark blue, blotchy, silty, slightly micaceous, hard, massive limestone which weathers dark grey to buff. In sec. 9, T. 30 S., R. 10 E., the member is 4 feet thick and consists of massive, light blue, dense, buff weathering, silty limestone.

Fauna.--- The member is generally quite unfossiliferous and what few fossils are found are poorly preserved. The following fossils were collected from several outcrops in the county: Myalina, Dictyoclostus, small gastropods, crinoid stems, and echinoid spines.

The base of the Bachelor Creek limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol H. The lateral variations found within the Bachelor Creek limestone are shown in the cross-sections illustrated in Figure 10. For measured sections of the Bachelor Creek limestone, see sections 40, 41, 42, 43, and 62 at the end of this report.

#### Aarde shale member

The Aarde shale was named by Moore (1932) from exposures on the Aarde farm in sec. 4, T. 26 S., R. 11 E., Greenwood county, Kansas.

Across Kansas, the member is blue-grey to yellowish-grey, clayey to sandy shale which contains a persistent coal (Modaway) and black fissle shale. Commonly, there is a thin,

dense, vertically jointed limestone just below the black fissle shale. The Nodaway coal varies from a few inches up to 2 feet in thickness and has been traced from Oklahoma north into Iowa and Nebraska. The Aarde shale ranges in thickness from 2 to about 15 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Aarde shale ranges from 1.6 up to over 5 feet in thickness. In sec. 25, T. 29 S., R. 10 E., the member is 1.6 feet thick and consists of 0.4 feet of dark grey clayey shale underlain by a 0.2 foot coal, followed downward by 1 foot of greenish underclay and yellowish shale. In sec. 16, T. 30 S., R. 10 E., the member is incompletely exposed but the following lithologic units were exposed, in ascending order: underclay, 1.3 feet, yellow to greenish, waxey; coal, 0.5 feet; shale, 0.5 feet, grey; limestone, 0.3 feet, dark grey, hard, weathers to light grey; shale, 1.2 feet, black, fissle; shale, 0.4 feet, grey, clayey.

In Elk county, the limestone within the Aarde shale was not found in sections studied north of T. 30 S. The coal and underclay were found to be very persistent, with the coal varying from 0.2 to 0.6 feet in thickness.

Fauna.--- Parts of the Aarde shale are fossiliferous and the following fossil zones were found to occur within the member in Elk county:

The black fissle shale in sec. 16, T. 30 S., R. 10 E., contains Streptognathodus, Cavusgnathus, Crurithyris, and

rare specimens of Hustedia.

The upper part of the shale in sec. 5, T. 29 S., R. 11 E., contains Bairdia, Amphissites, small Triticites, Rhombopora, Chonetes, Crurithyris, Punctospirifer, fenestellid bryozoans, and crinoid stems.

The thin limestone in sec. 16, T. 30 S., R. 10 E. and sec. 15, T. 31 S., R. 10 E., contains Chonetes, Hustedia, Lophophyllum, and many small shell fragments.

The lateral variations found within the Aarde shale are shown in the cross-sections illustrated in Figure 10. For measured sections of the Aarde shale, see sections 40, 41, 42, 43, 44, and 62 at the end of the report.

#### Church limestone member

The Church limestone was named by Condra (1927) from exposures on the Church farm, southeast of Du Bois, Nebraska.

In Kansas, the Church limestone is commonly one massive bed of blue to grey, brown weathering, "Cryptozoan" limestone which varies from 1.5 up to 6 feet in thickness (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Church limestone averages about 2 feet in thickness. In sec. 16, T. 30 S., R. 10 E., the Church limestone is 2.5 feet thick and consists of massive, light blue, rich-brown weathering, Cryptozoon limestone. In sec. 15, T. 31 S., R. 10 E., the member consists of two massive beds of dark blue,

hard, dense, buff weathering, fusulinid bearing limestone with a combined thickness of 1.8 feet.

In Elk county, the Church limestone is the most prominent member of the Howard limestone. Its massive character, algal-fusulinid fauna, and bright brown to buff color makes field identification of the Church limestone relatively certain.

Fauna.--- The Church limestone is the most fossiliferous member of the Howard limestone. The following fossils were collected from the member in sec. 25, T. 29 S., R. 10 E.: Triticites, Bairdia, Amphissites, Hollinella, Donaldina, Anomphalus, Punctospirifer, Crurithyris, Chonetes, Hustedia, Dictyoclostus, Neospirifer, Rhombopora, and crinoid plates and stems.

The lateral variations found within the Church limestone are shown in the cross-sections illustrated in Figure 10. For measured sections of the Church limestone, see sections 42, 43, 44, and 62 at the end of this report.

#### Winzeler shale member

The Winzeler shale was named by Moore (1932) from exposures on the Winzeler farm, sec. 4, T. 26 S., R. 11 E., Greenwood county, Kansas. Across Kansas, the member is blue-grey to yellowish, calcareous to clayey shale which varies from 3 to 8 feet in thickness (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Winzeler shale is very thin, having a maximum thickness in

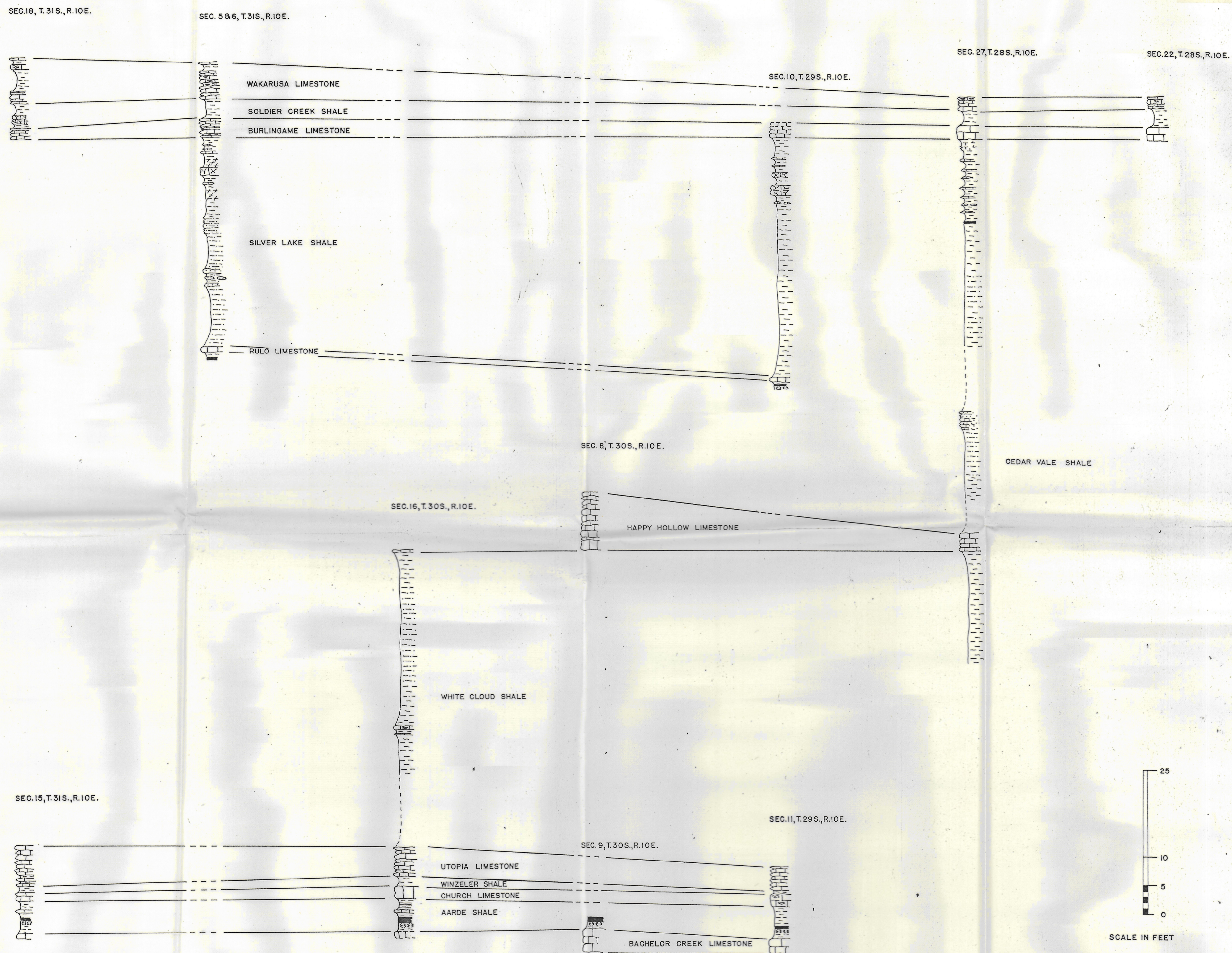


FIG. 10. CORRELATION OF MEASURED SECTIONS OF THE ROCKS OF THE LOWER PART OF THE  
WABAUNSEE GROUP.

the sections studied of slightly less than 2 feet. In sec. 16, T. 30 S., R. 10 E., the member is 1.6 feet thick and consists of yellow-brown clayey shale. In many of the outcrops, the member is reduced almost to a shale parting between the Church and overlying <sup>Utopia</sup> Utopia limestones. Because of the outcropping characteristics of the upper members of the Howard limestone, the Winzeler shale is poorly exposed and consequently is not well understood.

For measured sections of the Winzeler shale, see sections 44 and 62 at the end of this report.

#### Utopia limestone member

The Utopia limestone was named by Moore (1932) from exposures just east of the village of Utopia, Greenwood county, Kansas. Across Kansas, the member consists of grey to brown, locally coquinoid limestone which varies from about 1 to 16 feet in thickness (Moore, 1952).

Lithologic character and thickness.---- in Elk county, the Utopia limestone averages about 5 feet in thickness. In sec. 16, T. 30 S., R. 10 E., the member is well exposed and is composed of 4.8 feet of dark blue to grey, rust-brown weathering, thin to irregular bedded limestone which in the upper part is almost a coquina of Osagia and shell fragments. In sec. 11, T. 29 S., R. 10 E., the member is 4.7 feet thick and consists of dirty grey, buff to bright orange weathering, irregular thin bedded limestone.

Fauna.--- No collections were made from the Utopia limestone; however, in sec. 16, T. 30 S., R. 10 E., the member contains pelecypods, gastropods, productid brachiopods, Osagia, abundant echinoid spines, bryozoans, and crinoid stems. Composita, Chonetes, and Crurithyris were found in other exposures in the county.

The lateral variations found within the member are shown in the cross-sections illustrated in Figure 10. For measured sections of the Utopia limestone, see sections 42, 44, and 62 at the end of this report.

#### White Cloud shale

The White Cloud shale was named by Condra (1927) from exposures west of White Cloud, Doniphan county, Kansas. In this description, Condra included the beds between the Howard and Rulo limestones in the White Cloud shale. Condra (1930) restricted the White Cloud shale to the beds between the Howard and Happy Hollow limestones.

Across Kansas, the White Cloud shale varies from 30 to 80 feet in thickness and is composed of blue-grey to yellowish-brown, clayey to sandy shale which locally contains sandstones and conglomerates (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the White Cloud shale is about 50 feet thick. The formation is well exposed in sec. 16, T. 30 S., R. 10 E., where it contains the following lithologic units, in ascending order:

shale, 19 feet, lower part covered, upper part clayey to silty, finely laminated; limestone, 0.4 feet, dark grey to black, single bed, fossiliferous; shale, 0.1 foot, grey to dark grey, calcareous; limestone, 0.9 feet, silty, dark grey, shelly, with black <sup>*Cryptozoa*</sup> ~~*Stenocystis*~~; shale, 30 feet, grey to yellowish-grey, micaceous, finely laminated, sandy in upper part, vertical jointing present in middle and upper parts.

Fauna.--- In general, the main body of the formation is unfossiliferous; however, the limestones and intervening shale in the section described above contains the following fossils: <sup>*Cryptozoa*</sup> ~~*Stenocystis*~~, abundant Lophophyllum, Dictyoclostus, Derbya, Hustedia, Bairida, Hollinella, Ammodiscus, Cavusgnathus, and crinoid and echnoid plates and fragments.

For measured sections of the White Cloud shale, see sections 44 and 45 at the end of this report.

#### Happy Hollow limestone

The Happy Hollow limestone was named by Condra (1927) from exposures at the mouth of Happy Hollow Creek, northeastern Doniphan county, Kansas. The Happy Hollow limestone was at that time included in the White Cloud shale. Condra (1930) restricted the White Cloud shale to the beds below the Happy Hollow limestone and classed the latter as a member of the Scranton shale. Moore (1936a) concluded that if consistent procedures of classification and nomenclature

were to be followed, the members of the Scranton shale should be classed as formations.

In Kansas, the Happy Hollow limestone is a persistent, massive, pinkish-brown limestone characterized by large fusulinids and which locally is oolitic or algal. The thickness of the formation varies from 1 to 8 feet (Moore, 1951). Lithologic character and thickness.--- In Elk county, the Happy Hollow limestone varies from 2 up to over 10 feet in thickness; however, it is most commonly about 3 feet thick. In sec. 27, T. 28 S., R. 10 E., the member is 3.7 feet thick and is composed of light grey to pinkish-brown or "salmon" colored, fusulinid bearing limestone which is massive in lower part to irregular bedded above. In sec. 8, T. 30 S., R. 10 E., the formation is slightly less than 11 feet thick and consists of light grey to buff limestone which is massive in its lower part and very irregular bedded in its upper part. The member at this locality is very algal. In most exposures, the Happy Hollow limestone is one or two pinkish-brown, massive beds which are crowded with large, robust specimens of Triticites and rare Dunbarinella

The Happy Hollow is a fairly consistent outcropping unit and it usually forms a minor but recognizable bench across the county. The base of the formation is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol Hh.

Fauna.--- The Happy Hollow limestone is characterized by abundant large specimens of Triticites. Other fossils commonly found in the formation are: Crurithyris, Rhombopora, Osagia, fenestellid bryozoans, and echinoid spines. *Sunbainella*

For measured sections of the Happy Hollow limestone, see sections 44, 45, and 61 at the end of this report.

#### Cedar Vale shale

The Cedar Vale shale was named by Condra (1930) from exposures near Cedar Vale, Chautauqua county, Kansas. Across Kansas, the formation varies from 16 to about 60 feet in thickness and consists of blue to yellow-brown, clayey to sandy shale and sandstone in which the persistent Elmo coal occurs near the top.

Lithologic character and thickness.--- In Elk county, the Cedar Vale shale is about 30 feet thick, and consists of grey to grey-brown clayey shale which becomes sandy upward and locally passes into a grey to rust brown, thin to somewhat cross bedded, fine grained sandstone. The upper part of the formation contains the thin but persistent Elmo coal. The coal is 2 to 3 inches thick and is separated from the overlying Rulo limestone by from 1 to 8 inches of grey fossiliferous shale.

Fauna.--- The Cedar Vale shale is generally unfossiliferous; however, the thin shale above the coal and below the overlying

Rulo limestone contains the following fossils: Rhombopora, Crurithyris, Punctospirifer, Composita, Neospirifer, Chonetes, Astartella, Leda, Euphemites, Worthenia, Donaldina, Meekospira, and crinoid plates and stems.

For a measured section of the Cedar Vale shale, see section 45 at the end of this report.

#### Rulo limestone

The Rulo limestone was named by Condra and Bengston (1915) from exposures north of Hulo, Richardson county, Nebraska. Across Kansas, the formation is a bluish-grey, light brown, fossiliferous limestone from 1 to 4 feet thick.

Lithologic character and thickness.--- In Elk county, the Rulo limestone averages slightly less than 1 foot in thickness. In sec. 5, T. 31 S., R. 10 E., the Rulo limestone is 1.2 feet thick, dirty grey, brown weathering, shelly limestone which is algal in its upper part. In sec. 10 T. 29 S., R. 10 E., the Rulo limestone is 0.6 feet thick, shelly, dark grey, and sparingly fossiliferous.

Fauna.--- The Rulo limestone is sparingly fossiliferous. The following fossils were collected from the formation in sec. 5, T. 31 S., R. 10 E.: Osagia, Dictyoclostus, Worthenia, Neospirifer, echinoid spines, and crinoid stems.

The lateral variations found within the Rulo limestone are shown in the cross-sections illustrated in Figure 10.

For measured sections of the Rulo limestone, see sections 36 and 38 at the end of this report.

### Silver Lake shale

The Silver Lake shale was named by Beede (1898) from exposures near Silver Lake, Shawnee county, Kansas. In the original description, the Silver Lake shale was defined as including the beds between what are now known as the Elmo coal and the Burlingame limestone. Condra (1927) restricted the Silver Lake shale to the beds between the Rulo and Burlingame limestones.

Across Kansas, the Silver Lake shale is a grey to yellow clayey shale which contains impure platy limestones, sandy shales, and sandstones in which one or more coals are found. The thickness varies from 4 up to 45 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Silver Lake shale averages about 40 feet in thickness. The formation consists of thin, platy, impure, pelecypod bearing limestones and shales in its upper part, to sandy, grey, micaceous shales with thin sandstones and sandy concretions below. In the northern part of the county, a thin coal is present about 15 feet below the top of the formation. Vertical jointing is common in the lower part of the formation in most outcrops.

The Silver Lake and Cedar Vale shales crop out as a long grassed over slope between the bench forming Burlingame

and Happy Hollow limestones. The position of the Rulo limestone is marked by a very minor break in the slope about midway between the Happy Hollow and Burlingame limestones.

Fauna.--- The following fossils were collected from the thin limestones and shales in the upper part of the formation, in sec. 27, T. 28 S., R. 10 E.: Aviculopecten, Myalina, Derbya, Dictyoclostus, Juresania, Goniasma, Worthenia, Pharkidonotus, Rhombopora, Bairdia, Jonesina, and Hollinella.

The lateral variations found within the Silver Lake shale are shown in the cross-sections illustrated in Figure 10. For measured sections of the Silver Lake shale, see sections 36, 38, 39, 45, and 47 at the end of this report.

#### Burlingame limestone

The Burlingame limestone was named by Hall (1896) from exposures of an 8 foot shelly to massive limestone just west of Burlingame, Kansas. Across Kansas, the formation is a brownish, fine grained, hard, massive limestone which is algal in the upper part and fusulinid bearing below. The thickness of the formation varies from 2 to 16 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Burlingame limestone averages about 3 feet in thickness. The formation is thinner and somewhat more massive in the northern part of the county. In sec. 27, T. 28 S., R. 10 E.,

the formation is 2.1 feet thick and consists of bluish to brown, light brown weathering, massive limestone which is algal in its upper part and contains numerous small Triticites in its lower part. To the south, in sec. 18, T. 31 S., R. 10 E., the Burlingame limestone is 4.3 feet thick and consists of an upper 1.7 foot, algal, buff to brown limestone separated below from a thin bedded, grey mottled, brown weathering, 2.0 foot fusulinid bearing limestone by a 0.9 foot grey to buff, calcareous, algal shale.

The Burlingame and Wakarusa limestones, in Elk county, are separated by a thin shale (Soldier Creek shale) and as a consequence they outcrop almost as a single unit. The combined limestones form a definite bench which is readily traced across Elk county. The base of the Burlingame limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol B.

Fauna.--- The Burlingame limestone is characterized by the occurrence of numerous Osagia in the upper part and by numerous small Triticites in the lower part. The following fossils were collected from the formation in sec. 6, T. 31 S., R. 10 E. and sec. 27, T. 28 S., R. 10 E.: Aviculopecten, Astartella, Osagia, Tetrataxis, Triticites, Chonetes, Entelatas, Rhombopora, crinoid stems, and many shell fragments.

The lateral variations found within the Burlingame limestone are shown in the cross-sections illustrated in Figure 10. For measured sections of the formation, see sections 39, 45, 46, 47, and at the end of this report.

## Soldier Creek shale

The name Soldier Creek was used by Beede (1898) for about 40 feet of shale above the "Stanton" limestone and below the Wakarusa limestone. Moore (1936a) states that the original Wakarusa limestone of Beede is actually the Reading limestone and that the Wakarusa limestone, as now defined, was included in the upper part of Beede's "Stanton" limestone. Condra (1927) used the name Soldier Creek shale for the shale interval between the Burlingame limestone and the beds known as Wakarusa limestone. Because the name has been extensively used in this stratigraphic sense, the name is retained, in spite of the fact that it now refers to a shale stratigraphically below the one originally designated by Beede. Moore (1936a) considers this a case where usage takes precedence over priority.

Across Kansas, the Soldier Creek shale is a blue-grey, clayey to sandy shale which locally contains a coal in the upper part. The thickness varies from 1 up to about 25 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Soldier Creek shale averages slightly less than 3 feet in thickness. In sec. 27, T. 28 S., R. 10 E., the formation is 2.6 feet thick and consists of blue-grey clayey shale. In sec. 6, T. 31 S., R. 10 E., the Soldier Creek shale is 3.4 feet thick and is composed of bluish-grey to bluish-green clayey shale which is streaked with yellow.

Fauna.--- The formation in Elk county is only sparingly fossiliferous. Shale samples collected from several outcrops contain Hollinella, Bairdia, Textularia, and crinoid stems.

The lateral variations found within the Soldiers Creek shale are shown in the cross-sections illustrated in Figure 10. For measured sections of the Soldiers Creek shale, see sections 39, 45, 46, and 47 at the end of this report.

#### Wakarusa limestone

The Wakarusa limestone was named by Beede (1898) from exposures south of Auburn, Kansas. Moore (1936a) states that this limestone, identified in the type locality, is equivalent to the lower Emporia (Reading) limestone. Condra (1927) applied the name Wakarusa to a limestone about 25 feet above the Burlingame limestone in Nebraska, which when traced southward into Kansas, was found to be the upper part of Beede's "Stanton" limestone. Moore (1936a) favors retaining the Wakarusa limestone as employed by Condra because of the extensive use of the term in that sense.

Throughout Kansas, the Wakarusa limestone varies from 2 to 18 feet in thickness and consists mainly of dark blue, hard, dense, brown weathering, fossiliferous limestone. Locally, the formation may possess thin algal or molluscan limestones above and below the more persistent unit.

Lithologic character and thickness.--- In Elk county, the Wakarusa limestone averages about 5 feet in thickness.

In sec. 18, T. 31 S., R. 10 E., the formation is 7.7 feet thick and is composed of an upper light blue, dense, hard, Cryptozyma Ottensia bearing limestone in two beds separated by grey shale which is separated below from thin bedded, light blue, dense Cryptozyma Ottensia-Triticites bearing limestones by a 3.5 foot grey to dark grey shale. To the north, in T. 28 S., the formation is thinner and somewhat more massive in character.

In sec. 22, T. 28 S., R. 10 E., the Wakarusa limestone is 2 feet thick and consists of blue-grey, dense, brown weathering, algal-fusulinid bearing limestone.

Fauna.--- The following fossils were collected from the Wakarusa limestone in sec. 6, T. 31 S., R. 10 E.: Triticites, Dictyoclostus, Cryptozyma Ottensia, Dialasma, Streptognathodus, echinoid spines, crinoid plates and stems, small high-spired gastropods, and a few spongelike bodies which may be Somphosopongia.

The Wakarusa limestone can be distinguished from the underlying Burlingame limestone in Elk county by the larger Triticites and abundant Cryptozyma Ottensia which occur in the former.

The lateral variations found within the Wakarusa limestone are shown in the cross-sections illustrated in Figure 10. For measured sections of the Wakarusa limestone, see sections 39, 45, 46, 47, and 53 at the end of this report.

### Auburn shale

The Auburn shale was named by Beede (1898). The term was applied to 8 to 20 feet of shale between the Wakarusa and Elmont limestones, near Auburn, Kansas. Moore (1936a) states that the Wakarusa limestone of Beede is the lower Emporia limestone and that the limestone Beede called the Elmont is equivalent to the upper Emporia limestone. Therefore, the Auburn shale as originally defined, applied to the shale within the Emporia limestone. Condra (1927) used the name Auburn for the shale between the beds now known as the Reading and Wakarusa limestones. In so doing, he applied the name to the shale originally named the Soldier Creek by Beede (1898); however, Moore (1936a) favors retaining the name as employed by Condra as he considered that greater importance should be attached to the extensive usage in recent literature than to the priority claims of the unused and rather obscure original definition.

Across Kansas, the Auburn shale is a complex unit of shale, thin sandstones, limestones, conglomerates, and local coals which vary in thickness from 20 to 70 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Auburn shale averages slightly less than 40 feet in thickness. The formation is highly variable, consisting of red, grey, brown, and blue-green, clayey to sandy shales in which thin

blue limestones, grey, bedded to nodular siltstones, and buff to brownish "boxwork" limestones occur. The formation is variable from exposure to exposure and the reader is referred to the measured sections in the rear of the report for the detailed lithology of the various sections studied.

The Auburn shale forms a long, usually grassed over slope between the bench forming Reading and Wakarusa-Burlingame limestones.

Fauna.--- The Auburn shale is fossiliferous in part, with the thin limestones and shales in its middle and lower parts being almost coquinoïd in some localities. The following fossils were collected from the formation in sec. 7, T. 29 S., R. 9 E. and sec. 22, T. 28 S., R. 10 E.: Derbya, Septimyalina, Myalina, Juresania, Linoproductus, Chonetes, Aclistochara, Hollinella, Cavellina, Amphissites, Bairdia, Tetrataxis, Textularia, Hindeodella, Cavausgnathus, Rhombopora, fenestellid bryozoans, fish teeth, holothurian parts, and crinoid plates and stems.

The lateral variations found within the Auburn shale are shown in the cross-sections illustrated in Figure 11. For measured sections of the Auburn shale, see sections 37, 46, 47, and 53 at the end of this report.

### Reading limestone

The Reading limestone was named by Smith (1905) from exposures near Reading, Lyon county, Kansas. Beede (1898) used the name Wakarusa for what may be the limestone later named the Reading; if so, Beede's name should have priority. However, Condra (1927) used the name Wakarusa for a somewhat lower limestone in which stratigraphic sense, the term Wakarusa has gained widespread acceptance. Moore (1936a) concluded that usage should have precedence over priority in this case and that Condra's definition of the Wakarusa limestone should be retained. Further, because the Emporia limestone of Kirk (1896) can not be precisely determined in the outcrops around Emporia, priority dictates that the name Reading, proposed by Smith, should be the logical name for the limestones immediately above the Auburn shale.

Throughout Kansas, the Reading limestone varies from 1.5 up to 15 feet in thickness and consists of a persistent, blue, hard, dense, vertically jointed, fusulinid bearing limestone which locally may be both overlain and underlain by thin algal or brachiopod bearing limestones.

Lithologic character and thickness.--- In Elk county, the Reading limestone averages about 6 feet in thickness. In sec. 19, T. 31 S., R. 10 E., the formation is slightly less than 5 feet thick and consists of an upper 2.5 foot, blue, dense, vertically jointed, massive, fusulinid bearing limestone, separated below from a mottled, irregular bedded,

algal, buff weathering, 1.6 foot limestone by a 0.6 foot grey shale. Northward, the Reading limestone thickens to a maximum of about 10 feet. The added thickness is due, in most instances, to the appearance of two or three thinner limestones below the main dense, massive unit. However, in T. 28 S., there is a 4 foot, thin bedded, algal limestone which occurs above the main massive Reading limestone unit. In sec. 2, T. 30 S., R. 9 E., the formation consists of an upper 2.3 foot, blue-grey, dense, massive, vertically jointed, fusulinid bearing limestone which is separated below from 5 feet of thinner bedded, grey, algal or brachiopod bearing limestones and shales by a bluish-grey to bluish-black shale which is 2.6 feet thick.

The Reading limestone outcrops as a distinct bench which is readily identified across Elk county. The base of the Reading limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol R.

Fauna.--- The massive, vertically jointed unit of the Reading limestone contains abundant Triticites and rarer specimens of Crurithyris, Juresania, Punctospirifer, trilobite parts, and crinoid stems.

The lower beds, in sec. 19, T. 31 S., R. 10 E., contain abundant large crinoid stems, Rhombopora, Triticites, Amphissites, Bairdia, rare Streptognathodus, Composita, Punctospirifer, Chonetes, Juresania, and algae.

Some of the lateral variations found within the Reading limestone are shown in the cross-sections illustrated in Figure 11. For measured sections of the Reading limestone, see sections 37, 46, 47, 48, 51, 52, and 53 at the end of this report.

#### Harveyville shale

The name Harveyville was used by Moore (1934) for the shale interval between the Reading and Elmont limestones. The type locality, near Harveyville, Wabaunsee county, Kansas, and formal description were given by Moore in 1936.

Across Kansas, the Harveyville shale varies from 1 to 25 feet in thickness and consists of blue and greenish-brown, clayey to sandy shales and thin sandstones which locally contain a thin coal (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Harveyville shale averages about 9.5 feet in thickness. In the southern part of the county, in sec. 17, T. 31 S., R. 9 E., the formation is 7.7 feet thick and consists of 5.8 feet of blue-grey clayey shale with limonitic concretions separated below from 1.5 feet of greenish-grey to reddish shale by a 0.4 foot, buff to orange, nodular to "boxwork" limestone. In sec. 13, T. 31 S., R. 9 E., the Harveyville shale is slightly over 10 feet thick and is composed of algal grey shale which grades downward into blue-grey, micaceous, silty

to sandy shale which is streaked with orange and contains a few small limonitic concretions. Farther to the north, the Harveyville shale becomes very sandy and contains a thin coal in the lower part. This is shown in sec. 2, T. 30 S., R. 9 E., where the Harveyville shale is 8 feet thick and consists of blue-grey clayey shale above, which lower becomes very sandy and contains a thin, lenticular, grey to buff, fine grained sandstone about 2.5 feet above the base. A thin coal, about 1 inch thick, occurs about 1.5 feet below the sandstone. The interval between the coal and the underlying algal top of the Reading limestone consists of about a foot of dark blue to black shale.

Fauna.--- The Harveyville shale is only sparingly fossiliferous, with algae, and a few specimens of bryozoans and productid brachiopods being the most common fossils.

The lateral variations found within the Harveyville shale are shown in the cross-sections illustrated in Figure 11. For measured sections of the Harveyville shale, see sections 37, 47, 48, 52, and 53 at the end of this report.

#### Elmont limestone

The Elmont limestone was named by Beede (1898) from exposures of a 1 to 2 foot fossiliferous limestone near Elmont, Shawnee county, Kansas. The Elmont limestone is believed to be the upper part of the Emporia limestone of Kirk (1896); however, because the limestones referred to by Kirk are not

definitely known in the type area, the name Elmont is applied to the limestone immediately above the Harveyville shale.

Across Kansas, the Elmont limestone varies from 1 to 15 feet in thickness and consists of a persistent dark blue, massive, fusulinid bearing limestone which locally may be overlain and underlain by coquinoid or conglomeratic limestones (Moore, 1951).

Lithologic character and thickness.---- In Elk county, the Elmont limestone has a maximum measured thickness of slightly over 5 feet. The member changes markedly in lithology and faunal content across the county. In the more northerly outcrops, as in sec. 2, T. 30 S., R. 9 E., the formation is slightly less than 2 feet thick and consists of bluish to dirty grey, buff weathering, somewhat massive limestone which contains abundant, long, slender fusulinids. Southward, in sec. 19, T. 31 S., R. 10 E., the Elmont limestone is about 5 feet thick and is composed of bluish-grey, thin bedded, slightly cross-bedded, somewhat conglomeratic, highly crinoidal limestone in which no fusulinids were found.

Fauna.---- The faunal change, from a dominantly crinoidal limestone in the extreme southern portion of the county to a fusulinid bearing limestone in the more northerly outcrops, is one of the most striking paleontologic changes found to occur in the limestones of the Wabaunsee group in Elk county.

The more northerly outcrops of the formation contain long slender Triticites, Juresania, Rhombopora, Enteleles,

Crurithyris, Chonetes, Punctospirifer, trilobite fragments, and crinoid stems.

In T. 31 S., the formation is almost a coquina of crinoid stems; however, small gastropods, Myalina, rare Osagia, fenestellid bryozoans, and small shell fragments are found throughout.

The lateral variations found within the Elmont limestone are shown in the cross-sections illustrated in Figure 11. For measured sections of the Elmont limestone, see sections 37, 47, 48, 52, 53, and 54 at the end of this report.

#### Willard-Langdon shale

The Willard shale was named by Beede (1898) from exposures of shale near Willard, Shawnee county, Kansas. In the type area the shale interval between the Elmont and Tarkio limestones is about 55 feet thick.

The Langdon shale was named by Condra and Reed (1943) from exposures southeast of Langdon, Missouri, and is applied to the shale interval between the Maple Hill and Dover limestones.

In northern Kansas, the interval between the Elmont and Dover limestones is about 100 feet thick and contains the following formations, in ascending order: Willard shale, Tarkio limestone, Wamego shale, Maple Hill limestone, and Langdon shale. Southward, the Maple Hill and Tarkio lime-

stones disappear (Moore, 1936a) and the combined shales, which can no longer be differentiated, are referred to as the Willard-Langdon shale. The interval thins gradually to the south until it is only about 15 feet thick in Chautauqua county (Moore, 1951).

Lithologic character and thickness.---- In Elk county, the Willard-Langdon shale is very thin, averaging about 9 feet in thickness. Although the lithology of the interval is quite variable, there is a persistent coal, the Nyman, which occurs in its upper part. In sec. 14, T. 31 S., R. 9 E., the Willard-Langdon shale consists of 1.5 feet of grey to brown shales and thin, grey, flaggy limestone underlain by a 0.3 foot coal and 0.5 feet of bluish-grey underclay. Below the underclay, the interval contains 4.6 feet of greenish-grey, blocky to finely laminated, clayey shale which is streaked with yellow and orange. In sec. 2, T. 30 S., R. 9 E., the Willard-Langdon shale is 10.7 feet thick and contains the following lithologic units, in descending order: shale, 0.7 feet, brown, with abundant pelocypods; shale, 1.4 feet, highly calcareous, buff to grey, fossiliferous; coal, 0.2 feet; limestone, 0.5 feet, thin bedded, dark grey, with abundant plant remains; coal, 0.2 feet; limestone, 0.3 feet, dark grey to purplish, nodular, with plant remains; shale, 2.6 feet, blue-grey, clayey, with a thin coal streak 0.7 feet below the top; limestone, 1.4 feet, orange to buff, earthy, "boxwork"; shale, 3.4 feet, greenish-grey, clayey, with small

limonitic concretions in the upper part.

Fauna.--- The interval is fossiliferous in part, with the following genera being collected from the shales immediately above the Nyman coal in sec. 2, T. 30 S., R. 9 E.: Myalina, Derbya, Neospirifer, Composita, Punctospirifer, Juresania, Hollinella, Bairdia, Amphissites, Jonesina, Textularia, Baylea, Rhombopora, and crinoid stems and plates.

The lateral variations found within the Willard-Langdon shale are shown in the cross-sections illustrated in Figure 11. For measured sections of the Willard-Langdon shale, see sections 50, 52, 54, and 60 at the end of this report.

#### Dover limestone

The Dover limestone was named by Beede (1898) from exposures near Dover, Shawnee county, Kansas. The formation is represented by a single limestone bed in northern Kansas, by a limestone or calcareous sandstone in central Kansas, and by three limestones separated by shales in southern Kansas. The thickness ranges from 1 to about 25 feet, being thickest in southern Kansas where shales make up a major portion of the thickness (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Dover limestone averages about 21 feet in thickness. The formation consists of three thin limestones separated by grey, brown, and greenish-grey shales. The latter are cal-

careous to clayey and locally fossiliferous. The upper limestone is an algal (Osagia), blue-grey, thin bedded, brownish weathering limestone between 2 and 3 feet thick. The middle limestone, which is the most characteristic unit of the Dover limestone in Elk county, is a single bed of dark grey, slabby weathering limestone, which in every outcrop studied, was found to contain abundant black colored <sup>Cryptozoa</sup> Ottensia and slender Triticites. The lower limestone averages about 1.7 feet in thickness and is a massive, dense, dark blue, buff to bright orange weathering limestone which contains abundant specimens of Chonetes.

The limestones of the Dover form a low but recognizable bench across Elk county. The base of the Dover limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol D.

Fauna.--- The limestones and parts of the shales of the Dover limestone are fossiliferous. The following fossils were collected from the various indicated units of the formation in Elk county: upper limestone: Osagia, brachiopods and gastropods; shale between upper and middle limestone beds, 5 feet above base in sec. 14, T. 31 S., R. 9 E.: Ammobaculites, Tetartaxis, Ammodiscus, Hollinella, Amphissites, Bairdia, Streptognathodus, Crurithyris, Chonetes, Chonetina, Hustedia, Juresania, Punctospirifer, Marginifera, Composita, Dictyoclostus, Derbya, Ditomopyge, abundant holothurian discs, and crinoid stems and plates: middle limestone: <sup>Cryptozoa</sup> Ottensia,

slender Triticites, Crurithyris, Hustedia, Neospirifer, small gastropods, and crinoid stems; shale between middle and lower limestone beds: Hollinella, Bairdia, Deckerella, Chonetes, Worthenia, Amphiscapha, and Rhombopora; lower limestone bed: Chonetes, Neospirifer, Echinochonchus, Juresania, Worthenia, Amphiscapha, Donaldina, rare Triticites, echinoid spines, and crinoid stems.

The lateral variations found within the Dover limestone are shown in the cross-sections illustrated in Figure 11. For measured sections of the Dover limestone, see sections 49, 50, 52, 54, 60, 63, and 83 at the end of this report.

#### Dry shale

The Dry shale was named by Moore (1936a) from exposures of shale on Dry Creek, southwest of Emporia, Kansas. The name applies to the shaly beds between the Dover and Grandhaven limestones. Throughout most of Kansas, the formation consists of grey to reddish or green, clayey to sandy shales which vary from 3 to about 20 feet in thickness. In southern Kansas, the formation contains a thin coal in the upper part (Moore, 1936a).

Lithologic character and thickness.--- In Elk county, the Dry shale averages about 7 feet in thickness. In sec. 15, T. 31 S., R. 9 E., the formation is slightly less than 7 feet thick and consists of grey to brown shale with a thin coal 1.5 feet below the top. In sec. 27, T. 29 S., R. 9 E.,

the Dry shale is 6.5 feet thick and consists of grey shale with a thin coal 2 feet below the top.

Fauna.---- The following fossils were collected from the upper part of the shale in sec. 15, T. 31 S., R. 9 E.: Myalina, Hollinella, Cavellina, Bairdia, Donaldina, Worthenia, Euphemites, Bellerephon, Leda, Rhombopora, Punctospirifer, and crinoid stems and plates.

For measured sections of the Dry shale, see sections 49, 50, and 83 at the end of this report.

#### Grandhaven limestone

The Grandhaven limestone was named by Moore (1936a) from exposures near Grandhaven, Shawnee county, Kansas. The formation is not definitely known north of the Kansas River, but southward, the formation is persistent and consists of two relatively thin limestones separated by shale. The thickness of the Grandhaven limestone varies from 2 to about 10 feet (Moore, 1951).

Lithologic character and thickness.---- In Elk county, the Grandhaven limestone averages about 10 feet in thickness. The formation consists of two to three thin limestones separated by from 4 to 11 feet of grey to brown shale. Locally, a thin coal is found in the shale interval between the limestones. The lower limestone of the formation is dark grey to bluish, brown weathering limestone which is always less than 1 foot thick. The upper limestone is a grey to

bluish, rust brown weathering, algal limestone which averages about 1 foot in thickness. In sec. 11, T. 29 S., R 9 E., the lower part of the formation contains two thin limestones separated by about 1 foot of shale.

Outcrops of the Grandhaven limestone are seldom good, with exposures of the intervening shale being especially poor. As a consequence, this formation is not clearly understood in Elk county. The lateral variations found to occur in the beds here correlated across the county as the Grandhaven limestone are shown in the cross sections illustrated in Figure 11.

Fauna.---- Shale samples collected from the upper part of the shale portion of the formation in sec. 15, T. 31 S., R. 9 E., contain the following fossils: Cavellina, rare Cavusgnathus, Worthenia, Punctospirifer, abundant Crurithyris, Rhombopora, fenestellid bryozoans, and crinoid stems. The upper limestone is generally only sparingly fossiliferous, with Osagia, small brachiopods, and crinoid stems being the most common. The lower limestone contains Rhombopora, Crurithyris, bryozoans, and crinoid stems.

For measured sections of the Grandhaven limestone, see sections 49, 50, and 83 at the end of this report.

COMPOSITE  
 SEC. 13, T. 31S., R. 8E.  
 SEC. 18, T. 31S., R. 9E.

SEC. 4, T. 30S., R. 9E.

SEC. 27 & 11, T. 29S., R. 9E.

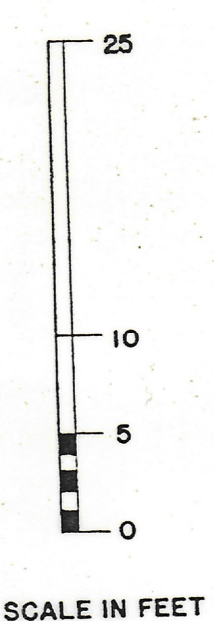
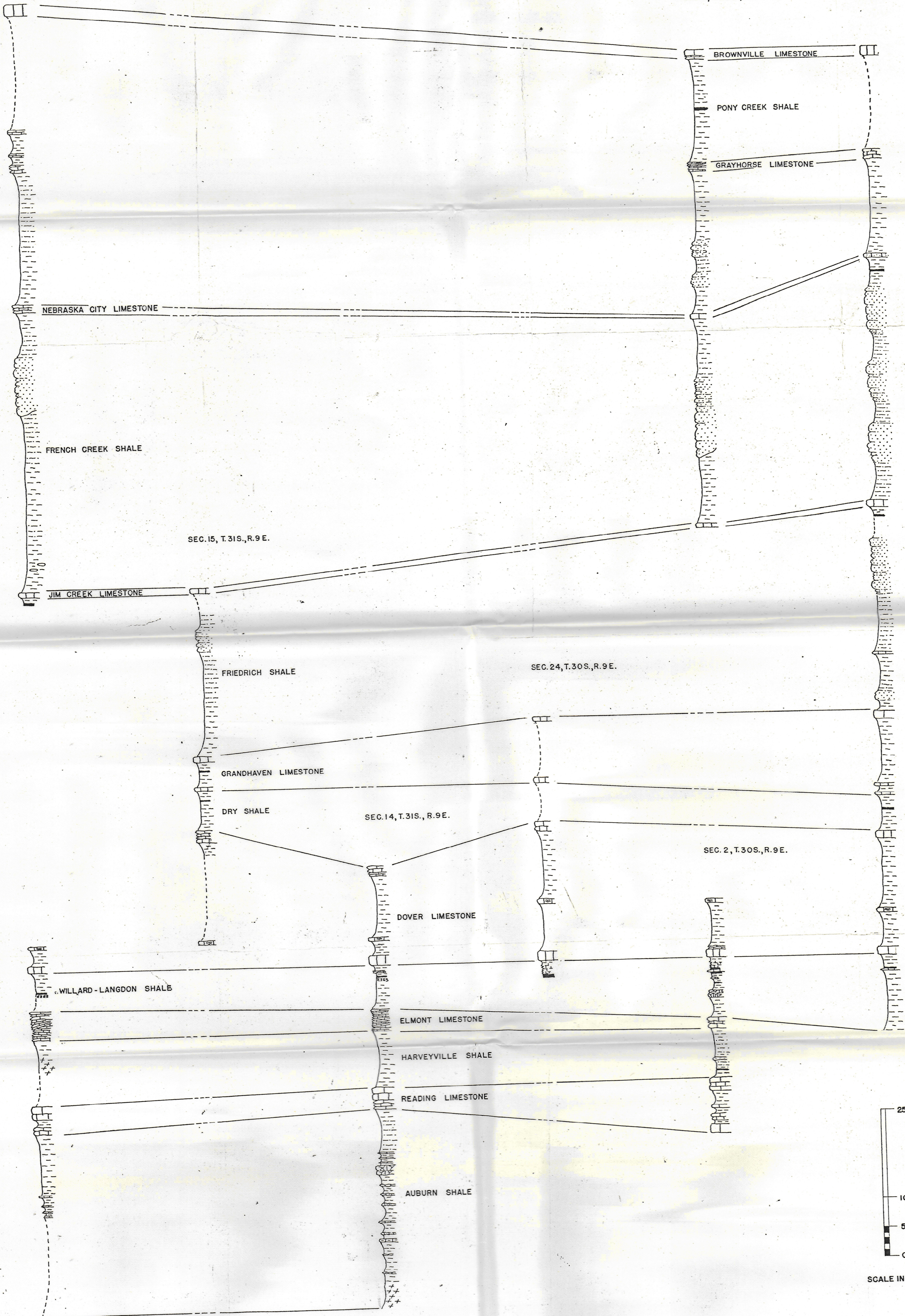


FIG. 11. CORRELATION OF MEASURED SECTIONS OF THE ROCKS OF THE UPPER PART OF THE WABAUNSEE GROUP.

## Friedrich shale

The Friedrich shale was named by Moore (1936a) from exposures on Friedrich Creek, Greenwood county, Kansas. The Friedrich shale includes the clayey to sandy shales and sandstones which occur in the interval between the Grandhaven and Jim Creek limestones. The formation averages about 15 feet in thickness (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Friedrich shale is about 30 feet thick. The formation consists of grey to bluish shales which become increasingly micaceous and sandy upward. A thin coal occurs in the upper part of the shale, usually being found about 1 foot below the overlying Jim Creek limestone. Below the coal, a sandstone, up to about 10 feet in thickness, usually occurs; however, locally, the position of the sandstone is occupied by sandy shales. In the more northerly outcrops, in T. 29 S., one or more thin pelecypod bearing limestones occur in the lower part of the formation.

Fauna.--- Shale samples collected from the shale interval between the coal and the overlying Jim Creek limestone in sec. 18, T.31 S., R. 9 E. contain the following fossils: Bairdia, Amphissites, Tetrataxis, Worthenia, Astartella, Composita, Crurithyris, and Rhombopora.

The lateral variations found within the Friedrich shale are shown in the cross-sections illustrated in Figure 11. For measured sections of the Friedrich shale, see sections 49 and 83 at the end of this report.

### Jim Creek limestone

The Jim Creek limestone was named by Moore (1936a) from exposures on Jim Creek, Pottawatomie county, Kansas. Across Kansas, the Jim Creek limestone is a thin but persistent limestone which is nowhere known to have a thickness of greater than 2 feet. The formation is a massive, bluish to grey, brown to reddish or purple weathering, fusulinid bearing limestone (Moore, 1936a).

Lithologic character and thickness.--- In Elk county, the Jim Creek limestone averages about 1 foot in thickness. In sec. 18, T. 31 S., R. 9 E., the formation is 1 foot thick and consists of massive, blue-grey, hard, brown to purplish weathering, fusulinid-pelecypod bearing limestone. In sec. 27, T. 29 S., R. 9 E., the Jim Creek limestone is 0.8 of a foot thick and is a dark blue, massive, purplish to dark grey and shelly weathering, sparingly fossiliferous limestone.

The purplish weathering is quite characteristic, and when considered along with the fusulinid-pelecypod fauna which it carries and with its stratigraphic position just above a thin coal, it makes field identification of the Jim Creek limestone quite positive. The Jim Creek limestone, being a persistent lithologic unit, probably should have been mapped; however, the formation usually crops out at the base of the lower slopes of the eastern edge of the Flint Hills where it is frequently badly covered.

Fauna.--- The Jim Creek limestone is characterized by the occurrence of Triticites and large pelecypods. The following fossils were collected from outcrops of the formation throughout Elk county: Triticites, Aviculopinna, Myalina, Juresania, and Rhombopora.

The stratigraphic position and lateral variations found to occur within the Jim Creek limestone in Elk county are shown in the cross-sections illustrated in Figure 11. For measured sections of the Jim Creek limestone, see sections 49, 53, 59, 82, and 83 at the end of this report.

#### French Creek shale

The French Creek shale was named by Moore (1936a) from exposure at French Creek, northeastern Pottawatomie county, Kansas. Across Kansas, the formation consists of bluish-grey to yellowish and brown, clayey to sandy shales, locally containing sandstone and one or more thin coals in the upper part. The thickness of the formation varies from 20 to 45 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the French Creek shale averages about 37 feet in thickness. In sec. 18, T. 31 S., R. 9 E., the French Creek shale is 34 feet thick, consisting of grey to greenish and blue-grey to dark grey, clayey to silty and sandy shale with a 10 foot massive to cross-bedded, micaceous, gray to brownish sandstone in the upper part. Farther to the north, in sec. 27,

T. 29 S., R. 9 E., the formation is 42 feet thick and contains the following lithologic units, in ascending order: shale, 11 feet, yellow to brown, sandy; sandstone, 15 feet, fine grained, buff to brownish, massive; shale and sandstone, 11 feet, buff to grey and brownish sandy shale grading upward into sandstone; shale, 3 feet, yellow to grey, clayey; coal, 0.2 feet; shale, yellowish-grey, clayey.

The base of the sandstone in sec. 18, T. 31 S., R. 9 E., and in sec. 3, T. 30 S., R. 9 E. is very sharp and shows evidence of channeling.

Fauna.--- The French Creek shale is relatively unfossiliferous, with no megafossils being found on the outcrop. Shale samples collected from 10 feet above the base of the formation in sec. 18, T. 31 S., R. 9 E. contain the following genera: Hollinella, Cavellina, Donaldina, Bellerophon, and a few small echinoid spines.

The lateral variations found within the French Creek shale are shown in the cross-sections illustrated in Figure 11. For measured sections of the French Creek shale, see sections 55, 59, and 82 at the end of this report.

### Caneyville limestone

The Caneyville limestone was named by Moore (1936a) from exposures in Caneyville Township, Chautauqua county, Kansas. The formation includes the previously defined Nebraska City (Condra, 1927) and Grayhorse (Bowen, 1918) limestones and the intervening shale. In Chautauqua county, a thin fusulinid bearing limestone occurs about 5 to 10 feet above the Nebraska City limestone (Moore, 1936a). Across Kansas, the formation varies from 12 to about 25 feet in thickness (Moore, 1951).

In Elk county, the Caneyville limestone averages about 25 feet in thickness. In the more northerly outcrops, the formation is 19 feet thick and consists of well-developed Nebraska City and Grayhorse limestones separated by 17 feet of yellow to grey shale. Southward, the shale unit thickens to about 25 feet and two or three thin limestones, one containing fusulinids, making their appearance about 5 or 10 feet below the Grayhorse limestone. Locally, sandstone occurs in the middle and lower part of the shale unit. The lateral variations of the formation are not clearly understood southward from T. 30 S.; however, the beds considered to constitute the Caneyville limestone are shown in the cross-sections illustrated in Figure 11.

### Nebraska City limestone member

The Nebraska City limestone was named by Condra (1927) from exposures southeast of Nebraska City, Nebraska. Across Kansas, the member varies from 1 to 5 feet in thickness and consists mainly of grey, soft, massive, sparingly fossiliferous limestone.

Lithologic character and thickness.--- In Elk county, the Nebraska City limestone is about 1 foot thick and consists of bluish-grey, dense, locally somewhat impure, massive, buff to orange weathering limestone.

Fauna.--- The Nebraska City limestone is sparingly fossiliferous but pelecypods and rare fusulinids are usually found in most localities. The following fossils were collected from the member across Elk county: Aviculopinna, Triticites, crinoid stems, and small brachiopods.

For measured sections of the Nebraska City limestone, see sections 55, 58, 59, and 82 at the end of this report.

The intervening, unnamed shale member of the formation ranges from 17 up to possibly 30 feet in thickness, having an observed thickness of almost 25 feet in sec. 13, T. 31 S., R. 8 E. The unit is bluish-grey to yellowish micaceous shale which locally contains sandstone and thin limestones. In the southern part of the county, in T. 31 S., R. 8 E., three thin limestones occur in the upper part of the interval. The lower limestone is lenticular, dense, bluish limestone

with small siltstone pebbles in the lower part. The middle 1 foot bed is thin-bedded, dark blue, brownish weathering limestone which is crowded with small gastropods, brachiopods, and bryozoans. The upper limestone is 0.5 feet thick, dark grey, yellow to rust weathering, and contains fusulinids. The upper part of the shale, above the three thin limestones, is grey, silty and contains abundant specimens of Myalina.

For measured sections of the shale unit of the Caneyville limestone, see sections 57 and 58 at the end of this report.

#### Grayhorse limestone member

The Grayhorse limestone was named by Bowen (1918) from exposures in Osage county, Oklahoma. Across Kansas, the Grayhorse limestone is a fragmental to coquinoid, grey, somewhat cross-bedded limestone up to 6 feet in thickness (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Grayhorse limestone is usually slightly over 1 foot thick and is a dark grey, buff to greyish weathering, massive limestone which breaks down into thin wedge shaped slabs which give the member a decided cross-bedded appearance.

Fauna.--- The Grayhorse limestone is characterized by the occurrence of numerous specimens of Myalina. Locally, the member is almost a coquina of small pelecypod fragments.

For measured sections of the Grayhorse limestone, see sections 49, 55, and 82 at the end of this report.

### Pony Creek shale

The Pony Creek shale was named by Condra (1927) from exposures on Pony Creek, south of Falls City, Nebraska, and included the beds between the Dover and Brownville limestones. Moore (1936a) restricted the Pony Creek shale to the interval between the newly defined Caneyville limestone (Moore, 1936a) and the base of the Brownville limestone.

Across Kansas, the Pony Creek shale ranges from 5 to 50 feet in thickness and consists mainly of bluish-grey shale. Locally, red clayey or sandy shale and sandstones occur in the middle part of the formation. The latter is a channel filling deposit, where in some localities, it is reported to cut down to or below the Friedrich shale. A thin coal is found in its upper middle part in southern Kansas (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Pony Creek shale has an average thickness of about 18 feet. The formation is completely exposed in sec. 4, T. 30 S., R. 9 E., where it is slightly less than 18 feet thick and consists of blue-green to yellowish and gray shales which grade upward into grey-brown and yellow shales. A thin coal, 0.2 feet thick, occurs 8.8 feet below the top of the formation.

It is interesting to note, that the channel sandstone reported in the Pony Creek shale in other parts of Kansas is not present in Elk county; however, a relatively thick and persistent channel filling sandstone occurs in the lower part of the French Creek shale.

Fauna.--- Shale samples collected from the shale just above the coal in sec. 4, T. 30 S., R. 9 E., contain the following genera: Pseudozygopleura, Donaldina, Bairdia, Jonesina, Astontella, Astorella, and Myalina.

For measured sections of the Pony Creek shale, see sections 55 and 56 at the end of this report.

#### Brownville limestone

The Brownville limestone was named by Condra and Bengston (1915) from exposures south of Brownville, Nemaha county, Nebraska. Across Kansas, the formation usually consists of one or two beds of dense, massive, fine-grained, brown to yellow weathering, fossiliferous limestone, varying from 2 to 8 feet in thickness (Moore, 1951).

Lithologic character and thickness.--- In Elk county, the Brownville limestone is between 1 and 2 feet thick. In sec. 13, T. 31 S., R. 8 E., the Brownville limestone is a light grey, single massive bed of buff to cream yellow weathering, fossiliferous limestone. In sec. 4, T. 30 S., R. 9 E., the formation is 1.7 feet thick and consists of grey, dense, grey to yellow-brown weathering limestone.

The Brownville limestone is a persistent outcropping limestone which forms a recognizable bench across Elk county. The top of the Brownville limestone, which also marks the top of the Pennsylvanian System in Elk county, is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol Bv.

Fauna.--- The Brownville limestone is characterized by the abundant occurrence of Triticites and Chonetes. The following fossils were collected from the formation in sec. 13, T. 31 S., R. 8 E.: Triticites, Chonetes, Marginifera, large crinoid stems, echinoid spines, and numerous bryozoans.

The lateral variations found within the Brownville limestone are shown in the cross-sections illustrated in Figure 11. For measured sections of the Brownville limestone, see sections 55 and 56 at the end of this report.

## PERMIAN SYSTEM

The Permian System in Elk county is represented by about 525 feet of sedimentary rocks, all of which belong to the lower Permian Wolfcampian Series.

The position of the base of the Permian has been an issue of disagreement ever since Permian rocks were recognized in the Mid-Continent region. Meek and Hayden (1858, 1859) published on the existence of Permian rocks in Kansas and considered the Permian as beginning at the top of the Ft. Riley limestone. Although subsequent authors have revised the position of the boundary many times, the general tendency has been to lower the position of the base of the Permian.

From 1895 to 1932 the great majority of geologists working in the Mid-Continent region considered the base of the Permian to lie within or at the base of the rocks now known as the Beattie limestone. Prosser (1895) somewhat arbitrarily placed the base of the Permian at the base of the Neosho formation (Morrill limestone). He considered that typically Carboniferous fossils became rare or disappeared above the base of the Neosho formation, while forms he considered to be characteristically Permian became common. Darton (1915) lowered the base of the Permian to the base of the Cottonwood

limestone, supposedly on paleobotanical evidence presented by White (Moore, 1940). This position for the base of the Permian was widely accepted until 1932. However, in an important paper, published in 1924, Beede and Kniker considered that the Neva limestone should be regarded as the base of the Permian in Kansas. They discussed the occurrence of "Schwagerina" (Paraschwagerina) in the Neva limestone and concluded that "Schwagerina" was of sufficient stratigraphic significance that its earliest occurrence could safely be regarded as the base of the Permian.

Moore (1932) concluded, that in view of the fact that there were no stratigraphic breaks between the Neva and the Americus limestones and that they were both very similar in regards fauna and lithology, that the base of the Permian should be lowered to the base of the Americus limestone.

Since 1934, the base of the Permian has generally been considered to be the disconformity at the base of the Indian Cave sandstone member of the Towle shale. Moore and Moss (1934) reported a disconformity, marked by channel sand fillings, about 100 feet below the Americus limestone, which was traceable from Oklahoma to Nebraska. Although there has been some disagreement with this placing of the position of the basal Permian, it has been accepted by the Kansas and Nebraska surveys and by Adams et al (1939). An excellent discussion of the Permian-Pennsylvanian boundary in the Kansas-Nebraska area was published by Moore in 1940.

In Elk county, the disconformity at the base of the Towle shale is indeed obscure. In fact, the basal Admire beds are shales, limestones, and sandy shales which contain no channel-filling sandstones. The thin upper Pennsylvanian limestones; the Brownville, Greyhorse, and Nebraska City limestones, were not observed to be cut out by channeling at any locality. The only evidence supporting the existence of a disconformity directly above the Brownville limestone seems to be a discolored zone in the lower part of the Towle shale, which may represent a period of weathering. Indeed, the only relatively thick sandstones in this part of the section occur locally between the Greyhorse and Nebraska City limestones and persistently between the Nebraska City and Jim Creek limestones. The lowermost of these sandstones does exhibit channeling to some degree, but even here, cutting out of the Jim Creek limestone was not observed.

On the accompanying serial geologic map (Plate 1), the base of the Permian is mapped as beginning immediately above the top of the Brownville limestone.

### Wolfcampian Series

The Kansas Geological Survey, in accordance with the standard Permian section of North America proposed by Adams et al (1939), has accepted the Wolfcamp Series as Lower Permian, and include in it all beds from the top of the Brownville limestone to the top of the Harington limestone member of the Nolans limestone. The ending -ian is used in this report in accordance with the policy of the Kansas Geological Survey.

All of the Permian rocks in Elk county belong to the Wolfcampian Series. Of the three recognized rock groups of the Wolfcampian Series, only the Admire and Council Grove groups are fully represented. The uppermost, the Chase group is represented in Elk county only by the rocks embracing the interval from the Wreford limestone to the lower limestone member of the Barneston limestone.

#### Admire Group

The term Admire was first used by Adams, Girty, and White (1903) for 40 feet of shale between the Americus limestone and the Emporia limestone. Condra (1927) realizing that Adams had erroneously correlated the rocks then known as the Emporia limestone, redefined the Admire shale to include all rocks from the base of the Americus limestone to the base of the Brownville limestone. Moore (1932) restricted the

Admire shale to the beds from the top of the Brownville limestone to the base of the Americus limestone. Moore and Condra (1932) defined the Admire shale to include all beds from the top of the Brownville limestone to the base of the Americus limestone, for the first time including the Oaks shale, Houchen Creek limestone, and Stine shale, previously included in the overlying Elmdale shale. Condra (1935) used the term Admire group for the interval from the top of the Brownville limestone to the base of the Americus limestone. The Admire group is recognized by the Kansas Geological Survey to include the following formations, in ascending order: Towle shale, Aspinwall limestone, Hawxby shale, Falls City limestone, West Branch shale, Five Point limestone, and Hamlin shale with the Stine shale, Houchen Creek limestone, and Oaks shale members.

In Elk county, the Admire group is about 110 feet thick. All of the above named members have been recognized in Elk county; however, the Aspinwall and Falls City limestones are not well developed. The Indian Cave sandstone member of the Towle shale is not present in Elk county. A generalized section of the rocks of the Admire group is illustrated in Figure 12. The lateral variations found within the rocks of the upper part of the group are shown in the cross-sections in Figure 13. The outcrop belt of the Admire group is shown in the accompanying areal geologic map (Plate 1). The group crops out as the upper part of the relatively steep slope

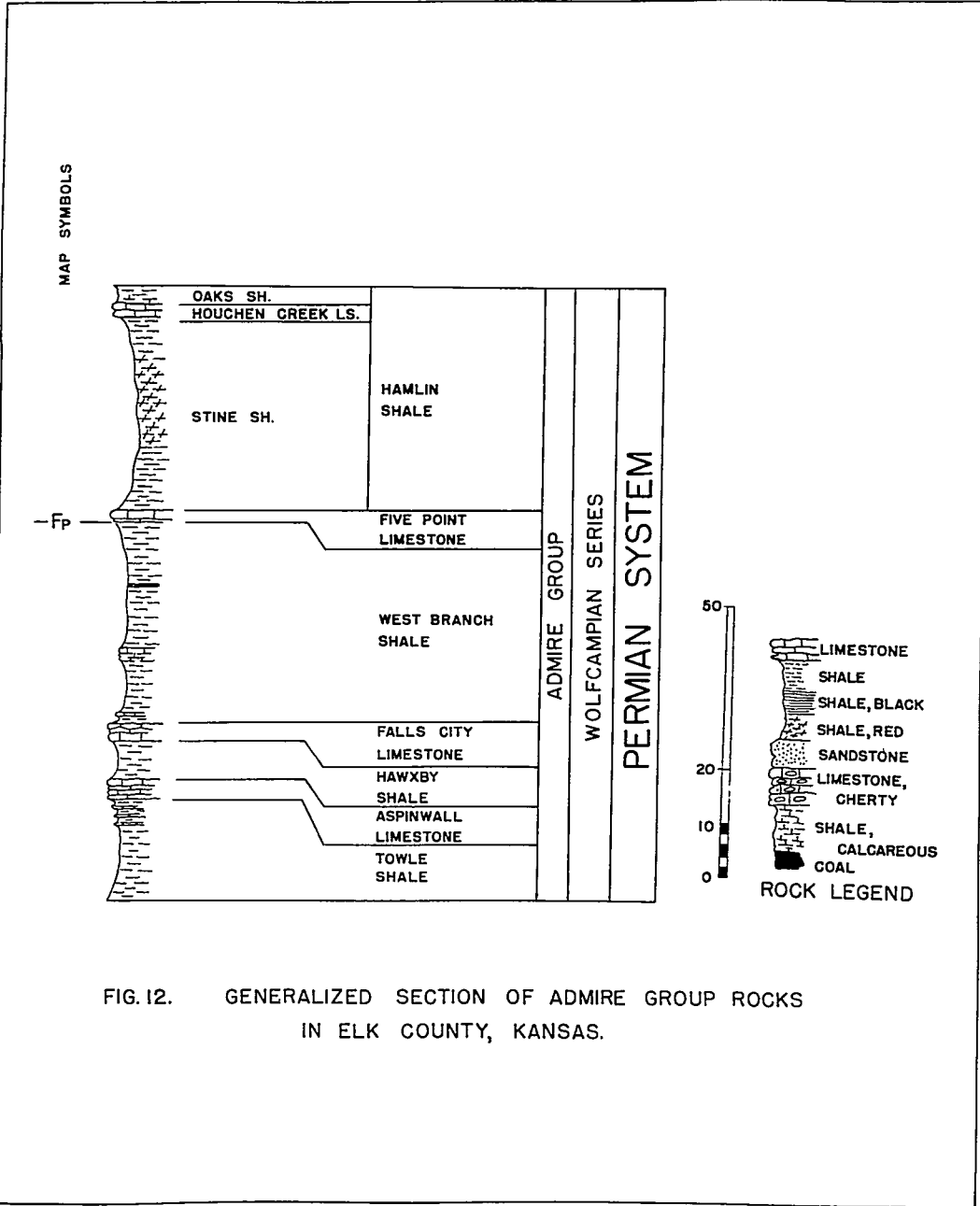


FIG. 12. GENERALIZED SECTION OF ADMIRE GROUP ROCKS IN ELK COUNTY, KANSAS.

immediately below the lower limestone bench of the Flint Hills. Because of the predominately shaly character of the Admire group, only two minor benches, those formed by the Houchen Creek and Five Point limestones, break the otherwise uniform slope between the Americus limestone and the top of the Pennsylvanian.

#### Towle shale

The Towle shale was named by Moore and Condra (1932) from exposures on the Towle farm, Richardson county, Nebraska. Throughout most of Kansas, the formation is a grey, clayey to sandy shale which locally may contain a well developed channel sandstone (Indian Cave) in the lower part. Over the state in general, the formation ranges in thickness from 15 to 135 feet, being thickest where the lower sandstone member is present (Moore, 1944).

Lithologic character and thickness.--- In Elk county, the Towle shale averages about 20 feet in thickness. The formation is generally a micaceous, yellow to grey shale which weathers to grey or greenish clay. In sec. 10, T. 30 S., R. 9 E., the upper part of the formation contains several very thin bluish limestones which are interbedded with grey and tan shales. The sandstone, which is so commonly reported in the lower part of the Towle shale in other parts of Kansas, was not found in any of the sections of the formation studied in Elk county. Here, the basal Permian Towle shale

appears to be conformable with the underlying beds of the Pennsylvanian. The only indication of the disconformity reported elsewhere in Kansas (Moore and Moss, 1934) appears to be a somewhat discolored zone which was noticeable a few feet above the Brownville limestone in sec. 4, T. 30 S., R. 9 E.

Fauna.--- The Towle shale is generally unfossiliferous; however, a shale sample collected about 15 feet above the base of the formation in sec. 13, T. 31 S., R. 8 E. contains numerous small algal bodies and rare specimens of Aclistochara and Jonesina.

Good exposures of the Towle shale are not common as the formation usually crops out as a grassed over slope between the benches formed by the Brownville and Five Point limestones. For measured sections of the Towle shale, see sections 55 and 68 at the end of this report.

#### Aspinwall limestone

The Aspinwall limestone was named by Condra and Bengston (1915) from exposures at Aspinwall, Nebraska. In the type locality, the formation is a single massive, light brown limestone averaging 1 to 2 feet in thickness. In Riley and Geary counties, Kansas, the Aspinwall limestone is about 4 feet thick, containing abundant pelecypod fragments (Jewett, 1941). In Lyon county, Kansas, the Aspinwall limestone is

represented by a 2 foot bed of crumbly to flaggy, pelecypod bearing limestone.

Lithologic character and thickness.--- In Elk county, the Aspinwall limestone averages slightly over 2 feet in thickness. In sec. 4, T. 30 S., R. 9 E., the Aspinwall limestone is 2.5 feet thick and consists of thin bedded, brownish, yellowish to tan weathering limestone. In sec. 13, T. 31 S., R. 8 E., the formation is 2.1 feet thick, consisting of an upper dark grey, slabby, buff weathering limestone and a lower dark brown to chocolate colored, cream yellow weathering limestone separated by 0.6 feet of shale. This formation is rarely well exposed and consequently is not well known.

Fauna.--- In Elk county, the Aspinwall limestone is quite fossiliferous and contains a mixed molluscan-molluscoid fauna. The genera most commonly present are Myalina, Juresania, Aviculopecten, Meekopora?, fenestellate bryozoans, and in some outcrops, crinoid stems.

The Aspinwall limestone does not outcrop well because of its rather crumbly, thin bedded character. Generally, the formation forms a slight bench in the grass covered slope formed by the thicker Towle-Hawxby shales. For measured sections of the Aspinwall limestone, see sections 55 and 68 in the rear of this report.

### Hawxby Shale

The Hawxby shale was named by Moore and Condra (1932). The type locality of the Hawxby shale is located on the Hawxby farm in sec. 7, T. 4 N., R. 15 E., Nemaha county, Nebraska (Wilmarth, 1938). Near Falls City, Nebraska, the Hawxby shale consists of 2.6 feet of bluish gray and red shales overlain by 10 feet of light blue-gray calcareous shale (Condra, 1935). Moore (1944) states that the formation is about 12 feet thick in northern Kansas and that it thickens to about 40 feet in southern Kansas.

Lithologic character and thickness.--- In Elk county, the Hawxby shale ranges from 6 to 8 feet in thickness. Lithologically, the formation is highly variable. In sec. 13, T. 31 S., R. 8 E., the formation consists of gray shale in its lower part which grades upward into grayish-green, micaceous, sandy shale. The upper 3 feet are a gray, micaceous, somewhat massive, limonite stained sandstone. In a good exposure in sec. 4, T. 30 S., R. 9 E., the formation consists of, in descending order: 2.5 feet of grey shale; 0.5 feet of bluish grey, nodular algal limestone; 4 feet of varicolored shale (red to purple, green, and yellow) which contains numerous small white algal bodies.

For measured sections in which the Hawxby shale is present, see sections 55 and 68 at the rear of this report.

### Falls City limestone

The name Falls City was applied by Condra and Bengston (1915) to a 3 to 6 foot, massive, brownish-mottled limestone near Falls City, Richardson county, Nebraska. In Riley county, Kansas, the Falls City limestone is a brownish-grey limestone about 3 feet thick with a coquina like "oatmeal" texture (Jewett, 1941). Elsewhere in Kansas, the Falls City limestone is reported by Moore (1944) to have a thickness that varies from 2 to 10 feet, averaging about 7 feet.

Lithologic character and thickness.--- In Elk county, the Falls City limestone is 2 to 3 feet thick. In sec. 4, T. 30 S., R. 9 E., the formation is a dirty, dark blue, dense limestone which weathers to a grey or orange-grey color. At this locality, it consists of a lower 2 foot, relatively massive bed, overlain by two 0.5 foot beds, the upper one of which is nodular in character. In sec. 13, T. 31 S., R. 8 E., the Falls City limestone is 1.8 feet thick and consists of three more or less uniform beds which have a brecciated to vuggy texture. The beds are yellowish grey in color, contain numerous calcite joint fillings, and weather to a light brown color.

Fauna.--- The Falls City limestone contains rather abundant fossil fragments, among which the most common are: Composita, Meekopora, Bellerophon, and crinoid stems. Fusulinids have been reported in the Falls City limestone (Moore, 1944); how-

ever, field examinations in Chataqua, Elk, and southern Greenwood counties did not reveal the presence of large fusulinids.

As is the case with all of the lower formations of the Admire group, good exposures of the Falls City limestone are not common. For measured sections of the Falls City limestone see sections 55 and 68 at the end of this report.

#### West Branch shale

The name West Branch was first used by Condra (1927) for beds exposed in West Branch Township, Pawnee county, Nebraska. In the type area, the formation is 26 feet thick. In Kansas, Moore (1944) reports that the West Branch shale varies from 10 feet in southern Kansas to about 30 feet in northern Kansas.

Lithologic character and thickness.--- In Elk county, the West Branch shale varies from 20 to about 36 feet in thickness. In sections 4 and 9, T. 30 S., R. 9 E., the entire West Branch shale is exposed and the formation contains the following lithologic variations, in descending order: 14.0 feet of greenish-grey shale; 0.2 feet of coal; 10.0 feet of bluish-black, finely laminated clayey shale; 3.0 feet of yellow to tan "boxwork" limestone; 11.0 feet of shale which varies from micaceous, greenish-grey at the top to almost black at the base and contains a 0.2 foot dark grey limestone

stringer about 2 feet from the base. The upper part of the formation is exposed in sec. 13, T. 31 S., R. 8 E. At this locality, the upper 16 feet of the formation consist mainly of greenish-grey to dark blue, micaceous shale with numerous thin calcareous blades. The thin coal bed present in the section above is also present; however, at this locality it occurs 8 feet below the top of the shale.

Fauna.--- Although no megafossils were found in the sections studied, shale samples collected from just above the coal in sec. 13, T. 31 S., R. 9 E., have yielded a small microfauna in which the following genera were found: Bairdia, Jonesina, and Conuspira.

For measured sections of the West Branch shale see sections 55 and 68 in the rear of this report.

#### Five Point limestone

The Five Point limestone was named by Moore and Condra (1932). The type section of the Five Point limestone is on Five Point Creek, near the Five Point School, sec. 25, T. 1 N., R. 15 E., Richardson county, Nebraska (Wilmarth, 1938). In Lyon county, Kansas, the Five Point limestone is 2 feet thick, the upper 0.5 feet is shaly to flaggy, the lower 1.5 feet is massive but crumbly (Moore, 1936).

Lithologic character and thickness.--- In Elk county, the Five Point limestone is about 2 feet thick. It is a dark grey to brownish-grey, massive limestone which weathers to a

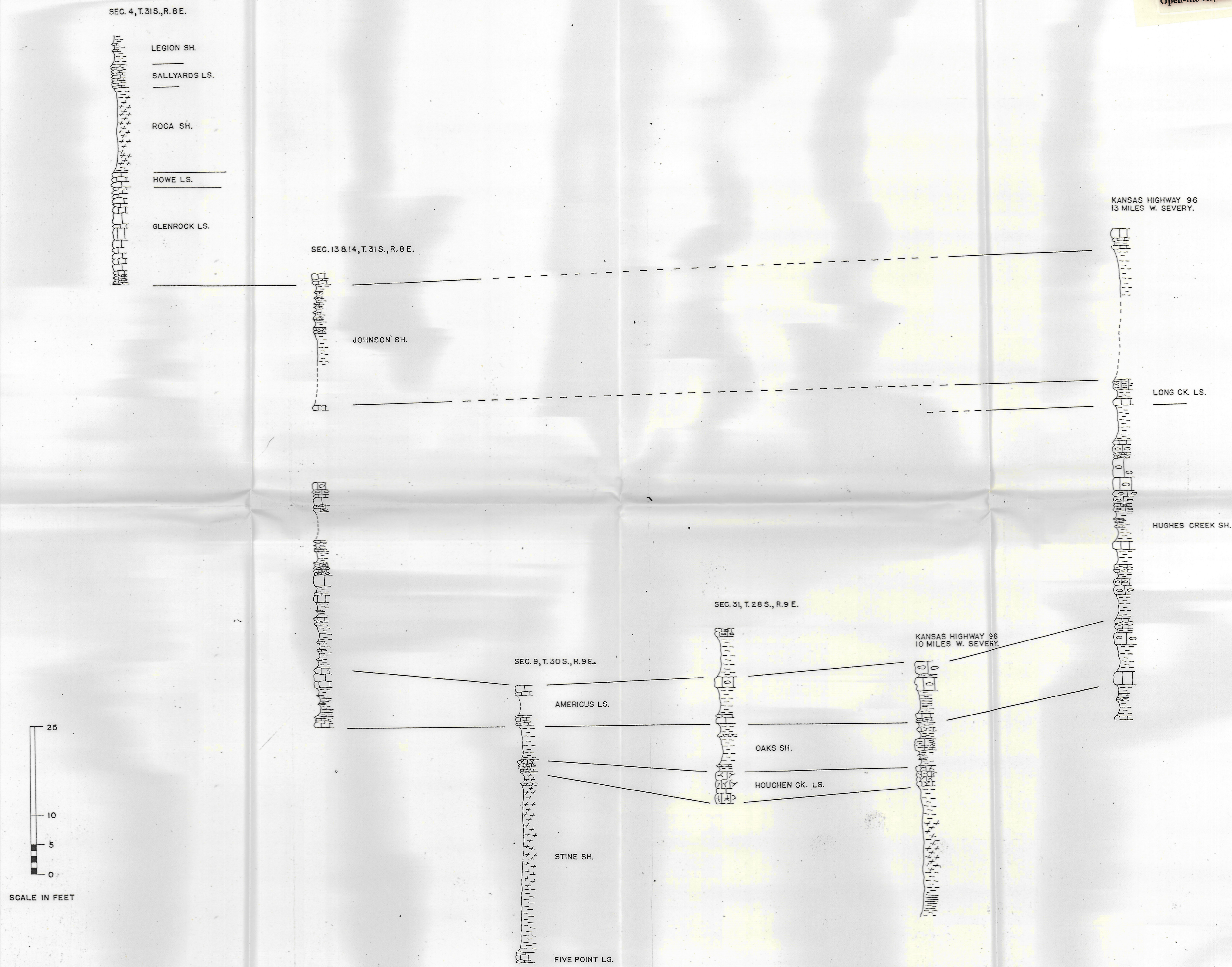


FIG. 13. CORRELATION OF MEASURED SECTIONS OF UPPER ADMIRE AND LOWER COUNCIL GROVE GROUPS.

yellowish-orange color. On the outcrop, the formation usually breaks down into two or three somewhat irregular beds.

Fauna.--- The Five Point limestone is the most fossiliferous formation in the Admire group. The most significant aspect of the fauna is the occurrence of fusulinids. Although fusulinids have been reported from the Falls City limestone in other parts of Kansas (Moore, 1944), no large fusulinids were found in the outcrops of the Falls City limestone in Elk county. The occurrence in the Five Point limestone represents the first abundant, if not the lowest occurrence of fusulinids in the Permian rocks of Elk county.

The following genera have been identified from the Five Point limestone: Chonetes, Neospirifer, Marginifera, Rhombo-pora, and Dunbarinella.

In Elk county, the Five Point limestone is the only mappable unit in the Admire group. In the field, the Five Point limestone forms the second rather conspicuous bench in the shale slope below the Americus limestone. On the accompanying areal geologic map (Plate 1), the Five Point limestone is mapped with the symbol Fp.

For measured sections of the Five Point limestone see sections 55 and 68 in the rear of this report.

### Hamlin Shale

The Hamlin shale was named by Condra (1935) and includes the following members, in ascending order: Stine shale, Houchen Creek limestone, and Oaks shale. The thickness for the Hamlin shale is reported by Condra to be from 42 to about 46 feet. In Elk county, the Hamlin shale is about 40 feet thick.

#### Stine shale member

The name Stine was applied by Condra (1927) to 9 to 18 feet of varicolored shales and thin interbedded limestones which are exposed south of Stine, Nemaha county, Nebraska. Condra regarded the Stine shale as a part of the Elmdale shale and stated that it was overlain by the Houchen Creek limestone and underlain by the Americus limestone. Moore and Condra (1932) in a revision of the Pennsylvanian, placed the Stine shale in the Admire group. Moore (1936) assigned the Stine shale to the Permian.

Lithologic character and thickness.--- In Elk county, the Stine shale averages about 32 feet in thickness. In a very complete exposure in sec. 4 and 9, T. 30 S., R. 9 E., the member is 35 feet thick and exhibits the following lithologic variations, in descending order: grey to green shale, 6 feet; varicolored red and green shale with a thin nodular siltstone just below the top, 19 feet; yellow to orange grey platy

shale, 5 feet; greenish-grey, blocky, clayey shale, 5.5 feet. In a less well exposed section in sec. 13, T. 31 S., R. 8 E., the shale is about 30 feet thick. At this locality, the middle part of the shale contains two thin "boxwork" siltstones and one thin, crinkly, finely bedded silty to sandy limestone.

Fauna.--- Although several shale samples were collected and checked for microfauna, the only fossils found were a few specimens of Jonesina. Small white algal bodies are common in the varicolored shale portions.

For measured sections in which the Stine shale is present, see sections 55, 68, 79 at the end of this report.

#### Houchen Creek limestone member

The Houchen Creek limestone was named by Condra (1927). In the type area, Houchens Creek, sec. 29, T. 6 N., R. 13 E., Nemaha county, Nebraska, the Houchen Creek limestone is a massive to irregular, algal, 5 foot limestone. The Houchen Creek limestone was originally considered to be part of the Elmdale shale; however, Moore and Condra (1932) transferred the Houchen Creek limestone to the Admire shale.

Lithologic character and thickness.--- In Elk and southern Greenwood counties, the Houchen Creek limestone averages about 3.5 feet in thickness. The Houchen Creek limestone is a persistent, buff to orange-yellow, earthy to shaly limestone which characteristically possesses<sup>a</sup> well developed calcite veinwork. On weathering, the more resistant calcite veins

stand out in bold relief and produce a pronounced "boxwork" appearance. Surprisingly enough, this unit outcrops rather well and commonly forms a recognizable bench, the first one below the Americus limestone. The lateral changes in the Houchen Creek limestone are shown in Figure 13.

For detailed descriptions of the Houchen Creek limestone see measured sections 55, 68, 74, and 79 in the rear of this report.

#### Oaks shale member

The name Oaks shale was introduced by Moore and Condra (1932) for the beds lying between the Americus and Houchen Creek limestones. The type area is given by Wilmarth (1938) as the Oaks farm, sec. 9, T. 1 N., R. 15 E. Near Salem, Nebraska, Condra (1935) reported that the Oaks shale was 17 to 18 feet thick. Moore (1944) stated that the Oaks shale varies from about 10 feet in southern Kansas to about 20 feet in northern Kansas.

Lithologic character and thickness.--- In Elk and southern Greenwood counties, the Oaks shale varies from about 3 to about 7 feet in thickness, averaging about 6 feet. In a complete exposure in sec. 9, T. 30 S., R. 9 E., the unit is 6 feet thick and is composed of a dark grey to almost black shale in its lower part which grades upward through yellowish-grey shale into brown shale at the top. The upper 1 foot contains

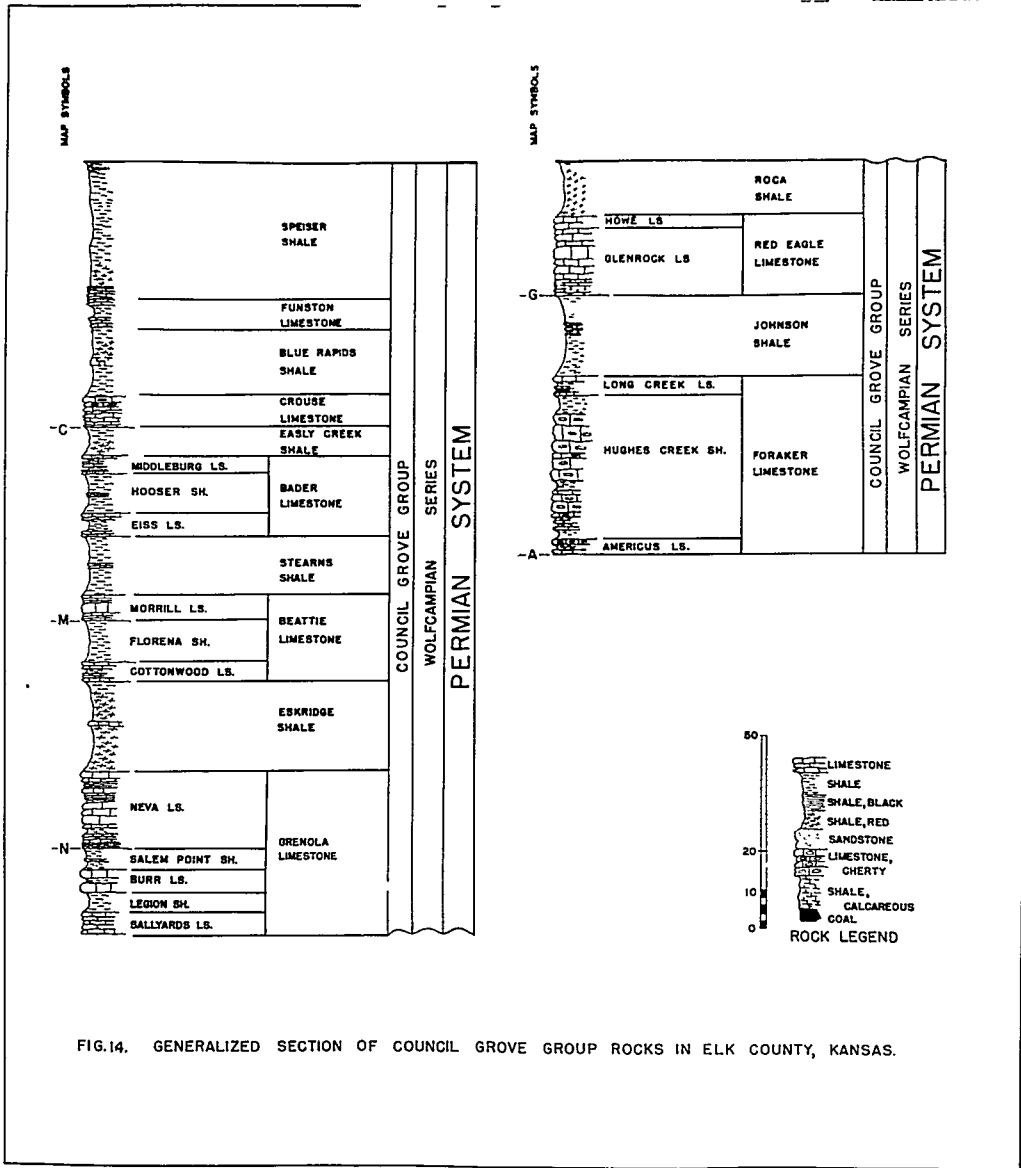
numerous small white algal masses. In sec. 31, T. 28 S., R. 9 E., the formation is a light brown algal shale at the top which grades downward into yellowish-grey shale, blue platy shale, and finally into greenish-grey shale at the base. A thin, dense, yellow to grey, algal, nodular limestone occurs just below the brown shale at the top. In the basal part of the shale, between the green and blue shales there is a thin, dark grey, white weathering, unfossiliferous limestone. Farther to the north, in southern Greenwood county, the unit thickens to about 8 feet. Figure 13 illustrates the lateral changes found in measured sections of the Oaks shale.

Fauna.--- Several shale samples were collected and studied from various outcrops of the Oaks shale. With the exception of numerous small algal masses, they proved to be barren of fossils.

For detailed descriptions of the Oaks shale, see measured sections 55, 68, 74, and 79 at the rear of this report.

#### Council Grove Group

Prosser (1902) proposed the term Council Grove as a stage name for the interval from the top of the Eskridge shale to the base of the Wreford limestone. Beede (1922) lowered the base of the Council Grove stage to the base of the Neva limestone. Moore (1932) introduced the present interpretation of the Council Grove group when he included in it all beds from



the base of the Americus limestone to the base of the Wreford limestone.

In Elk county, the Council Grove group is generally well exposed and is almost ideal for mapping on areal photographs. Almost all major limestones outcrop as recognizable benches which can be readily followed with the aid of a stereoscope. However, detailed information concerning the intervening shales is much less readily obtainable as the outcrop belt of the Council Grove group is almost invariably covered with a relatively thick growth of excellent pasture grass.

A generalized section of the rocks of the Council Grove group is shown in Figure 14. The outcrop pattern of the rocks of the group is shown on the accompanying areal geologic map (Plate 1). Cross-sections showing the lateral variations which occur in some of the formations of the group are shown in Figures 13 and 15.

#### Foraker limestone

The name Foraker limestone was applied by Heald (1916) to about 74 feet of cherty limestones, soft thin bedded limestones, and shales in the Foraker Quadrangle, Oklahoma. Condra (1935) described the Foraker limestone formation as being 43-50 feet thick and divided it into the following subdivisions, in ascending order: Americus limestone, Hughes Creek shale, and Long Creek limestone.

In Elk county, the Foraker limestone is a cherty limestone and shale formation about 55 feet thick which carries a prolific fusulinid fauna.

#### Americus limestone member

The Americus limestone was named by Kirk (1896). At the type locality, near Americus, Kansas, the unit consists of an upper blue limestone separated from a lower buff limestone by a 4 foot shale. Bass (1929) considered the lowermost chert bearing, fusulinid limestone bed of the Foraker limestone in Cowley county as being equivalent to the lower buff limestone unit of the Americus limestone of the type area. Because the upper limestone bed, in the type area, did not appear to him to be continuous, Bass restricted the Americus limestone in Cowley county to a 2.5 to 4 foot limestone bed. However, comparisons of numerous complete exposures in Elk and southern Greenwood counties, with published sections from the type locality and other parts of Kansas, seem to warrant recognition of the three-fold nature of the Americus limestone in southern Greenwood and Elk counties. I am therefore considering the Americus limestone of Bass as the upper limestone unit of the Americus limestone and am also including the shale and first limestone below in the Americus limestone. In most occurrences, the lower limestone unit is characterized by the absence of chert and fusulinids but does contain a conglomeratic zone of rounded to flattish, tan to grey-blue, limey

pebbles. This zone is persistent through Elk county and serves well as a basis for recognition of the lower limestone unit of the Americus limestone.

Lithologic character and thickness.--- In Elk and southern Greenwood counties, the Americus limestone varies from 7.5 to about 11 feet in thickness. In sec. 13, T. 31 S., R. 8 E., the Americus limestone consists of two limestones separated by a shale with an aggregate thickness of about 10 feet. The lower limestone is bluish-grey, massive in the lower part, irregularly bedded in the upper half, with a conglomeratic zone of tan to grey limey pebbles in the massive part. The intermediate shale is about 4.5 feet thick and consists of blue-grey to black shale and thin blue limestone stringers. In parts, the shale is almost coaly. The upper limestone is blue-grey, dense, massive, about 3.5 feet thick. In northern Elk county, sec. 31, T. 28 S., R. 9 E., the member is about 7.5 feet thick and consists of, in descending order: limestone, 1.6 feet, blue-grey, massive, cherty; shale, 4.4 feet, bluish to yellow with a few thin platy to nodular limestones just above the base; limestone, 1.4 feet, two bluish-grey beds, lower bed contains thin conglomeratic zone of grey to tan limey pebbles.

Fauna.--- The Americus limestone is highly fossiliferous. In all outcrops studied, the upper limestone unit contains abundant fusulinids. The lower limestone and shale were fossiliferous only in certain localities.

In sec. 13, T. 31 S., R. 8 E., the lower limestone contains the following genera: Meekella, Juresania, Linoproductus, and unidentified pelecypods fragments resembling Aviculopecten. In other outcrops, the lower limestone has yielded Meekopora, Triticites, small pelecypods, and fenestellid bryozoans. A shale sample collected from the middle shale unit of the member at the above locality has yielded Hollinella, Jonesina, and other unidentified ostracod genera. The upper limestone unit contains bryozoans, brachiopods, and abundant specimens of large Triticites and rare specimens of Dunbarinella. In this part of the member, the fusulinids are found abundantly in both the chert and limestone.

The Americus limestone forms the first resistant bench in the lower part of the Flint Hills escarpment. Its line of outcrop is generally marked by an accumulation of large, flat limestone slabs.

The lateral variations within the Americus limestone are shown in Figure 13. For detailed sections of the Americus limestone see sections 55, 68, 74, 77, and 79 at the rear of this report. The base of the Americus limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol A.

### Hughes Creek shale

The Hughes Creek shale was named by Condra (1927) from 35 to 50 feet of blue and dark shales and thin limestones exposed along Hughes Creek, Nemaha county, Nebraska. In Riley county, Kansas, the Hughes Creek shale consists of about 40 feet of shale and thin limestones (Jewett, 1941). Moore (1936) illustrated a section of the Hughes Creek shale in Wabaunsee county, Kansas, which was about 34 feet thick. In this section, the Hughes Creek shale consists of about 20 to 25 per cent limestone with the remainder being shales and calcareous shales. Farther to the north, in Riley county, the sections described by Jewett are a little less limey, containing about 20 per cent limestone.

Lithologic character and thickness.--- In Elk and southern Greenwood counties, the Hughes Creek shale is about 40 feet thick and consists mainly of dense, grey, massive, cherty, fusulinid bearing limestones and grey, yellow, and blue-grey fossiliferous shales. In a completely exposed section along Kansas Highway 96, about 13 miles west of Severy, Kansas, the Hughes Creek shale is about 50 per cent limestone. The lower 33 feet of the Hughes Creek shale is well exposed along U.S. Highway 160, west of Grenola, Elk county.

A comparison of the percentage of limestone in the Hughes Creek shale in northern Kansas (20-25 per cent) with a similar percentage figure for southern Kansas (50 per cent)

readily shows the pronounced southward thickening which occurs in the limestone units of the Hughes Creek shale member. Complete exposures of the Hughes Creek shale are not common; in fact, only in the relatively recent road cuts along U.S. 160 and Kansas 96 can the true character of the member be seen. Although the limestones are fairly well exposed in innumerable creek bed exposures, the shale intervals are not. In studying such exposures one very readily gets the erroneous impression that the Hughes Creek shale is almost totally a limestone unit. This is shown in the sections published by Bass (1929) from Cowley county, which in general, show the Hughes Creek shale interval to contain almost no shale.

Fauna.--- The limestones and shales of the member are highly fossiliferous, with abundant fusulinids being the most interesting and important aspect of the fauna.

The bluish shales and thin dark limestones just above the base of the Hughes Creek shale in sec. 13, T. 31 S., R. 8 E., contain the following fossils; Crurithyria, Linoproductus, Derbya, Meekella, large Triticites, Neospirifer, Edmondia, Amodiscus, Cribrogenerina, Bigenerina, Climacammina, Bairdia, Macrocypris, fenestellid bryozoans, echinoid spines, conodonts, and small crinoid stems. The following genera were collected from a brown shale 19 feet above the base of the member in the same locality: Lissochonetes, Chonetes, Triticites, Bairdia, Hollinella, Amodiscus, and Cribrogen-

erina. Almost all of the limestones in the above exposure contain abundant fusulinids, the most common genera being Triticites; however, Schwagerina and Dunbarinella are also present. In the fine exposure along Kansas Highway 96, 13 miles west of Severy, the following genera were collected from a brown calcareous shale 28 feet above the base of the member: Composita, Triticites, Hustedia, Allorisma, Neospirifer, Linoproductus, Myalina, and Juresania.

For measured sections in which the Hughes Creek shale is present see sections 68, 74, and 77 at the rear of this report.

#### Long Creek limestone member

The Long Creek limestone was named by Condra (1927) from outcrops along Longs Creek, at Auburn, Nemaha county, Nebraska. At the type locality, the unit consists of irregular to cavernous, buff to yellow weathering limestone, averaging about 4 feet in thickness. Bass (1929) did not distinguish the Long Creek limestone in his Cowley county report; however, Jewett (1941) reported that Bass (personal communication) had been able to correlate the Long Creek limestone with the upper part of the Foraker limestone in southern Kansas. In Riley and Geary counties, the Long Creek limestone is a series of thin yellow limestones and interbedded yellow shales averaging about 8 feet in thickness. Moore (1936) described

a section from Wabaunsee county in which the Long Creek limestone is about 12 feet thick and consists of light grey, medium bedded limestone which is somewhat sandy near the top.

Lithologic character and thickness.--- In southern Greenwood county, the Long Creek limestone is about 5 feet thick. In a good exposure along Kansas Highway 96, about 13 miles west of Severy, the member consists of the following lithologic units, in descending order: limestone, 1.5 feet, wavy to irregular, thin bedded, grey-brown, vuggy, weathers to buff color; shale, 1.7 feet, brown at top to grey platy at the base, limestone, 1.2 feet, massive, dark grey to bluish, fusulinid bearing, with a thin algal veneer on the top. Although no complete sections of the Long Creek were measured in Elk county, the 5 to 6 foot interval above the Hughes Creek shale consists of interbedded shales and thin yellowish to tan weathering grey limestones. The upper limestone, well exposed in a small pit along U.S. Highway 160, west of Grenola, is about 1 foot thick, is dense, grey to tan, tough, non-fossiliferous, algal appearing limestone which weathers from white to a bright yellow-orange. The Long Creek limestone occupies a position far back on the dip slope formed by the thick limestones in the upper part of the Hughes Creek shale. Consequently, it does not outcrop well. Occasionally, the upper limestone of the Long Creek can be identified on grass covered slopes by its distinctive lithology.

Fauna.--- In general, the Long Creek limestone is not highly fossiliferous in Elk and southern Greenwood counties. However, the following fossils were identified: Triticites, Schwagerina, algae, and a few pelecypods.

For measured sections in which the Long Creek limestone is present, see sections 69 and 77 at the end of this report.

#### Johnson shale

The Johnson shale was named by Condra (1927) from exposures 1.5 miles north of Johnson, Johnson county, Nebraska. In the type area, the formation consists of 16 to 18 feet of bluish argillaceous shale with occasional sandy layers, calcareous plates, gypsiferous material, and geodes. In Riley and Geary counties, the Johnson shale is about 16 feet thick and consists mainly of grey shale with several thin beds of argillaceous limestone (Jewett, 1941). Near Elmdale, the Johnson shale is about 12 feet thick and consists of the following zones, ascending order: 8.4 feet of brownish-grey shale, 0.6 feet of grey earthy limestone, and 3.1 feet of fissile black shale (Moore, 1936).

Lithologic character and thickness.--- In Elk county, the Johnson shale is about 20 feet thick. In an excellent exposure in sec. 14, T. 31 S., R. 8 E., the upper 7 feet consist of bluish-black shale with several thin blue, dense, nodular limestones. This is underlain by a 1.9 foot yellow-

ish vuggy, earthy limestone which contains a profusion of variously oriented calcite veins which stand out on weathering and produce a honeycomb or boxwork appearance. The lower 10 feet are grey to brown shales which contain numerous small white algal masses and scattered thin calcareous blades. In southern Greenwood county, the formation has a thickness of about 22 feet.

Fauna.--- The Johnson shale is very fossiliferous; however, the fossils are generally common only in the upper part. The following fossils were found in the upper part of the formation in sec. 14, T. 31 S., R. 8 E.: Septimyalina, Aviculopecten, Edmondia, Allorisma, Linoproductus, Juresania, Hollinella, Jonesina, Girtyspira, Coryella?, Macrocypris, Bairdia, crinoid stems, echinoid spines and plates, holothurian wheels, small high-spined gastropods, and rare conodonts.

For measured sections in which the Johnson shale is present see sections 69 and 77 at the end of this report.

#### Red Eagle limestone

The Red Eagle limestone was named by Heald (1916) from exposures near the Red Eagle School, southwest of Foraker, Oklahoma. In the original description of the formation, Heald stated that the total thickness was not accurately determined but that sections up to about 17 feet were measured. Bass (1929) correlated about 19.6 feet of limestone in Cowley

county, Kansas, with the Red Eagle limestone of Oklahoma. Condra (1935) extended the usage of the name Red Eagle limestone into Nebraska, where he considered it as a formation in which he placed the Howe limestone, Bennett shale, and Glenrock limestone members.

In Elk county, the Red Eagle limestone is about 19 feet thick and contains the Howe and Glenrock limestone members. The Bennett shale member, which is recognized farther to the north, is absent in Elk county. Here, the formation is almost exclusively a limestone unit. Although the formation is a continuous limestone in its upper part, the Howe and Glenrock limestones can be distinguished on the basis of the former's distinctive lithology.

#### Glenrock limestone member

The Glenrock limestone was named by Condra (1927) from exposures northwest of Glenrock, Nemaha county, Nebraska, where the unit is a dense, dark grey, buff to light grey weathering limestone between 1 and 2 feet thick. In Riley and Geary county, the Glenrock is quite variable, changing from a fusulinid bearing yellow limestone in some localities to dense grey hard limestone or what appears to be an intraformational breccia in others (Jewett, 1941). Near Elmdale, the Glenrock limestone is a single massive bed of light grey to yellow limestone about 5 feet thick (Moore, 1936).

Lithologic character and thickness.--- In the most complete section of the Glenrock limestone measured, in a creek bottom along the Santa Fe Railway tracks, on the Elk-Cowley county line, west of Grenola, the unit consists of about 17 feet of mostly massive, grey, hard, crystalline limestone which weathers to a light buff or grey. The lower two to three feet are more thinly bedded and contain some thin shales along the bedding planes. Along Kansas Highway 96, about 13 miles west of Severy, the base of the member is exposed and consists of, in ascending order: 0.9 feet, light buff, soft limestone; 0.5 feet, grey shale with small algal bodies; 2.0 feet, grey to buff limestone becoming massive in the upper part. The Glenrock limestone possesses a rather prominent system of NE-SW trending joints which are visible and appear to be quite characteristic of the member as seen in areal photographs.

Fauna.--- The Glenrock limestone is fossiliferous, especially in the lower part. Immediately below the lower limestone in some localities, fusulinids can be found in great abundance in small "nests" or "pockets" in the top of the underlying Johnson shale. This mode of occurrence of fusulinids has been noted at other more northerly outcrops of the Glenrock limestone in Kansas (Thompson, personal communication).

The following fossils were collected from the lower one foot of the member in sec. 14, T. 31 S., R. 8 E.: Hustedia,

Lophophyllum, Juresania, Neospirifer, Bairdia, Amphisites,  
Knightina, Hollinella, Plectogyra, Jonesina, Bigenerina,  
Climacammina, Tetrataxis, Triticites, Schwagerina, Dunbar-  
inella, crinoid stems, bryozoans, small gastropods, and  
conodonts.

The base of the Glenrock limestone is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol G. For measured sections in which the Glenrock limestone is present, see sections 69, 71, and 77 at the rear of this report.

#### Howe limestone member

The Howe limestone was named by Condra (1927) from exposures south of Howe, Nebraska. In the type locality the unit is 4 feet thick and is a dark grey, massive, dense, limestone that weathers to a buff or yellow color. The weathered limestone often has a vesicular or cavernous appearance. In northern Kansas, the Howe limestone is 2 to 4 foot, massive, grey to brown, unfossiliferous limestone which locally resembles a mudstone (Jewett, 1941). Near Elmdale, the Howe limestone consists of a 1.5 foot grey mudstone underlain by 3.0 feet of shale followed downward by a 1.0 foot, earthy, grey to yellowish limestone (Moore, 1936).

Lithologic character and thickness.--- In Elk county, the Howe limestone is 2.5 to 3.0 feet thick and is composed of light buff to whitish, soft, massive limestone which weathers

grey to yellowish-grey. The limestone has a sugary to conglomeratic appearance due to the large number of small algal bodies present. The limestone is weakly cemented and it is often possible to separate the algal masses from the matrix with the point of a pencil. Because of the soft nature of the limestone, good outcrops of the member are not common. In an excellent exposure in the creek bank in sec. 3, T. 31 S., R. 8 E., the Howe limestone is about 2.5 feet thick. The Howe limestone is differentiated from the immediately underlying Glenrock limestone by the above lithologic characteristics.

Fauna.--- The Howe limestone contains abundant, small algal bodies of the type generally referred to Osagia. A few staffeloid appearing foraminifera and small gastropods are also present.

For measured section in which the Howe limestone is present, see section 71 at the rear of this report.

#### Roca shale

The Roca shale was named by Condra (1927) from exposures at Roca, Lancaster county, Nebraska. In the type area, the unit is about 18 to 20 feet thick and is composed of bluish-grey, olive green, and reddish shale with a few thin pelecypod bearing limestones in the upper part. In this description, Condra included all beds from the base of the Neva limestone

to the top of the Howe limestone in the Roca shale. Condra and Busby (1933) defined the Grenola formation to include all beds from the top of the Neva limestone to the base of the Sallyards limestone. In so doing, they removed limestone and shale units from the upper part of the original Roca shale and placed them in the newly defined Grenola formation. They proposed the following names, in ascending order, for the interval from the top of the restricted Roca shale to the base of the Neva limestone: Sallyards limestone, Legion shale, Burr limestone, and Salem Point shale. The Kansas Geological Survey considered the Sallyards limestone and the Legion shale as subdivisions of the Roca shale (Moore, 1944); however, in a recent publication of the Kansas Survey (Moore, 1951), the Sallyards limestone and Legion shale are placed in the Grenola formation and the Roca shale, as now redefined in Kansas, coincides with the Roca shale as restricted by Condra and Busby.

Lithologic character and thickness.--- In Elk county, the Roca shale is about 15 feet thick. The upper few feet are grey to brown shales that in some outcrops contain small, white to cream colored algal bodies. The remainder of the formation consists of red to purplish red shale; however, in some localities, the lower few feet may be green, grey, or brown in color. The Roca shale usually forms a grassed over slope; however, complete exposures can be seen just south of U.S. Highway 160 at the Elk-Cowley county line and in the

creek bank in sec. 4, T. 31 S., R. 8 E.

For measured sections in which the Roca shale is present, see sections 70 and 71 at the end of this report.

#### Grenola limestone formation

The Grenola formation was named by Condra and Busby (1933) from exposures in ravines and creeks north and south of U.S. Highway 160, 4 to 5 miles west of Grenola, Elk county, Kansas. As defined by them, the formation embraced all rocks from the top of the Roca shale to the top of the Neva limestone and included the following members, in ascending order: Sallyards limestone, Legion shale, Burr limestone, Salem Point shale, and Neva limestone. The two lower members were long regarded by the Kansas Survey to be subdivisions of the Roca shale; however, in a recent publication by the Kansas Survey (Moore, 1951), the formation is now defined in Kansas to include the five members as proposed by Condra and Busby.

In the type area, Condra and Busby reported the formation to have a thickness of about 47 feet. In a more completely exposed section in sec. 4, T. 31 S., R. 8 E., about 2 miles northwest of the type area, the formation has a thickness of about 42 feet.

### Sallyards limestone member

The Sallyards limestone was named by Condra and Busby (1933) from outcrops 1 mile northeast of Sallyards, Greenwood county, Kansas. In the type locality, the member consists of 2.6 feet of bluish-grey, yellow to light grey weathering limestone containing pelecypods, brachiopods, and bryozoans. Near Elmdale, Kansas, the Sallyards limestone is an ash-grey, hard, thin bedded, pelecypod bearing limestone which becomes a hard limey shale in the upper part (Moore, 1936). In outcrops near Humboldt, Nebraska, the Sallyards limestone is a grey, shaly, calcareous bed about 6 inches thick (Condra and Busby, 1933).

Lithologic character and thickness.--- In Elk county, the Sallyards limestone varies in thickness from 3.5 to 4.1 feet. In a good exposure in a creek bed, 5 miles west of Grenola, the member is a bluish-grey, massive, 3.5 foot, pelecypod bearing limestone which weathers to irregular slabs. In sec. 4, T. 31 S., R. 8 E., the Sallyards limestone consists of 4.1 feet of grey, platy to irregular, buff to dark grey weathering, pelecypod bearing limestone.

Fauna.--- The Sallyards limestone contains a rather abundant molluscan fauna. The following fossils are common in the member: Myalina, Aviculopecten, Composita, crinoid stems, and bryozoans.

For measured sections of the Sallyards limestone, see sections 70 and 71 at the end of this report.

## Legion shale member

The Legion shale was named by Condra and Busby (1933) from exposures along U.S. Highway 40, southwest of the American Legion grounds, southwest of Manhattan, Kansas. At the type locality, the unit is 4.6 feet thick and consists of the following lithologic types, in descending order: shale, black, fissile, 8 to 10 inches; mudstone, dark grey, argillaceous, 4 inches; shale, dark grey, calcareous, 1 foot; shale, grey, calcareous, blocky, 2 feet. Near Americus, Kansas, the unit is 7 feet thick and consists mainly of olive colored shale with calcareous concretions (Condra and Busby, 1933). One mile southwest of Salem, Nebraska, the Legion shale is a green, platy shale about 6 inches thick.

Lithologic character and thickness.--- In Elk and eastern Cowley counties, the Legion shale is about 5 feet thick. In the only section measured, along the Santa Fe Railroad tracks, in sec. 4, T. 31 S., R. 8 E., the member consists of grey to buff, finely laminated shale with a few thin limestone stringers.

Fauna.--- The Legion shale is sparingly fossiliferous. The only fossils found were rare specimens of Juresania and a few small pelecypods.

For a measured section of the Legion shale see section 71 at the end of this report.

### Burr limestone member

The Burr limestone was named by Condra and Busby (1933) from exposures in the bluffs and ravines west of the South Fork of the Little Nemaha River, 2.5 miles northwest of Burr, Otoe county, Nebraska. Near Humboldt, Nebraska, the member is about 10 feet thick and is composed of an upper 3.6 foot, bluish-grey, dense, fine grained limestone with many ostracods. The upper limestone is underlain by a brown, fissile, 3.6 foot shale, which in turn is underlain by a 2.6 to 4 foot, grey, slabby, yellowish weathering limestone with a few greenish-grey shale partings (Condra and Busby, 1933). In Riley county, the Burr limestone is 7.4 feet thick and consists of an upper 4.5 foot, light grey, somewhat laminated, ostracod limestone underlain by 1.4 feet of black to grey, fissile shale. The lower unit is a light, impure, argillaceous, fossiliferous limestone 2 feet thick (Jewett, 1941). Near Elmdale, Kansas, the Burr limestone is 11.4 feet thick and consists mainly of ash-grey, hard, dense, massive to platy limestone underlain by 4.5 feet of dark blue, fissile shale and calcareous shale.

Lithologic character and thickness.--- In Elk and eastern Cowley county, the Burr limestone is about 4 feet thick and consists of two massive, blue-grey to dark grey, dense limestones separated by a 0.2 foot shale. The upper units of the Burr limestone are exposed along Kansas Highway 96, about

15 miles west of Severy, and consists of an upper massive, 1.5 foot, grey to bluish limestone underlain by 0.3 feet of buff, platy shale.

Fauna.--- The upper limestone unit of the Burr limestone characteristically contains abundant, small, high-spined gastropods (often filled with crystalline calcite) and smooth ostracods. The following fossils were collected from the upper limestone bed in sec. 4, T. 31 S., R. 8 E.: small Myalina, Jonesina, Bairdia, and small gastropods.

For measured sections of the Burr limestone see sections 71 and 76 at the end of this report.

#### Salem Point shale member

The Salem Point shale was named by Condra and Busby (1933) from roadcut exposures at Salem Point, 1.5 miles northwest of Salem, Richardson county, Nebraska. Near Salem, Nebraska, the member is a calcareous shale about 7 to 8 feet thick. Southward, in Riley and Geary counties, Kansas, the Salem Point shale averages about 8 feet in thickness, with the upper part being mainly grey argillaceous shale. The lower part becomes increasingly more calcareous downward and there are a few thin local limestones in the basal part (Jewett, 1941). Near Elmdale, the Salem Point shale is about 12 feet thick and consists of greenish-grey shales separated by a 1.8 foot ash-grey limestone, the latter being traversed by vertical veinlets which stand out on weathering (Moore, 1936).

Lithologic character and thickness.---- In Elk, southwestern Greenwood, and eastern Cowley counties, the Salem Point shale averages about 7 feet in thickness. In sec. 4, T. 31 S., R. 8 E., the Salem Point shale is 8.0 feet thick and consists of, in descending order: shale, 2.5 feet, grey to brown; limestone, 0.6 feet, yellow to brown, soft, earthy, with a prominent network of calcite veinlets; shale, 2.1 feet, grey-brown; limestone and shale, 2.8 feet, limestone is blue to buff, platy, molluscan, and is interbedded with grey shale. Along Kansas Highway 96, about 15 miles west of Severy, the Salem Point shale is 5.5 feet thick. Although the unit is largely covered, the middle of the unit is marked by a 1 foot buff "boxwork" limestone and the lower part by thin, dense, pelecypod bearing limestones. It is interesting to note that the veinlet filled "boxwork" limestone found in the member in Elk county is persistent at least as far north as Elmdale, Kansas.

For measured sections of the Salem Point shale, see sections 71 and 78 at the rear of this report.

#### Neva limestone member

The Neva limestone was named by Prosser (1902) from about 10 feet of massive, blue-grey limestones separated by a thin shale, which are exposed northeast of Neva, Kansas, near the junction of the Diamond Creek and the Cottonwood River

valleys. Condra (1927) described the Neva limestone in Nebraska as consisting of four or five limestones and interbedded shales. Bass (1929) states that the general characteristics of the Neva limestone in the type area, persist into Cowley county. He gives the thickness of the Neva limestone in Cowley county as ranging from 22 to 28 feet. Condra and Busby (1933) designated the Neva limestone as the top member of the newly defined Grenola formation and correlated measured sections containing the Neva limestone from Nebraska southward into Oklahoma. Throughout Kansas, the Neva limestone consists of four or five limestones separated by shales, having an overall thickness that varies from 16 to 24 feet (Moore, 1951).

Lithologic character and thickness.--- In Elk, eastern Cowley, and southwestern Greenwood counties, the Neva limestone is about 20 feet thick. In a good exposure along Kansas Highway 96, about 15 miles west of Severy, the Neva limestone consists of the following lithologic units, in descending order: limestone, 4.2 feet, massive, grey to buff; shale, 3.4 feet, limy in upper part, lower part grey to brown, clayey; limestone, 2.2 feet, in two beds separated by thin shale, massive, blue-grey, weathers platy; shale, 2.8 feet, dark grey with a few calcareous hard streaks; limestone, 3.8 feet, three beds separated by thin shales; limestone, 2.7 feet, nodular, thin bedded. Farther to the south, in an excellent exposure in sec. 4, T. 31 S., R. 8 E.,

the Neva limestone is 20.5 feet thick and is composed almost entirely of limestone. The shale intervals found in the Neva limestone in southwestern Greenwood county are here almost completely occupied by nodular or thin bedded limestones. A small amount of chert is present in the upper Neva limestone in sec. 16, T. 31 S., R. 8 E.

In spite of the limy character and relatively great thickness, the Neva limestone generally does not crop out in the manner one would expect. The upper massive limestone unit is persistent and its position is usually well marked in grassed over slopes; however, the lower limestone units are usually marked by one or two minor benches. Generally speaking, the third bench below the top of the Neva marks the approximate position of the base of the Neva limestone, with the fourth bench, often quite prominent, being formed by the Burr limestone. Consequently, the base of the member is somewhat difficult to map; however, the position of the base of the Neva limestone is shown on the areal geologic map (Plate 1) its line of outcrop is designated by the symbol N.

Fauna.--- The most significant feature of the fauna of the Neva limestone is the abundance of the fusulinid genus Paraschwagerina, long regarded as an index to the lower Permian.

Fusulinids occur abundantly throughout the member, being found in almost every limestone and shale. Paraschwagerina is most abundant in the upper half of the member, while

slender specimens of Schwagerina seem to be characteristic of the lower part, especially, the shale breaks just above and within the lower nodular limestone unit.

The following fossils were collected from the Neva limestone in sec. 4, T. 31 S., R. 8 E., Triticites, Schwagerina, Dunbarinella, Schubertella, Paraschwagerina, Chonetes, Composita, Punctospirifer, Neospirifer, Lophophyllum, Rhombopora, Deckerella, Climacammina, Tetrataxis, Bairdia, Hollinella, Knightina, Macrocypris, Cavellina, echinoid spines and plates, fenestellid bryozoans, fish teeth, conodonts, crinoid stems, and small gastropods.

For measured sections of the Neva limestone, see sections 70, 71, and 78 at the rear of this report.

#### Eskridge shale

The Eskridge shale was named by Prosser (1902) from exposures near Eskridge, Wabaunsee county, Kansas. In the type area, the formation consists of 30 to 40 feet of varicolored shales with minor thin limestones. In Riley and Geary counties, Kansas, the Eskridge shale is about 36 feet thick and consists of a lower grey to varigated shale unit separated from an upper grey shale by a calcareous zone of impure, lenticular, sparingly fossiliferous limestones (Jewett, 1941).

Lithologic character and thickness.--- In Elk, eastern Cowley, and southwestern Greenwood counties, the Eskridge shale averages about 23 feet in thickness. In an excellent exposure in sec. 4, T. 31 S., R. 8 E., the Eskridge shale is slightly less than 20 feet thick and consists of the following lithologic units, in descending order: shale, 8.0 feet, grey at top grading into red; limestone, 1.2 feet, massive, dense, purplish-green, blotchy, hard, heavy; shale, reddish-purple, becoming green and blotchy in lower part; limestone, 0.5 feet, dense, greenish-grey; shale, 2.9 feet, greenish-grey to red. Farther to the north, in southwestern Greenwood county, the formation is about 28 feet thick and consists of grey, buff, green, and red shales with four thin zones of greenish-grey, dense, heavy limestones. In Elk county, the Eskridge shale usually forms a grassed over slope; however, the massive, purplish to greenish colored limestone that occurs near the middle of the formation is very resistant and its position is usually marked by a slight bench. Because of its distinctive lithology, this limestone can be readily identified and is quite usable in local stratigraphic work.

Fauna.--- Shale samples collected from the upper part of the formation in sec. 16, T. 31 S., R. 8 E., were practically barren of fossils, the exception being numerous, small, white to cream colored algal bodies. The thin limestones, present in all exposures of the formation, are generally

sparingly fossiliferous, with the following fossils having been collected at several localities: Aviculopecten, Myalina, and small high-spired gastropods.

The cross-sections illustrated in Figure 15 show the lateral variations found within the Eskridge shale. For measured sections of the Eskridge shale, see sections 70, 71, and 76 at the end of this report.

#### Beattie limestone

The Beattie limestone was named by Condra and Busby (1933) and includes the Cottonwood limestone, Florena shale, and Merrill limestone members. The formation is named for the town of Beattie, Marshall county, Kansas. In Pawnee county, Nebraska, the formation is about 15 feet thick (Condra and Busby, 1933).

In Elk, eastern Cowley, and southwestern Greenwood counties, the three members are well represented and range in thickness from 15 to about 29 feet, averaging about 23 feet.

#### Cottonwood limestone member

The Cottonwood limestone, as we know, it was variously referred to as "Fusulina limestone," "Alma limestone", "Cottonwood Falls limestone", and "Manhattan limestone"; however, Prosser (1894) proposed the name Cottonwood forma-

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Missing Figure 15 (Page 214)

tion to include the above limestone and the shales immediately overlying it. He referred to the limestone as the Cottonwood limestone and the shale above it as the Cottonwood shale. The latter name was dropped when Prosser (1902) renamed the shale the Florina shale. The type area of the Cottonwood limestone is in the exposures along the Cottonwood River, near Cottonwood Falls, Kansas.

Throughout most of Kansas, the Cottonwood limestone is about 6 feet thick and is a massive, light buff, white to light grey weathering fusulinid bearing limestone. However, in southern Kansas, the member thins and becomes shaly (Moore, 1951).

Lithologic character and thickness.--- In Elk, eastern Cowley, and southwestern Greenwood counties, the Cottonwood limestone averages about 5 feet in thickness. In an outcrop located along Kansas Highway 96, about 15 miles west of Severy, the Cottonwood limestone is 4.9 feet thick and consists of dark grey to buff, massive, grey weathering, fusulinid bearing limestone. In sec. 14, T. 29 S., R. 8 E., the member is 4.9 feet thick and consists of thin, blue-grey, fusulinid bearing limestones interbedded with grey shales. In sec. 4, T. 31 S., R. 8 E., the Cottonwood limestone is 4.8 feet thick and is made up mainly of blue, dense, thin, slabby to nodular limestones and blue-grey shales. The lower limestones, however, are buff to yellow, soft, argillaceous, and contain numerous gastropods and pelecypods.

The lateral change, from a predominantly limestone unit to one of minor limestones interbedded with shales, is well shown in the outcrops studied across Elk county. This lateral variation is shown in the cross-sections illustrated in Figure 15.

Fauna.--- The following fossils were collected from the Cottonwood limestone in eastern Cowley county: Schubertella, Triticites, Schwagerina, Ditomopyge, Composita, Derbya, Amphiscapha, Juresania, Edmondia, Allorisma, echinoid spines and plates, fenestellid bryozoans, and gastropods.

In the more southerly outcrops of the Cottonwood limestone, the fusulinids, especially Schubertella, are common only in the upper part of the unit, while the lower, more shaly portion, is crowded with pelecypods, gastropods, and well preserved productid brachiopods.

In Elk county, the Cottonwood limestone usually forms a very slight bench occurring below the more pronounced bench of the Morrill limestone; however, in the more northerly part of the county, the thin limestone beds in the member thicken somewhat and the line of outcrop becomes more marked.

For measured sections of the Cottonwood limestone, see sections 70, 71, 72, and 78 at the end of this report.

## Florena shale member

Prosser (1902) proposed the name Florena shale for from 2 to 13 feet of fossiliferous shales (previously known as the Cottonwood shales) overlying the "Alma limestone" or Cottonwood limestone. He considered the Florena shale as the lower part of the Garrison formation. The upper part of the Garrison formation, extending up to the base of the Wreford limestone, was called Neosho. Moore (1936) regarded the previously named units of the Garrison formation as separate formations within the Council Grove group and discarded the name Garrison.

In the type locality, near Florena, Kansas, the Florena shale is exposed in quarries along the Big Blue River.

In Riley and Geary counties, the Florena shale is a grey, argillaceous shale generally less than 10 feet thick and contains numerous specimens of Chonetes (Jewett, 1941). Near Strong City, the Florena shale is 13 feet thick and is a grey, calcareous to clayey shale which is very fossiliferous in its lower half (Moore, 1936).

Lithologic character and thickness.--- In Elk, southwestern Greenwood, and eastern Cowley counties, the thickness of the Florena shale averages about 8 feet. Along Kansas Highway 96, about 15 miles west of Severy, the Florena shale is slightly less than 6 feet thick and is a brown to grey, clayey, fossiliferous shale. In sec. 14, T. 29 S., R. 8 E.,

the member is 9 feet thick and is composed of grey, clayey, fossiliferous shale which becomes more calcareous and hard in its lower part. In a good exposure in sec.4, T. 31 S., R. 8 E., the Florena shale is 14 feet thick and consists of buff to grey, highly fossiliferous shale which contains three or four thin, discontinuous, nodular, light grey, argillaceous limestones in its upper part. Although the Florena shale generally forms a grassed over slope below the bench forming Morrill limestone, it is readily identified by the numerous specimens of well preserved fossils, especially Chonetes, which weather out and lie on the surface.

Fauna.--- The Florena shale is the most fossiliferous Permian rock unit in Elk county. The following fossils were collected from outcrops in southwestern Elk and eastern Cowley counties: Triticites, Schubertella, Schwagerina, Derbya, Meekella, Composita, Dialasma, Crurithyris, Chonetes, Dictyoclostus, Juresania, Nuculana, Edmondia, Aviculopecten, Septimyalina, Allorisma, Pleurophorus, Amphiscapha, Ditomopyge, Stereostylus, Bairdia, Amphissites, Knightina, Hollinella, Tetrataxis, Climacammina, conodonts, echinoid spines and plates, numerous bryozoans, crinoid stems and plates.

The lateral changes occurring within the Florena shale are shown in the cross-sections illustrated in Figure 15.

For measured sections of the Florena shale, see sections 70, 71, 72, and 78 at the end of this report.

#### Morrill limestone member

The Morrill limestone was named by Condra (1927) from exposures of 1 to 2 feet of yellowish limestone, two miles northwest of Morrill, Kansas. In Riley and Geary counties, the Morrill limestone is about 3 feet or less in thickness and consists of brownish-grey limestone that weathers into a mass of irregular, pitted, granular, brown limestone (Jewett, 1941). In an exposure just west of Strong City, the Morrill limestone is a little over 4 feet thick and consists of two massive limestones separated by a thin calcareous shale (Moore, 1936).

Lithologic character and thickness.--- In Elk and eastern Cowley counties, the thickness of the Morrill limestone averages just over 9 feet. In sec. 14, T. 29 S., R. 8 E., the member is 9 feet thick and consists of thin to massive beds of bluish-grey, buff to light grey weathering limestone. The most massive units, 4 to 5 feet below the top, weather to a light grey and possess a very irregular deeply pitted surface. In sec. 4, T. 31 S., R. 8 E., the member is 7 feet thick. The upper 3 feet consist of buff to whitish, irregular, thin bedded limestone. The middle of the unit

is a massive, 2 foot bed of buff to bluish, slightly cherty limestone which weathers to an irregular, pitted surface, light grey in color. The lower 2 feet are composed of thin, irregular to nodular, algal, buff to yellowish limestones interbedded with buff to yellowish fossiliferous shales.

Throughout its line of outcrop in Elk county, the Morrill limestone forms a distinct, recognizable bench. The member is readily identified on the outcrop by its peculiar pitted weathered surface and by the occurrence of robust Schwagerina and very numerous echinoid spines and plates. In many of the outcrops, the echinoid spines and spine bases are surrounded by a light grey algal appearing mass in which the echinoid parts seem to have served as a nucleus around which the grey material was deposited.

Fauna.--- The lower part of the Morrill limestone contains abundant fusulinids and echinoid spines and plates; however, the upper part of the member is sparingly fossiliferous. The following fossils were collected from outcrops in sec. 4, T. 31 S., R. 8 E., and in sec. 14, T. 29 S., R. 8 E.: rare Ottonosia, Composita, robust Schwagerina, Hollinella, Bairdia, Knightina, Amphissites, Tetrataxis, Climacammina, echinoid spines and plates, and crinoid stems.

On the accompanying areal geologic map (Plate 1), the base of the Morrill limestone is mapped and its position is indicated by the symbol M. The cross-sections illustrated in Figure 15 show the lateral changes occurring within the

Morrill limestone. For measured sections of the Morrill limestone, see sections 70, 71, 72, and 78 at the end of this report.

#### Stearns shale formation

The Stearns shale was named by Condra (1927) from exposures south of the Stearns School, northeast of Humboldt, Nebraska. In the original description of Condra, the Stearns shale is listed as being 14 feet thick and as consisting mainly of varicolored shales which are somewhat calcareous in its lower part. The Stearns shale was originally considered by Condra as a subdivision of the Garrison formation; however, in 1935, he considered it as a separate formation within the Council Grove group, as did Moore, 1936.

In Riley and Geary counties, the Stearns shale is about 20 feet thick and is composed mainly of grey unfossiliferous shales in which a few thin limestones may be present (Jewett, 1941). Near Strong City, the Stearns shale is about 10 feet thick and is composed of greenish, crumbly shale underlain by 2.5 feet of grey mudstones and shales (Moore, 1936).

Lithologic character and thickness.--- In Elk county, the Stearns shale is about 13 feet thick. Although this formation is almost always poorly exposed, in a rare completely exposed section in sec. 14, T. 29 S., R. 8 E., the

formation consists of 5 feet of grey shales above, separated from about 6 feet of red and brown shales below by a 2.5 foot interval of dark grey to bluish, nodular, fossiliferous limestones and shales.

Fauna.--- The colored shales of the lower part of the formation contain numerous small algal bodies. The middle nodular limestones and shales have yielded the following fossils: Meekella, Juresania, and Aviculopecten.

The Stearns shale and the overlying Bader formation are not well exposed in Elk county. Considerable difficulty was encountered in determining the detailed lithology and boundaries for the recognized units occurring within this interval. Although several sections embracing this interval were measured, only the one in sec. 14, T. 29 S., R. 8 E. was well enough exposed to allow reasonably accurate correlation. See sections 70 and 72 at the end of this report for detailed measurements of the Stearns shale.

#### Bader formation

The Bader formation was named by Condra (1935) to include the following subdivisions, in ascending order: Siss limestone, Hooser shale, and Middleburg limestone. The type exposure is located near Bader, Kansas.

In Elk county, the Bader formation is about 28 feet thick and is composed of bluish-grey to greenish-grey, thin

bedded limestones interbedded with gray, buff, yellow, brown, green, and red shales. Although the three members of the formation are recognized, the boundaries seemingly are not sharply defined. The only persistent outcropping units of the formation are the more massive upper limestone beds of the Eiss limestone.

#### Eiss limestone member

The Eiss limestone was named by Condra (1927) from exposures on the Eiss farm, 8 miles south of Humboldt, Nebraska. In the type area, the member is slightly less than 10 feet thick and is composed of two limestones separated by about 7 feet of fossiliferous bluish shale.

Lithologic character and thickness.--- In Elk county, the Eiss limestone is about 11 feet thick. In sec. 14, T. 29 S., R. 8 E., the member consists of the following lithologic units, in descending order: limestone, 2 feet, relatively massive, blue-grey, weathers to light grey with a distinctive pitted surface; shale, 2 feet, red to green, algal; limestone and shale, 7 feet, upper part buff, thin bedded fossiliferous limestone, lower part grey fossiliferous shale and thin, nodular, bluish limestones. Throughout its line of outcrop, the upper more massive limestone beds of the Eiss limestone form a distinct bench. In the outcrop, the upper Eiss limestone can be identified by its characteristically light colored, pitted weathered surface. Although the slightly lower

Morrill limestone weathers in a similar fashion, the absence of abundant echinoid parts and fusulinids in the Eiss are usually sufficient to allow differentiation of the two limestones.

Fauna.--- The following fossils were collected from the lower fossiliferous limestones and shales of the Eiss limestone in sec. 14, T. 29 S., R. 8 E.: Meekopora, Neospirifer, numerous bryozoans, Ditomopyge fragments, Meekella, Bairdia, and Jonesina.

For measured sections of the Eiss limestone, see sections 70 and 72 at the end of this report.

#### Hooser shale member

The Hooser shale was named by Condra and Upp (1931) from highway and ravine exposures just east of Hooser, Kansas. In the type area, the unit consists of 11 feet of red, grey, and olive shales with a fossiliferous limy zone near its top.

Lithologic character and thickness.--- In Elk county, the Hooser shale is about 11 feet thick and consists of the following lithologic units, in descending order: shale, 4.7 feet, finely laminated, buff to yellow; limestone, 0.2 feet, greenish-grey, molluscan; limestone and shale, 2.5 feet, interbedded, fossiliferous, dark blue to greenish, nodular limestone and buff shales; shale, 4.2 feet, vari-

colored, somewhat algal. This unit is almost always poorly exposed and only in the section measured in sec. 14, T. 29 S., R. 8 E. was it possible to observe the detailed lithology of the member.

Fauna.--- The thin fossiliferous limestones in the middle of the Hooser shale contain the following fossils:

Juresania, Aviculopecten, Septimyalina, and bryozoans. No microfossils were found in several shale samples collected from the lower part of the member.

For measured sections in which the Hooser shale is present, see sections 70 and 72 at the end of this report.

#### Middleburg limestone member

The Middleburg limestone was named by Condra and Upp (1931) from exposures on Easley Creek, 1.5 miles south of the Middleburg School, Richardson county, Nebraska. In the type area, the Middleburg limestone is about 4 feet thick and is composed of varicolored limestones with a minor amount of olive colored shale.

Lithologic character and thickness.--- In Elk county, the Middleburg limestone is about 6 feet thick and consists of thin, grey to greenish, dense, tough, light grey to whitish weathering, pelecyped limestones interbedded with grey to greenish shales. In general, this member outcrops rather poorly; however, its position below the more easily weathered Easley Creek shale is marked by a low indistinct bench.

Fauna.---- The following fossils were collected from the Middleburg limestone in sec. 16, T. 31 S., R. 8 E.: Jur-esania, Aviculopecten, Pseudomonotis, Myalina, Septimyalina, and Jonesina.

For measured sections of the Middleburg limestone, see sections 70 and 72 at the end of this report.

#### Easly Creek shale

The Easly Creek shale was named by Condra (1927) from exposures on Easly Creek, Richardson county, Nebraska, which included all beds from the top of the Eiss limestone to the base of the Sabetha (Crouse) limestone. Condra and Upp (1931) redefined the Easly Creek shale and restricted it to about 14 feet of olive and maroon-grey shales between the base of the Crouse limestone and the top of the newly defined Middleburg limestone.

In Riley and Geary counties, Kansas, the formation consists of 15 to 20 feet of grey and green shales which contain chocolate-colored material above and red below (Jewett, 1941).

Lithologic character and thickness.---- In Elk county, the Easly Creek shale averages about 10 feet in thickness and is composed of shales which are brown above and red below, and in which abundant small white algal bodies are common. The distinctive color zonation and the position immediately

below the bench forming Crouse limestone makes the Easley Creek shale relatively easy to identify in the field. Other than the small white algal masses, no fossils were found in the formation.

For measured sections of the Easley Creek shale, see sections 70 and 72 at the end of this report.

### Crouse limestone

The Crouse limestone was named by Heald (1916) from a prominent limestone occurring about 50 feet above the Cottonwood limestone in the northwestern corner of the Foraker quadrangle, Osage county, Oklahoma. Condra (1927) applied the name Sabetha to about 12 feet of limestone in the vicinity of Sabetha, Kansas; however, Condra and Upp (1931), as a result of field work in southern Kansas, concluded that the Sabetha limestone was equivalent to the Crouse limestone of Heald. Accordingly, the name Sabetha was dropped from stratigraphic use.

Condra (1935) proposed the name Bigelow formation to include the Funston limestone, Blue Rapids shale, and Crouse limestone. Jewett (1941) proposed, that to be consistent with classification applied above and below the Bigelow formation, the three units of the Bigelow formation should be recognized as separate formations within the Council Grove group and the name Bigelow should be dropped from

stratigraphic usage. The Kansas Geological Survey agreed with this proposal and the name Bigelow is no longer used in Kansas.

Lithologic character and thickness.--- In Elk county, the Crouse limestone is about 9 feet thick and generally consists of the following lithologic zones, in descending order: 2 to 3 feet of thin, platy, yellowish limestone; 3 to 4 feet of blue-grey, dense, massive, locally cherty limestone; about 3 feet of irregular, thin to nodular, algal limestone. The Crouse limestone, along its line of outcrop across Elk county, forms a distinct bench which is held up mainly by the more massive beds in the middle and upper part of the formation. Identification in the field can usually be made on the basis of thickness, lithology, and <sup>with</sup> the occurrence of algal discs (Ottonosia). The Ottonosia are especially abundant in the lower nodular phase. The base of the formation is mapped on the accompanying areal geologic map (Plate 1) and its position is indicated by the symbol C.

Fauna.--- The Crouse limestone is sparingly fossiliferous; however, the basal nodular beds in some localities contain very abundant specimens of Ottonosia and poorly preserved and less numerous specimens of Composita and Juresania.

For measured sections of the Crouse limestone, see sections 70, 72, and 76 at the end of this report.

## Blue Rapids shale

In redefining the Speiser shale, originally defined to include all beds from the top of the "Sabetha" limestone to the base of the Wreford limestone, Condra and Upp (1931) introduced the name Blue Rapids shale for the thin limestones and shales between the top of the Crouse limestone and the base of the newly defined Funston limestone. The Blue Rapids shale was named from about 21 feet of varicolored shales and thin limestones exposed about 1½ miles north of Blue Rapids, Kansas.

In Riley and Geary counties, Kansas, the Blue Rapids shale is composed of grey shales which contain minor amounts of red shale and one thin unfossiliferous limestone, having a total thickness of 20 to 30 feet. Near Hooser, Kansas, the formation is about 16 feet thick and consists mainly of olive, grey, and red shales with a minor amount of slabby calcareous shale in its lower part (Condra and Upp, 1931).

Lithologic character and thickness.--- In Elk county, the thickness of the Blue Rapids shale averages about 23 feet. A complete exposure of the formation in sec. 14, T. 29 S., R. 8 E., shows the following lithologic zones, in descending order: shale, 5 feet, brown to greenish; shale, 15 feet, red, algal at top with a thin, nodular limestone about 3 feet below the top, shale becomes bluish-grey in the middle and greenish, calcareous in its lower part, with a 1.5 foot grey

to greenish limestone about 5 feet above the base. In a partially exposed section in sec. 27, T. 28 S., R. 8 E., the formation is about 25 feet thick and consists of grey, brown, and bluish-grey shales with two or three thin limestones. The uppermost thin limestone, about 3 feet below the top of the formation, contains a few small, irregular chert nodules.

Fauna.--- The Blue Rapids shale is generally unfossiliferous; however, the thin interbedded limestones were found to contain the following fossils in some localities: Aviculo-pinna, Juresania, and shell fragments.

For measured sections in which the Blue Rapids shale is present, see sections 72 and 76 at the end of this report.

#### Funston limestone

The Funston limestone was named by Condra and Upp (1931) from about 8 feet of limestones and shales exposed in the bluffs of the Kansas River valley, south of Funston, Kansas. Originally, the rocks of the formation were included in the Speiser shale by Condra (1927); however, Condra and Upp redefined the Speiser shale in 1931 and restricted it to the beds between the Wreford and the newly defined Funston limestones.

Lithologic character and thickness.--- In Elk county, the Funston limestone is 11 to 12 feet thick and consists

generally of two limestones separated by shales. The shales are grey, buff, to red. Some buff to brownish, calcareous shales, with minor amounts of thin, nodular limestones, occur locally. In sec. 14, T. 29 S., R. 8 E., the lower part of the formation is exposed and it consists of a 2 foot grey to light blue, almost coquinoïd limestone which has a massive top, overlain by grey to buff, calcareous, fossiliferous shale and thin nodular limestone beds. The upper limestone is exposed in sec. 27, T. 28 S., R. 8 E., where it is about 4 feet thick and consists of grey to almost white, dense limestone, which is platy in its upper part but becomes more massive lower. At this locality, the intervening shale is about 5.5 feet thick and is composed of grey shale containing two red streaks near its middle.

Fauna.--- The middle shaly interval of the formation is fossiliferous in some localities. The following fossils were collected from this interval in sec. 14, T. 29 S., R. 8 E.: Composita, Juresania, fenestellid bryozoans, and crinoid stems. The lower limestone in the same locality possesses numerous fragments of small pelecypods and small high-spined gastropods.

For measured sections in which the Funston limestone is present, see sections 72, 73, and 76 at the rear of this report.

## Speiser shale

The Speiser shale was named by Condra (1927) from outcrops in Speiser Township, Richardson county, Nebraska. In the original description, the Speiser shale included all beds from the top of the Crouse limestone to the base of the Wreford limestone; however, Condra and Upp (1931) redefined the Speiser shale and restricted it to the interval between the Funston and the Wreford limestones. The restricted Speiser shale is reported by them to vary in thickness from 18 to 19 feet in Nebraska to 34 to 35 feet in southern Kansas.

Lithologic character and thickness.--- In Elk county, the Speiser shale averages about 28 feet in thickness. In sec. 35, T. 28 S., R. 8 E., the formation is 27 feet thick and consists of the following lithologic zones, in descending order: interbedded grey to buff, thin, nodular limestones and buff shales which contain numerous well preserved, large specimens of Derbya, about 10 feet; shale, light grey, fossiliferous, 3 feet; shale, red to reddish-brown, algal, 10 feet; shale, red, green, and whitish, algal, 4 feet. Although no sandstones were present in the formation in Elk county, an exposure of the formation measured south of Dexter, Cowley county, contains three or four lenticular sandstones in its upper part. Because of its position immediately below the scarp forming Wreford limestone, the

Speiser shale forms a rather steep slope and is usually fairly well exposed. The formation can usually be readily identified in the field on the basis of its stratigraphic position and by the large specimens of Derbya which occur in its upper part.

Fauna.--- The upper part of the formation is fossiliferous and is especially characterized by the abundant occurrence of very large, well preserved specimens of Derbya which are found in association with Juresania, Septimavalina, Composita, Aviculopinna, bryozoans, and crinoid stems.

The lateral changes within the Speiser shale are shown in the cross-sections illustrated in Figure 15. For measured sections of formation, see sections 73, 75, 76, and 80 at the end of this report.

#### Chase group

Prosser (1895) applied the name Chase formation to about 265 feet of interbedded flinty limestones and shales between the Neosho and Marion formations in Chase county, Kansas. In 1905, Prosser concluded that the rocks originally included in the Chase formation contained several lithologic units which were mappable and that these subdivisions should be regarded as separate formations. In so doing, Prosser raised the Chase from formational to stage rank and included in it all beds from the base of the Wreford

to the top of the Winfield limestones. The interval designated by Prosser as a stage has long been used as a group term in Kansas. The base of the Chase group has remained as first designated, the base of the Wreford limestone; however, the top of the group has been shifted upward and is now placed at the top of the Herington limestone.

In Elk county, only the lower formations of the Chase group are present; of these, only the Wreford limestone has any areal distribution, with the Florence limestone and Matfield shale being found only in two small outliers in sec. 22, T. 28 S., R. 8 E. Because of the limited outcrop belt of the lower Chase group in Elk county, the thicknesses and lithologies in the following discussion were obtained from exposures in Cowley county.

The base of the Chase group is mapped on the accompanying areal geologic map (Plate 1) and its line of outcrop is indicated by the symbol W. A generalized section of the rocks of the Chase group in Elk county is shown in Figure 16.

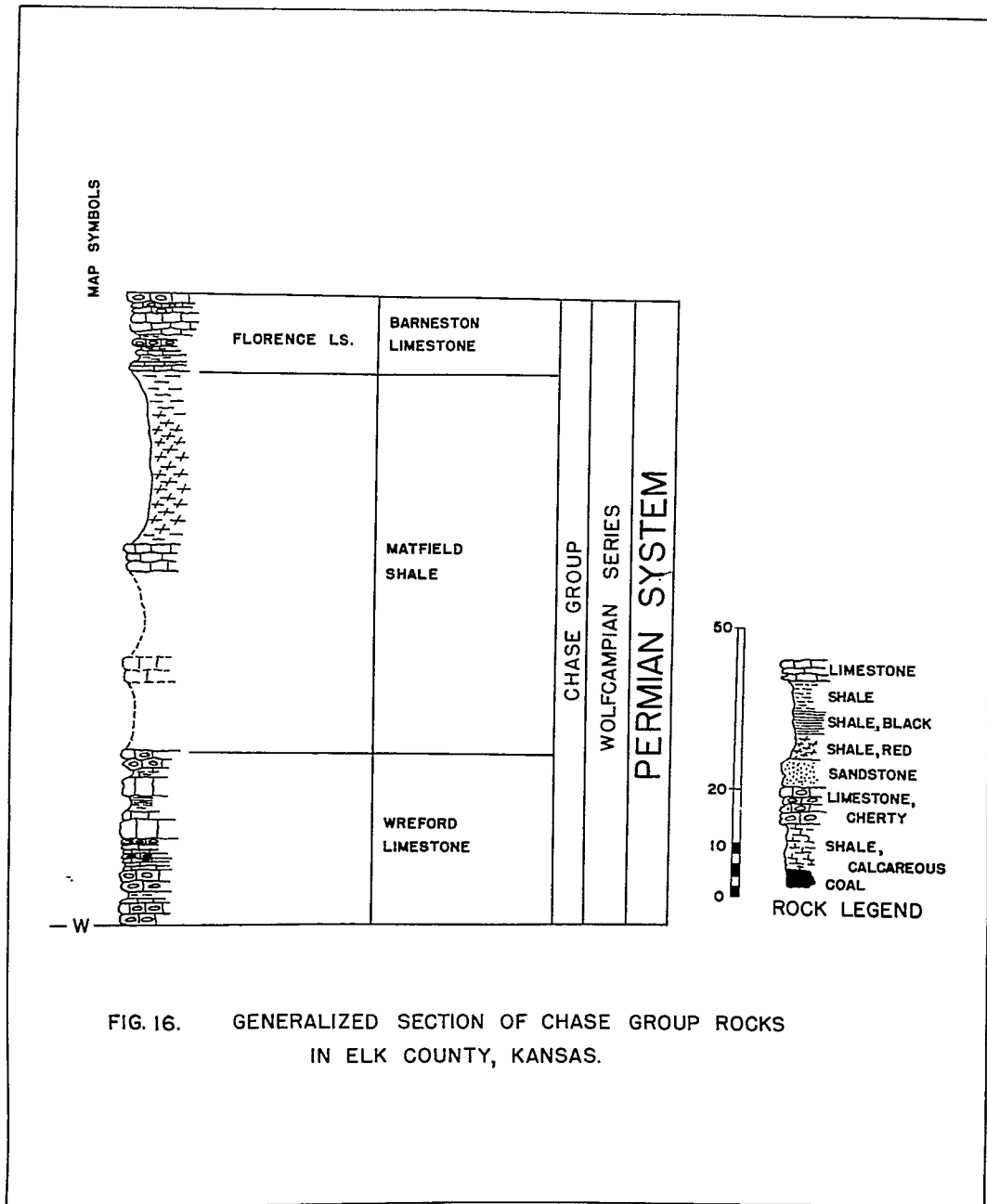


FIG. 16. GENERALIZED SECTION OF CHASE GROUP ROCKS IN ELK COUNTY, KANSAS.

## Wreford limestone

The Wreford limestone was named by Hay (1891) from exposures near Wreford, Geary county, Kansas. Condra and Upp (1931) separated the Wreford limestone into the following members, in ascending order; Fourmile limestone, Havensville shale, and Schroyer limestone. Because the name Fourmile had previously been used in Oklahoma, Moore (1936) substituted the term Threemile for the lower member.

Lithologic character and thickness.--- Throughout its more northerly zones of outcrop in Kansas, the three members designated by Condra and Upp are readily recognizable and have been described from many localities. In Cowley county, the formation is almost exclusively limestone. Consequently, the Havensville shale member has not been correlated in this area with any degree of certainty. Bass (1929) measured and described several exposures of the Wreford limestone in Cowley county which averaged about 33 feet in thickness. In a completely exposed section, just east <sup>of</sup> the junction of Kansas Highways 15 and 38, north of Dexter, the Wreford limestone is 32 feet thick and consists of the following lithologic units, in descending order: limestone, 3.9 feet, grey, massive in the middle, cherty, sparingly fossiliferous; shale, 0.7 feet, grey-brown, calcareous; limestone, 5.4 feet, massive, grey-brown, weathers into thin, irregular beds; shale, 2.5 feet, black fissile in upper half, lower

half buff, calcareous; limestone, 6.0 feet, grey, soft, algal, sparingly fossiliferous, massive, with a 0.5 foot chert bed just above the base; limestone, 4.2 feet, nodular, grey to brown, with abundant blue chert nodules and thin blue chert beds; limestone, 9.5 feet, generally massive, blue to grey-brown, blue chert nodules abundant, fossiliferous. The Havensville shale member should probably be correlated with the 8.5 feet of shale and massive, soft, fossiliferous, non-cherty limestone occurring about 9 feet below the top of this section.

In western and northwestern Elk county, measurable exposures of the Wreford are limited to only a few feet of the lower cherty beds. Consequently, no complete sections were studied in Elk county. Although the Wreford forms a pronounced <sup>scarp</sup> and the base of the formation was mapped, the upper beds are generally reduced to a chert rubble which blankets the pronounced bench held up by the formation. The complete thickness of the formation is presented only in the extreme northwest corner of the county; however, here the unit is covered in part and detailed lithology is not readily obtainable.

Fauna.--- The following fossils were collected from the formation north of Dexter; Dictyoclostus, Composita, Rhombo-pora, Osagia, crinoid stems, echinoid spines and plates, pelecypod fragments and productid spines.

In the accompanying areal geologic map (Plate 1), the base of the Wreford limestone is mapped and its line of outcrop is indicated by the symbol W. For measured sections of the Wreford limestone, see sections 75, 76, and 80 at the end of this report.

### Matfield shale

The Matfield shale was named by Prosser (1902) from exposures in Matfield township, Chase county, Kansas. In the type area, the formation is 60 to 70 feet thick and consists mainly of varicolored shales with minor amounts of shaly, occasionally cherty, or grey limestones. Condra and Upp (1931) divided the formation into three members, which in ascending order are: Wymore shale, Kinney limestone, and Blue Springs shale.

The Matfield shale is exposed in the extreme northwestern corner of Elk county and has a thickness of 55 to 60 feet. However, due to its limited areal distribution and covered condition in Elk county, it was necessary to study the formation in Cowley county. The thicknesses and lithologies in the following discussion were taken from sections measured in Cowley county by Bass (1929) and Condra and Upp (1931), which were visited by the writer, and from a section measured at the junction of Kansas Highways 15 and 38, north of Dexter.

### Wymore shale member

The Wymore shale was named by Condra and Upp (1931) from exposures 2.5 miles east of Wymore, Nebraska. In the type area, the member is about 20 feet thick and consists of varicolored shales and thin mudstones.

In the section described by Bass (1929) south of Silverdale, Cowley county, the Wymore shale is about 9 feet thick and is composed of red clayey shales overlain by grey to dark grey calcareous shale. In the section just east of Burden, Cowley county, described by Condra and Upp (1931), the Wymore shale is about 9 feet thick and consists of about 5.0 feet of grey and red shales separated below from 3.5 feet of grey to red shales by a grey-lavender limestone.

### Kinney limestone member

The Kinney limestone was named by Condra and Upp (1931) from exposures in the railroad cut just east of Kinney, Gage county, Nebraska. In Nebraska, the member is about 12 feet thick and consists of the following lithologic zones, in ascending order: limestone, 5 feet, grey; shale, 5 to 6 feet, grey; two limestone-mudstones separated by shale, 1.7 feet (Condra and Upp, 1931). East of Burden, the member is 15.5 feet thick and contains the following zones, in ascending order: limestone, two beds separated by a thin shale, fossiliferous, 2.5 feet; limestone, dark grey,

massive, fossiliferous, about 5.0 feet; shale, grey, fossiliferous, about 2.0 feet; limestone, grey, fossiliferous, 6.0 feet (Condra and Upp, 1931).

In the extreme northwestern corner of Elk county, the Kinney limestone crops out as two benches separated by a covered shale interval. The benches, which are relatively prominent, being overlain and underlain by shales, are easily followed on areal photographs with the use of a stereoscope.

#### Blue Springs shale member

The Blue Springs shale was named by Condra and the Upp (1931) from exposures southeast of Blue Springs, Nebraska. In Nebraska, the member is 28 to 29 feet thick and consists mainly of varicolored shales. In Riley and Geary counties, Kansas, the member is 25 to 45 feet thick and is composed of yellow to grey shales above and varicolored shales below (Jewett, 1941). East of Burden, Condra and Upp (1931) described the Blue Springs shale as being about 25.0 feet thick and consisting of about 14 feet of grey, red, and olive shales separated below from 8.0 feet of limy grey shale by a 2.5 foot, grey, massive limestone (called by them the Bruno limestone).

North of Dexter, at the junction of Kansas Highways 15 and 38, the Blue Springs shale is exposed and consists of

about 5.0 feet of thin bedded to nodular, blue to grey, fossiliferous limestones and grey, clayey to calcareous shales underlain by 21.0 feet of bluish-grey and bright red shales. The lower 6.0 feet of the member are partially covered but consist of an upper 1.8 foot, dense, grey-green limestone (Bruno limestone ?) underlain by calcareous shale.

The upper 5 feet of the member, north of Dexter, contain the following fossils: Juresania, Dictyoclostus, Derbya, Myalina, Aviculopecten, Septimyalina, Rhombopora, Composita, Bairdia, echinoid spines, fenestellid bryozoans, crinoid stems, and numerous gastropods.

For a measured section of the Blue Springs shale, see section 81 at the end of this report.

#### Barneston limestone

The Barneston limestone was named by Condra and Upp (1931) to include the Florence flint and the Fort Riley limestone. Moore (1936) applied the name Oketo shale to the thin discontinuous shale unit between the Fort Riley and Florence limestones. The formation, as now recognized, contains the following members, in ascending order: Florence limestone, Oketo shale, and Fort Riley limestone.

The lowermost member, the Florence limestone, is present in the extreme northwestern corner of Elk county where it forms the cap of two small outliers.

### Florence limestone member

The Florence limestone member was named by Prosser (1895) from exposures near Florence, Marion county, Kansas. Prosser (1902) used the term "Florence flint" for about 20 feet of very cherty limestone exposed in railway cuts 1 to 2 miles northeast of Florence. He further stated that the original Florence limestone (Prosser, 1895) was apparently equivalent to the main ledge of the Fort Riley limestone and that the name should be abandoned. Moore (1936) applied the name Florence limestone to the chert bearing beds overlying the Blue Rapids shale and underlying the newly defined Oketo shale.

In Elk county, the Florence limestone forms the cap of two small outliers in the extreme northwestern part of the county; however, as the exposures are rather poor and are considerably obscured by a mantle of weathered chert, no sections were measured in the county.

In Cowley county, Bass (1929) states that the Florence limestone thins from 35 feet in sec. 16, T. 31 S., R. 5 E., to about 11 feet in sec. 18, T. 35 S., R. 5 E. The section, described below, was measured at the junction of Kansas Highways 15 and 38, north of Dexter, Cowley county. It represents the lower part of the member and is considered to be about equal to the thickness of the cap formed by the Florence limestone in Elk county and consists of the following zones, in descending order: Limestone, grey to buff,

sugary, with numerous tan and grey chert nodules, fossiliferous, 4.2 feet; limestone, buff, massive, non-cherty, 3.2 feet; shale, grey, calcareous, 0.8 feet; limestone, buff to grey, soft, weathers shaly, fossiliferous, with a few small chert nodules, 1.2 feet. The following fossils were collected from the above measured sections:

Pseudoschwagerina, Schwagerina, Dictyoclostus, crinoid stems, echinoid spines, and many small shell fragments.

For a measured section of the Florence limestone, see section 81 at the end of this report.

## DESCRIPTIONS OF MEASURED SECTIONS

### SECTION 1

Measured along the west side of north-south county road, center sec. 17, T. 31 S., R. 13 E., Elk county.

Thick-  
ness  
(feet) Bed

Lawrence shale

Ireland sandstone member

14.5 (1) Sandstone, massive, grey to reddish-grey, medium to fine grained, reddish to buff weathering, friable to well cemented; lower part grades into reddish-grey, sandy shale.

Stranger formation

Robbins shale member

25.0 (2) Shale, reddish to buff or grey, sandy above to clayey below; with several greenish to buff sandstones in the upper part.

25.0 (3) Shale, bluish-grey, streaked with yellow to orange; interbedded with thin plates of sandstone; grey concretions are common throughout.

70.0 (4) Shale, grey to bluish-grey, sandy above to clayey below; concretions numerous in upper part.

SECTION 2

North-center, sec. 3, T. 32 S., R. 13 E., Chautauqua county.

## Stranger formation

## Haskell limestone member

- 1.0 (1) Limestone, blue, dense, hard, massive; with abundant Ottonosia.

## Vinland shale member

- 35.0 (2) Shale and sandstone, almost completely covered.

## Westphalia limestone member

- 1.0 (3) Limestone, thin bedded, irregular to platy, sandy to silty, dark grey, fossiliferous.
- 1.1 (4) Limestone, massive, dark grey, mottled, dirty, micaceous, sandy; with Osagia and abundant fusulinids.

## Tonganoxie sandstone member

- 6.4 (5) Shale, bluish-grey, clayey at top to finely bedded and hard platy below.
- (6) Sandstone, greyish to buff; only the upper part is exposed.

SECTION 3

Measured along US Highway 160 from top of hill to creek at bottom, in SW $\frac{1}{4}$ , sec. 6, T. 31 S., R. 13 E., Elk county.

## Lawrence shale

## Ireland sandstone member

- 80.0 (1) Sandstone, massive in upper part, becoming thinner bedded and cross-bedded lower; grey to buff or reddish, fine grained. This exposure represents a deep channel filling deposit having a total thickness estimated up to 100 feet.

SECTION 4

Measured along north-south county road between sections 11 and 12, T. 29 S., R. 13 E., Wilson county. This section was furnished by H. C. Wagner.

## Lawrence shale

## Ireland sandstone member

- 2.5 (1) Sandstone, fine grained, buff, massive, limonite spots; top not present.

## Stranger formation

## Robbins shale member

- 40.0 (2) Sandstone and shale, sandstone in the upper part is shaly, tan to grey and reddish; poorly exposed; grades downward into grey, silty shale which contains numerous concretions.

## Haskell limestone member

- 2.7 (3) Limestone, grey to tan, uneven beds, blotchy appearance, Ottonosia

## Vinland shale member

- 2.5 (4) Limestone, silty to shaly, grey; upper part almost coquina of pelecypods, bryozoans, and crinoid stems.
- 1.1 (5) Sandstone, fine grained, grey, streaked with brown.
- 0.8 (6) Shale, clayey to silty, grey to brown; with a carbonaceous streak in the middle.

## Westphalia limestone member

- 1.2 (7) Limestone, chocolate brown, highly jointed, brown weathering; with abundant Osagia.
- 1.7 (8) Limestone, clayey to sandy, fragmental.
- 1.8 (9) Limestone, sandy, impure, greyish-tan to chocolate brown, fossiliferous.

## Tonganoxie sandstone member

- 0.8 (10) Sandstone, limy, brown to grey, fine grained, massive.
- 7.0 (11) Sandstone, fine grained, thin bedded, grey, micaceous, ripple marked; concretionary zones in upper part.
- 1.0 (12) Sandstone, massive, lenticular, micaceous, light grey, brown weathering.
- 3.0 (13) Sandstone, finely banded, thin to medium bedded, micaceous, grey to brown; with many ironstone concretions.
- 1.0 (14) Sandstone, massive, ripple marked, tan, micaceous, fine grained.
- 2.5 (15) Sandstone, grey, massive, fine grained, lenticular; contains pebbles of thin bedded sandstone which possess contorted bedding.
- 9.5 (16) Sandstone, limy, thin bedded, grey, iron stained, micaceous.
- 2.0 (17) Sandstone, ripple marked, fine grained, medium bedded, highly contorted.
- 12.7 (18) Sandstone, thin bedded, grey, micaceous, ripple marked, brown weathering; contains plant fragments, The base of the member is not exposed.

SECTION 5

Measured along north-south county road in east-center sec. 21, T. 31 S., R. 13 E., Elk county.

## Stranger formation

## Robbins shale member

- 52.0 (1) Sandstone and shale, reddish-brown somewhat massive sandstone above grading downward into bluish-grey, silty to clayey shale.

## Haskell limestone member

- 1.4 (2) Limestone, dirty bluish-grey, massive, hard, weathers with a brownish crust; contains abundant Ottonosia.

## Vinland shale member

- 14.9 (3) Shale, grey to yellowish above to greenish below, silty to clayey, pelecypods occur in the upper part.

## Tonganoxie sandstone member

- 1.6 (4) Sandstone, grey to greenish, calcareous, weathers to a dirty grey-brown, massive bed; upper surface covered with castings; lower surface somewhat irregular.

## Weston shale

- 22.0 (5) Shale, silty, grey to greenish; with occasional small concretions. Only the upper part of the Weston shale is exposed here.

SECTION 6

Measured from quarry on top of hill eastward to stream bed, center sec. 23, T. 30 S., R. 12 E., Elk county.

## Oread limestone

## Leavenworth limestone member

- 1.5 (1) Limestone, dark blue, dense, vertically jointed; with small fusulinids.

## Snyderville shale member

- 55.0 (2) Shale and sandstone, covered; with the exception of greenish-grey sandstone and shale in the lower part.

## Toronto limestone member

- 0.6 (3) Limestone, grey to dark grey, one massive bed which weathers into thin irregular plates; with brachiopods and crinoid stems.
- 1.0 (4) Shale, grey, clayey; with a few calcareous plates.
- 0.8 (5) Limestone, like bed 3, but more fossiliferous.

## Lawrence shale

- 65.0 (6) Shale, covered for the most part, with the exception of grey to yellowish shale in the upper part and some greenish to grey, thin bedded sandstone in the middle. The upper shale contains abundant fusulinids just below the overlying limestone.

## Amazonia limestone member

- 9.0 (7) Limestone, thin, slabby, dark blue to grey, grey to buff or whitish weathering; very fossiliferous, especially fusulinids.

## Ireland sandstone member

- 30.0 (8) Sandstone, yellow to buff, fine grained, reddish to buff and grey weathering, very massive.

SECTION 7

Measured in road ditch of north-south county road in NW $\frac{1}{4}$ , sec. 24, T. 31 S., R. 12 E., Elk county.

## Lawrence shale

## Amazonia limestone member

- 2.8 (1) Limestone, bluish, hard, thin bedded, fossiliferous; with Osagia common in the upper two beds and fusulinids common below.
- 0.4 (2) Shale, blue-grey, clayey.
- 0.3 (3) Limestone, light grey, fine grained, speckled, sandy.

SECTION 8

Measured along north-south county road, east quarter corner, sec. 34, T. 28 S., R. 13 E., Elk county.

## Stranger formation

## Westphalia limestone member

- 0.6 (1) Limestone, blue-grey, dense, hard, weathers dark grey; with algae and rare fusulinids.

- 055 (2) Limestone, blue-grey, thin bedded, shaly.  
 2.0 (3) Limestone, mottled, grey, massive, somewhat irregular, highly algal.

#### SECTION 9

Measured in road cut at the corner in NE $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 27, T. 30 S., R. 12 E., Elk county.

Oread limestone

Toronto limestone member

- 0.6 (1) Limestone, dirty, dark grey, shelly, weathers to grey-buff; with brachiopods.  
 0.8 (2) Shale, blue-grey, clayey, fossiliferous.  
 0.3 (3) Limestone, dark grey, weathers to dark grey to buff; with brachiopods, corals, and crinoid stems.

Lawrence shale

- 1.6 (4) Shale, grey, with hard calcareous plates; contains Chonetes above and extremely abundant fusulinids below.  
 0.1 (5) Coal.

#### SECTION 10

Measured in roadcut, one-half mile west of junction of US. Highway 54 and Kansas Highway 105, northwest of Toronto, Kansas.

Oread limestone

Toronto limestone member

- 4.3 (1) Limestone, grey to dark grey, weathers light grey to buff and orange, wavy to thin bedded, fossiliferous.  
 0.2 (2) Shale, grey, clayey, somewhat irregular in thickness.  
 5.7 (3) Limestone, light blue, dense, very massive but with incipient wavy bedding; robust Triticites common.

## Lawrence shale

- 0.5 (4) Shale, dark grey, clayey.
- 0.5 (5) Coal.
- 2.0 (6) Shale, blue-grey underclay above, becomes grey mottled below.

SECTION 11

Measured just above the parking area below the Fall River Dam, Greenwood county, Kansas.

## Oread limestone

## Heumader shale member (Heumader-Kanwaka shale)

- 40.0 (1) Shale, dark grey, clayey; with a few thin buff sandy plates near the top; fossiliferous.

## Plattsmouth limestone member

- 9.4 (2) Limestone, mottled, grey to buff, coarsely crystalline, thin, wavy bedded, fossiliferous.

## Heebner shale member

- 4.5 (3) Shale, upper part grey brown, lower part black fissile.

## Leavenworth limestone member

- 1.3 (4) Limestone, dark blue, massive, hard, brittle, vertically jointed; contains small Triticites.

SECTION 12

Measured in roadcut exposure along Kansas Highway 96, about 8.5 miles east of Severy, Greenwood county, Kansas.

## Oread limestone

## Kereford limestone member

- 0.6 (1) Limestone, dark grey, thin irregular bedded.
- 2.0 (2) Limestone, massive, dark grey, weathers to dirty dark grey; with abundant Triticites and Osagia.

SECTION 13

Measured along east-west county road about 10 miles north and 1 mile west of the east entrance to the Fall River Dam, Greenwood county, Kansas.

## Oread limestone

## Kereford limestone member?

- 1.1 (1) Limestone, bluish-grey, dense, thin wavy bedded, weathers to greyish-buff, fossiliferous.

## Heumader shale member

- 6.4 (2) Shale, grey, clayey; with a few white algal knobs in the upper part.
- 1.0 (3) Limestone, dark blue, massive bed, mottled with buff, weathers to orange buff; contains Myalina and gastropods.
- 7.4 (4) Shale, brown, clayey; mostly covered.

## Plattsmouth limestone member

- 9.8 (5) Limestone, thin irregular to wavy bedded, white to grey, coarsely crystalline; with abundant Triticites, brachiopods, and crinoid stems.

## Heebner shale member

- 1.9 (6) Shale, upper part grey, clayey shale; lower part black, hard, fissile.

## Leavenworth limestone member

- 1.3 (7) Limestone, dark blue, dense, hard; with a few small fusulinids. The lower 0.3 feet are nodular, dark blue, and contain abundant small black fusulinids.

## Snyderville shale member

- 24.2 (8) Shale, grey, clayey above to greenish-grey and reddish below.
- 1.0 (9) Limestone, thin bedded, grey to greenish, algal; contains pebbles of buff limestone; abundantly fossiliferous.
- 11.8 (10) Shale, grey to green and reddish, with small algal knobs; lower part is sandy and micaceous.

- 3.7 (11) Sandstone and shale, lenses of greenish-buff, fine grained, cross-bedded sandstone and greenish-grey, micaceous, sandy shale.
- 4.3 (12) Shale, reddish, clayey.
- 1.3 (13) Sandstone, thin bedded, greenish-grey, micaceous, dirty.
- 16.2 (14) Shale, greenish-grey, sandy shale in upper part; reddish clay below.

#### SECTION 14

Measured along the west road ditch of a north-south county road in south center, sec. 21, T. 28 S., R. 12 E., Elk county, Kansas.

#### Lecompton limestone

#### Spring Branch limestone member

- 6.4 (1) Limestone, three massive beds separated by thin bedded to nodular limestones. Upper limestone is dark grey, mottled, dense, light buff weathering and contains Neospirifer, Triticites, Osagia, and echinoid spines. Middle bed is mottled, impure, sandy, and algal. The lower bed is massive but weathers to thin irregular slabs.

#### Kanwaka shale

#### Stull shale member

- 9.0 (2) Shale, greyish-green, clayey; algal in its upper part, becomes reddish in lower part.
- 4.7 (3) Shale, grey, clayey, with numerous thin limestones. The thin limestones are highly fossiliferous, containing numerous specimens of Chonetes, Derbya, Amphiscapha, and abundant Triticites. Well preserved plant remains are found in the lower part of the shale.
- 2.6 (4) Shale, orange to buff, clayey.
- 8.0 (5) Shale, covered.
- 1.0 (6) Shale, bluish-grey, clayey; contains a few Myalina.

- 3.7 (7) Shale, mostly covered, but contains several thin buff limestones with Chonetes.
- 5.3 (8) Shale, mottled, red, green, blue, and orange; with a few thin, green, micaceous, sandy plates and ironstone concretions.

Clay Creek limestone member

- 2.1 (9) Limestone, thin, slabby, grey, almost coquinoid; interbedded with grey, clayey shales.
- 0.9 (10) Shale, grey-brown to buff, clayey; with thin calcareous plates.
- 2.9 (11) Limestone, thin bedded, grey, buff to orange weathering; lower bed is impure and sandy. Fossils are less common than in bed 9, but fusulinids are present.

Jackson Park shale member

- 6.4 (12) Shale, bluish-grey, clayey; with orange streaks and a few small ironstone concretions.
- 8.0 (13) Shale, covered.
- 8.0 (14) Sandstone, buff to yellow, fine grained, hard, massive; becomes lighter in color and friable below.
- 4.5 (15) Sandstone, light buff to yellowish, slabby bedded; slightly cross-bedded in the middle.
- 6.0 (16) Sandstone, light buff, fine grained, very massive; base not exposed.

SECTION 15

Measured in ditch of the north-south county road in SE $\frac{1}{4}$ , sec. 30, and NE $\frac{1}{4}$  sec. 31, T. 28 S., R. 12 E., Elk county, Kansas.

Deer Creek limestone

Rock Bluff limestone member

- 1.7 (1) Limestone, dark blue, hard, dense, vertically jointed, weathers with a brownish crust; contains fusulinids, brachiopods, and small shell fragments.
- 35.0 (2) Covered interval representing the Oskaloosa shale and Ozawie limestone.

## Tecumseh shale

- 5.0 (3) Shale, blue-grey to reddish-grey and green; with some irregular calcareous streaks.
- 0.5 (4) Sandstone, greenish-grey, micaceous.
- 4.0 (5) Shale, green, clayey; grades downward into red and back into green; algal.
- 1.0 (6) Sandstone, thin bedded, greenish-grey; interbedded with red and green, sandy to clayey shales.
- 0.8 (7) Sandstone, fine grained, hard, light grey.
- 6.8 (8) Sandstone, light grey to green, somewhat calcareous, hard, irregular bedded.
- 0.7 (9) Shale, green to reddish, clayey.
- 0.5 (10) Sandstone, green, hard, fine grained.
- 3.0 (11) Shale, green, micaceous, sandy.
- 0.2 (12) Sandstone, green, hard, fine grained.
- 4.0 (13) Shale, dark grey to reddish; base is not exposed.

SECTION 16

Measured in roadcut along north-south county road in NW $\frac{1}{4}$  sec. 29, T. 28 S., R. 12 E., Elk county, Kansas.

## Deer Creek limestone

## Oskaloosa shale member

- 1.7 (1) Shale, grey-brown, clayey; with a few calcareous streaks; algal.
- 5.3 (2) Shale, greenish-grey to reddish; with several thin, micaceous, platy sandstones in lower part.
- 17.0 (3) Shale, red, clayey; with occasional green, silty plates.
- 0.5 (4) Sandstone, thin, platy, light green to grey, fine grained.

- 11.6 (5) Shale, red, green, and purple clay; with occasional thin, buff to green siltstones.

Ozawkie limestone member

- 3.1 (6) Limestone, mottled light grey, orange to yellowish weathering, algal; tends to split into three beds; fossiliferous.

Tecumseh shale

- 4.0 (7) Shale, red to purplish, clayey; with a few small algal knobs; base not exposed.

### SECTION 17

Measured in roadcut from top of hill to creek bed below school, NE $\frac{1}{4}$  sec. 7, T. 29 S., R. 12 E., Elk county, Kansas.

Lecompton limestone

Avoca limestone member

- 0.6 (1) Limestone, dark blue, hard, vertically jointed, weathers buff, algal (Osagia).
- 1.0 (2) Limestone, dark blue, hard, irregular, thin bedded.
- 0.6 (3) Shale, grey, clayey.
- 1.3 (4) Limestone, dark blue, vertically jointed, dense, brittle; abundant black "Cryptozoans".
- 4.8 (5) Mostly covered, but contains thin, slabby fusulinid bearing limestones in the lower part.

King Hill shale member

- 4.0 (6) Shale, covered.

Beil limestone member

- 2.0 (7) Limestone, slabby, rich yellow; not well exposed.
- 8.7 (8) Limestone, light grey, cream-yellow weathering; more massive bedded in upper part; very fossiliferous.

## Queen Hill shale member

- 2.0 (9) Shale, bluish-grey, clayey; not well exposed.

## Big Springs limestone member

- 1.5 (10) Limestone, dark blue, dense, hard, brittle, vertically jointed; with abundant small Triticites.
- 1.5 (11) Shale, grey, clayey.
- 2.5 (12) Limestone, blue-grey, sandy to silty, thin bedded, sparingly fossiliferous.

## Doniphan shale member

- 17.5 (13) Shale, grey, sandy to silty; with several thin greenish-grey sandstones in the middle.

## Spring Branch limestone member

- 1.7 (14) Limestone, mottled, fossiliferous, light grey, algal; with irregular bottom.
- 1.5 (15) Shale, grey.
- 1.6 (16) Limestone, bluish-grey, massive, impure, sandy in the lower part; Chonetes common.

## Kanwaka shale

## Stull shale member

- 26.0 (17) Shale, grey to brownish, clayey; with a few thin, yellowish, slabby limestones in the upper part; lower part covered.

## Clay Creek limestone member

- 3.8 (18) Limestone, thin, platy, grey; interbedded with grey shales; contains Myalina and many brachiopods.

## Jackson Park shale member

- 27.0 (19) Shale and sandstone, almost all covered.
- 7.0 (20) Sandstone, irregular to cross-bedded, green to grey and buff; interbedded with micaceous, sandy shales.

SECTION 18

Measured along south side of county road in SE $\frac{1}{4}$  sec. 5,  
T. 29 S., R. 13 E., Elk county, Kansas.

## Oread limestone

## Snyderville shale member

- 11.5 (1) Shale, sandy to silty; mostly covered.
- 12.0 (2) Sandstone and shale, buff to dirty yellow, fine grained, irregular beds, massive but seldom over a foot thick, interbedded with sandy shale.
- 13.5 (3) Shale, light yellow to reddish, sandy; interbedded with occasional thin, slabby, orange to grey sandstone; becomes reddish and clayey below.
- 21.0 (4) Shale, yellow to light grey, clayey; contains scattered sandy to silty plates, reddish clay, and ironstone concretions.

## Toronto limestone member

- 0.8 (5) Limestone, dark grey to brown, mottled, occasional silty splotches, weathers dirty grey, fossiliferous.
- 1.4 (6) Limestone and shale, silty to sandy, mottled greenish-grey, interbedded with grey shale; contains abundant pelecypods and productid brachiopods.
- 1.0 (7) Limestone, two beds, mottled grey and yellow, somewhat irregularly bedded; contains abundant fusulinids; underlain by thin shale parting.
- 1.6 (8) Limestone, two beds, blue, hard, dense, vertically jointed, sparingly fossiliferous; underlain by thin shale parting.
- 1.0 (9) Limestone, massive, blue, weathers to rich orange-yellow, highly fossiliferous.
- 0.6 (10) Limestone, nodular, blue, interbedded with grey shale; almost coquina of fusulinids.

## Lawrence shale

- 1.0 (11) Shale, grey, calcareous, with abundant fusulinids.

SECTION 19

Measured along Kansas Highway 99 and along road into Sedan City Lake, T. 33 S., R. 11 E., Chautauqua county, Kansas.

## Lecompton limestone

## Spring Branch limestone member

- 3.3 (1) Limestone, algal (Osagia), mottled, weathers buff to orange-yellow, somewhat irregular bedded; in three beds, with upper bed underlain by grey to light buff shale.

## Heumader-Kanwaka shale

- 8.7 (2) Shale, light-grey to yellowish, streaked with hard plates; becomes sandy and micaceous below.
- 26.9 (3) Shale and sandstone, thin, grey to buff sandstones interbedded with yellow-grey, sandy to silty shale.
- 12.0 (4) Sandstone, massive, bench forming, red to buff weathering, fine grained, interbedded with sandy shales.
- 8.6 (5) Shale, grey to grey-blue, clayey; partially covered.
- 7.6 (6) Shale, mottled, hard, blocky, red to yellowish, sandy in places; contains a hard, dirty, grey sandstone in the middle.
- 13.5 (7) Sandstone, massive, fine grained, somewhat cross-bedded, weathers buff to reddish.
- 3.0 (8) Shale, blue to yellow, streaked, micaceous, platy, silty to sandy.
- 2.0 (9) Sandstone, dark grey, thin bedded, ripple marked; interbedded with sandy shale.
- 10.0 (10) Shale, grey-blue, micaceous, platy to blocky, with some orange and black streaks; becomes sandy, greenish, and concretionary below.
- 12.5 (11) Shale, grey to bluish, silty, micaceous; with a few concretions and impressions of pelecypods and Derbya in the hard silty plates near the base.
- 23.5 (12) Shale, blue, blocky, becomes grey and clayey below.
- 8.0 (13) Shale, grey, clayey to calcareous, highly fossiliferous.

SECTION 20

Measured along Kansas Highway 99, center sec. 8, T. 33 S., R. 11 E., Chautauqua county, Kansas.

## Lecompton Limestone

## Queen Hill shale member

- 3.0 (1) Shale, blue to yellow-grey, clayey; top not exposed.

## Big Springs limestone member

- 1.0 (2) Limestone, thin, platy; interbedded with grey, clayey shale; highly fossiliferous.
- 1.0 (3) Limestone, massive, dirty, brown.
- 0.5 (4) Limestone, thin bedded, grey to buff, highly sandy; lower plates may be called sandstones.

## Doniphan shale member

- 1.3 (5) Shale, blue to grey, clayey, contains a few white algal knobs in lower part.

## Spring Branch limestone member

- 1.5 (6) Limestone, mottled, greenish to grey, weathers to bright buff, highly algal, fossiliferous.

SECTION 21

Measured along Kansas Highway 99, NW $\frac{1}{4}$  sec. 8, T. 33 S., R. 11 E., Chautauqua county, Kansas.

## Lecompton limestone

## Beil limestone member

- 6.2 (1) Limestone, irregular to wavy bedded, thin bedded, weathers to light grey in upper part to cream-yellow below; Orania, Syringopora, and Triticites, Common.

Queen Hill shale member

- 8.4 (2) Shale, gray to bluish, clayey, blocky.
- 2.7 (3) Shale, black, fissile, contains a few woody streaks.

- 0.2 (4) Limestone, black, heavy, weathers dark grey; Crurithyris common.

### SECTION 22

Measured along Kansas Highway 99, NW $\frac{1}{4}$  sec 8, T. 33 S., R. 11 E., Chautauqua county, Kansas.

#### Lecompton limestone

##### Avoca limestone member

- 1.0 (1) Limestone, dark dirty grey; one massive bed; contains abundant black "Cryptozoans" (Ootonosia).
- 2.7 (2) Shale, grey, clayey, highly fossiliferous.
- 0.7 (3) Limestone, thin, platy, grey, highly fossiliferous; interbedded with fossiliferous, grey shale.
- 1.0 (4) Limestone, massive, dirty, grey, weathers to dark grey, fossiliferous.

##### King Hill shale member

- 1.2 (4) Shale, grey to reddish, clayey.

##### Top of Beil limestone.

### SECTION 23

Measured along Kansas Highway 99, SW $\frac{1}{4}$  sec. 5, T. 33 S., R. 11 E., Chautauqua county, Kansas.

#### Deer Creek limestone

##### Rock Bluff limestone member

- (1) Limestone, grey-blue, hard, dense, vertically jointed; no measurement.

##### Oskaloosa shale member

- 8.5 (2) Shale, grey, clayey above to red and greenish below.
- 0.5 (3) Limestone, greenish-grey, mottled, irregularly bedded, dense, algal.
- 1.2 (4) Shale, red to greenish, clayey; partially covered.

Ozawkie limestone member

- 3.5 (5) Limestone, three irregular beds; grey to buff, mottled, algal; lower two beds separated by thin yellow shale.

Tecumseh shale

- 9.2 (6) Shale, red to greenish-grey, clayey; partially covered.
- 1.2 (7) Shale, grey to greenish, hard, platy, silty.
- 1.9 (8) Sandstone, buff to grey, mottled, weathers reddish; forms slight bench.
- 7.4 (9) Shale, grey to yellowish-grey; with a few small concretions and silty to sandy plates.
- 2.6 (10) Shale, grey to yellow, clayey, fossiliferous.
- 20.5 (11) Shale, yellowish-grey above to blocky grey below; small concretions present; not completely exposed.

Lecompton limestone

Avoca limestone member

- 1.7 (12) Limestone, dark grey, dirty, weathers slabby to irregular flakes, fossiliferous; Ottonosia common.
- 2.8 (13) Shale, grey to yellowish, clayey.
- 1.7 (14) Limestone, thin bedded, dark grey, fossiliferous, with grey shaly partings.

King Hill shale member

- 3.3 (15) Shale, grey, badly covered.

Beil limestone member

- 4.2 (16) Limestone, thin, irregular to wavy bedded, weathers grey to light yellow above to bright cream-yellow below; highly fossiliferous, with Caninia being extremely abundant.

Queen Hill shale member

- 8.3 (17) Shale, grey, clayey.

- 3.0 (18) Shale, black, fissile.
- 0.2 (19) Limestone, black, hard, heavy, weathers dark grey; contains abundant Crurithyris.
- 6.4 (20) Shale, black, fissile above; grey, blocky, streaked with black below.

Big Springs limestone member

- 0.8 (21) Limestone, thin bedded, platy, dark brown to mottled; lower plates very sandy; fossiliferous in upper part.
- 1.0 (22) Doniphan shale member
- 1.3 (22) Shale, yellow to bluish-grey, clayey; partially covered.
- 0.2 (23) Limestone, brown, dirty, weathers reddish; crowded with Osagia.
- 1.3 (24) Shale, grey-brown; not well exposed.

Spring Branch limestone member

- 5.0 (24) Limestone, greenish-grey to buff, mottled, irregular bedded, highly algal (Osagia).

SECTION 24

Measured along Kansas Highway 99, SW $\frac{1}{4}$  sec. 33, T. 33 S., R. 11 E., Chautauqua county, Kansas.

Oread limestone

Plattsmouth limestone member

- 15.0 (1) Limestone, light grey to buff, light grey to almost white weathering, wavy bedded, coarsely crystalline; pockets of black shale along the bedding planes in lower part; slightly cherty above; fossiliferous.

Heebner shale member

- 4.7 (2) Shale, grey to brownish above to black, fissile below; upper grey shale is highly fossiliferous.

## Leavenworth limestone member

- 1.6 (3) Limestone, hard, dense, blue, vertically jointed, weathers with a cream yellow crust, fossiliferous.

## Snyderville shale member

- 1.3 (4) Shale, dark grey to almost black, highly fossiliferous.
- 0.5 (5) Limestone, thin, black to dirty grey, fossiliferous.

SECTION 25

Measured along county road in SW $\frac{1}{4}$  sec. 5, T. 29 S., R. 13 E., Elk county, Kansas.

## Oread limestone

## Kereford limestone member

- 0.8 (1) Limestone, dark grey, weathers to buff and reddish-grey, shelly; two thin beds separated by grey shale; Triticites extremely abundant.

## Heumader shale member

- 16.5 (2) Shale, grey, clayey below to yellowish-grey, silty above; extremely fossiliferous in lower part.

Top of Plattsmouth limestone.

SECTION 26

Measured in roadcut along county road in SE $\frac{1}{4}$  sec. 29, T. 31 S., R. 12 E., Elk county, Kansas.

## Heumader-Kanwaka shale

- 4.9 (1) Shale, brown to bluish-grey, mottled, clayey.
- 6.1 (2) Shale, grey, clayey, mottled with bluish-green; contains abundant well preserved specimens of Astartella.
- 0.1 (3) Limestone, grey, fossiliferous.
- 2.6 (4) Shale, yellow below to grey above, clayey, fossiliferous.

SECTION 27

Measured along county road in SE $\frac{1}{4}$  sec. 35, T. 29 S.,  
R. 11 E., Elk county, Kansas.

## Deer Creek limestone

## Ervine Creek limestone member

- 5.0 (1) Limestone, light-grey, mottled, irregular to wavy bedded, grey to brown weathering.

## Larsh-Burroak shale member

- 3.0 (2) Shale, grey to brown above; covered below.

## Rock Bluff limestone member

- 1.5 (3) Limestone, dark blue, hard, dense, brittle, vertically jointed, abundant fusulinids.

## Oskaloosa shale member

- 4.0 (4) Shale, covered.

- 2.7 (5) Shale and sandstone, buff to grey shales with occasional thin, buff, fine grained, micaceous sandstones.

- 6.4 (6) Sandstone, buff, banded, cross-bedded, massive in part, weathers to grey or yellowish-grey; with shaly breaks.

- 10.0 (7) Sandstone and shale, almost totally covered.

## Ozawkie limestone member

- 0.8 (8) Limestone, dark grey, massive, hard, irregular base, weathers dark grey, algal, fossiliferous.

- 0.4 (9) Shale, grey-brown, irregular.

- 1.0 (10) Limestone, blue-grey, buff, mottled, weathers buff, abundant fusulinids.

## Tecumseh shale

- 3.4 (11) Shale, grey, mottled with green and red, blocky.

- 4.0 (12) Shale, covered.

- 1.7 (13) Sandstone and shale, silty, hard, micaceous, thin bedded, fine grained; interbedded with reddish-grey, sandy shale.
- 22.0 (14) Covered.  
Top of Avoca limestone.

### SECTION 28

Measured along north-south county road in north-center sec. 15, T. 31 S., R. 12 E., Elk county, Kansas.

Oread limestone

Leavenworth limestone member

- 1.8 (1) Limestone, dark blue, dense, hard, brittle, vertically jointed, fossiliferous, weathers with brown crust.
- Snyderville shale member
- 4.1 (2) Shale, blue-grey, clayey.
- 6.2 (3) Shale, clayey, blue-grey to greenish and red.
- 2.0 (4) Shale, grey, clayey to silty, with thin greenish-buff, micaceous sandstones.
- 4.8 (5) Shale, red, clayey, blocky.
- 3.3 (6) Siltstone, dark green to greyish-green, hard, platy; interbedded with grey, micaceous shale.
- 1.2 (7) Sandstone, silty, massive, dark green, hard, micaceous, fine grained; with mudcracks.
- 6.6 (8) Shale, clayey, mottled blue-green and red.
- 5.4 (9) Shale, red, clayey.
- 5.3 (10) Siltstone, micaceous, sandy, tough, mottled, greenish-grey, massive to indistinct bedding.
- 5.6 (11) Shale, red and green.
- 5.9 (12) Siltstone and shale, grey to green, massive siltstones interbedded with grey and green, micaceous, platy shale.

19.8 (13) Sandstone, fine grained, micaceous, streaked with yellow, alternately massive and thin bedded; cross-bedded in the middle.

4.7 (14) Shale, buff to grey or green, micaceous, clayey, blocky to finely bedded.

Top of Toronto limestone.

#### SECTION 29

Measured along north-south county road in SW $\frac{1}{4}$  sec. 22, T. 30 S., R. 12 E., Elk county, Kansas.

Heumader-Kanwaka shale

3.7 (1) Sandstone, fine grained, massive, micaceous, streaked with orange and green, weathers reddish to buff.

32.0 (2) Shale, blue-grey to buff, silty to sandy, concretionary above to dark grey, clayey, highly fossiliferous below.

Plattsmouth limestone member

1.5 (3) Limestone, thin bedded, soft to earthy, light buff to grey.

18.0 (4) Limestone, dark bluish-grey, dense, irregular to wavy bedded, brittle, weathers brownish to almost white, coarsely crystalline, fossiliferous.

Heebner shale member

1.7 (5) Shale, grey, clayey.

3.0 (6) Shale, black, fissile.

Leavenworth limestone member

1.0 (7) Limestone, dark blue, hard, brittle, vertically jointed, weathers with brown crust.

SECTION 30

Measured in roadcut of county road in SW $\frac{1}{4}$  sec. 9,  
T. 30 S., R. 11 E., Elk county, Kansas.

## Deer Creek limestone

## Ervine Creek limestone member

- 20.0 (1) Limestone, light grey to bluish, thin to wavy bedded, weathers to light buff or grey and white, fossiliferous, coarsely crystalline.

## Larsh-Burroak shale member

- 1.6 (2) Shale, grey to bluish-grey, clayey.  
1.2 (3) Shale, hard, fissile, black; with rare conodonts.

## Rock Bluff limestone member

- 2.0 (4) Limestone, hard, dense, brittle, dark blue, weathers with a light brown crust, vertically jointed; one massive bed which tends to split in the middle.

## Oskaloosa shale member

- 8.0 (5) Shale, covered.  
13.5 (6) Shale, red, clayey; with minor amounts of grey and greenish clay.  
4.2 (7) Limestone, two massive but irregular, greenish-grey to dark grey, dense, algal, white to buff weathering beds separated by a variable grey clay parting.  
2.4 (8) Shale, red, clayey, with a few white algal nodules.

## Ozawkie limestone member

- 2.1 (9) Limestone, upper part thin bedded, dark grey to greenish; lower part massive, grey to buff, mottled, buff weathering; fossiliferous throughout; algal.

## Tecumseh shale

- 10.2 (10) Shale, greenish-grey, clayey; becomes silty below.  
8.0 (11) Siltstone, light green, micaceous, hard, weathers to light grey-green; interbedded with grey and green, clayey to sandy shales.

SECTION 31

Measured in road ditch along east-west county road in SE $\frac{1}{4}$  sec. 10, T. 30 S., R. 11 E., Elk county, Kansas.

Deer Creek limestone

Ozawkie limestone member

1.3 (1) Limestone, hard, dense, fine grained, blue-grey, weathers to grey-buff; contains fusulinids.

Tecumseh shale

5.7 (2) Shale, grey, clayey, with a few small white algal knobs.

18.0 (3) Sandstone, thin bedded, micaceous, fine grained, weathers reddish, cross-bedded, grey to buff.

6.5 (4) Shale, red to buff, sandy; largely covered.

1.3 (5) Shale, red, clayey; with thin, greenish-grey siltstone plates.

6.0 (6) Siltstone, hard, tough, dark grey to green, micaceous.

3.9 (7) Shale, grey, finely laminated, silty to sandy, micaceous.

5.5 (8) Shale, red to grey, clayey; contains green, silty plates near the top.

4.5 (9) Shale, red and green, clayey.

0.4 (10) Limestone, dark grey, shelly, fossiliferous.

12.0 (11) Shale, bluish-grey, finely laminated; with occasional calcareous nodules and plates; Myalina common at the top.

Top of Avoca limestone.

SECTION 32

Measured in roadcut along east-west county road in SE $\frac{1}{4}$  sec. 36, T. 29 S., R. 11 E., Elk county, Kansas.

## Lecompton limestone

## Avoca limestone member

- 2.0 (1) Limestone, thin bedded, dark grey, dirty, weathers dark grey, slabby; fusulinids and other fossils common.

## King Hill shale member

- 5.0 (2) Shale, blue-grey, clayey; mostly covered.

## Beil limestone member

- 7.0 (3) Limestone, grey, dense, mottled, weathers to cream yellow, massive, irregular to wavy bedded; large fusulinids and Syringopora common.

- 1.5 (4) Shale, grey, covered.

- 0.8 (5) Limestone, blue-grey, dense, hard, one massive bed, weathers grey to buff; abundant small fusulinids.

## Queen Hill shale member

- 5.3 (6) Shale, dark grey, clayey, partially covered.

## Big Springs limestone member

- 0.9 (7) Limestone, one massive bed; dark bluish-grey, dense, weathers with a brown crust, fossiliferous.

- 0.5 (8) Limestone, dark blue, weathers grey to buff; contains many fusulinids.

- 1.0 (9) Shale, grey, clayey; fusulinids abundant.

- 0.2 (10) Limestone, dark blue-grey, weathers buff; fusulinids abundant.

- 0.8 (11) Shale, grey, clayey.

- 0.5 (12) Limestone, dark grey, dirty, impure, weathers to grey-yellow, fossiliferous.

## Doniphan shale member

- 1.9 (13) Shale, bluish-grey, clayey.

15.0 (14) Sandstone and shale, greenish-grey, ripple marked, cross-bedded; interbedded with grey, sandy shale.

13.0 (15) Covered.

Spring Branch limestone member

3.0 (16) Limestone, mottled, blue-grey to brown, algal, uneven upper surface, sparingly fossiliferous.

SECTION 33

Measured in road ditch along north-south county road in center sec. 21, T. 30 S., R. 11 E., Elk county, Kansas.

Lecompton limestone

Avoca limestone member

0.7 (1) Limestone, dirty, dark grey, weathers with a light brown crust, fossiliferous.

0.8 (2) Shale, grey to brown, clayey, fossiliferous.

0.2 (3) Limestone, thin, dark grey, weathers buff.

1.1 (4) Shale, grey, clayey, fossiliferous.

0.9 (5) Limestone, dark blue, dense, hard; one massive bed; contains abundant black Ottonosia.

0.9 (6) Shale, grey, fossiliferous.

0.7 (7) Shale and limestone, buff shale interbedded with buff, thin limestone plates.

4.1 (8) Limestone, bluish-grey, thin irregular beds, weathers to grey and buff; thin brown shale along the bedding planes; extremely fossiliferous.

King Hill shale member

10.6 (9) Shale, greyish-green and red, clayey.

Beil limestone member

9.5 (10) Limestone, massive, light grey to brownish weathering, irregular to wavy bedded; corals and fusulinids common.

SECTION 34

Measured in the abandoned quarry in SE $\frac{1}{4}$  sec. 12, T. 31 S., R. 10 E., Elk county, Kansas.

## Calhoun shale

- 2.9 (1) Shale, grey, clayey, partially covered.
- 1.9 (2) Limestone and shale, blue-grey, silty, micaceous, weathers to buff grey; interbedded with silty, hard, finely laminated shales.
- 4.6 (3) Shale, grey-brown, clayey, slightly micaceous, fossiliferous.

## Deer Creek limestone

## Ervine Creek limestone member

- 5.5 (4) Limestone, light grey, dense, thin irregular beds separated by grey-brown shale.
- 1.2 (5) Shale, bluish-grey, clayey; with a thin, blue, nodular limestone in the middle.
- 3.4 (6) Limestone and shale, alternating dark blue, thin, even bedded limestones and dark blue shales; fossiliferous, with the upper limestone containing Ottonosia.  
*Top limestone - 1877*
- 21.5 (7) Limestone, light grey to bluish, coarsely crystalline, highly fossiliferous; massive bedded below to thinner, irregular to wavy bedded above; weathers light grey to almost white below to grey above; stylolites common; marcasite clusters along bedding planes in middle; with black, thin, discontinuous shales along bedding planes in lower part.

SECTION 35

Measured from top of bench above low water bridge to water level of Elk River, SW $\frac{1}{4}$  sec. 12, T. 30 S., R. 10 E., Elk county, Kansas.

## Topeka limestone

## Coal Creek limestone member

- 0.3 (1) Limestone, thin bedded, light grey, weathers grey to white; Osagia and Triticites common.

- 2.2 (2) Limestone, light blue to grey, weathers to grey-buff, irregular to thin, wavy bedded; with thin, brown shale breaks between beds; Ottonosia in upper beds; fusulinids extremely abundant.
- 2.4 (3) Limestone, blue-grey, mottled, massive, wavy bedded, highly fossiliferous.
- 0.7 (4) Shale, grey to buff; with a few yellowish, calcareous stringers.
- 0.4 (5) Limestone, dense, blue-grey, hard, weathers to buff, fossiliferous.

Holt shale member ?

- 1.9 (6) Shale, dark grey to buff, clayey, blocky, contains several thin blue-grey limestone plates; fossiliferous.
- 1.5 (7) Shale, dark grey, weathers to light grey; contains three thin limestone plates which are covered with oriented Triticites and other fossils.
- 1.2 (8) Shale, blue-grey, finely laminated, silty, hard, sparingly fossiliferous.
- 12.5 (9) Shale, grey-blue above to grey, greenish and yellowish below, jointed, blocky above to more finely bedded below, sparingly fossiliferous.

Du Bois limestone member ?

- 0.4 (10) Limestone, dark blue to black, vertically jointed, tough; contains Lingula and Ostracods.

Turner Creek shale member ?

- 0.5 (11) Shale, brown, clayey.

Sheldon limestone member?

- 0.5 (12) Limestone, one bed, dense, mottled, blue-grey, contains Juresania.
- 0.3 (13) Shale, blue-grey, clayey.
- 0.3 (14) Limestone, dark grey, dirty, sandy, weathers dark grey.

Jones Point shale member

- 5.0 (15) Shale, bluish-green to grey and brown, clayey; contains several thin, impure limestone stringers.

## Curzon limestone member

- 0.6 (16) Limestone, dark grey to bluish, hard, dense, with Fusulinids.

## Hartford limestone member

- 4.1 (17) Limestone, massive, dark grey to buff, mottled, silty and sandy below; Neospirifer and Echinochonus common.

## Calhoun shale

- 2.8 (18) Shale, blue, silty, finely bedded, with thin calcareous sandstone plates.

## Deer Creek limestone

## Ervine Creek limestone member

- 2.7 (19) Limestone, light blue, micaceous, silty to sandy, vertically jointed, weathers to bluish-grey, interbedded with dark blue shales which contain several thin, discontinuous, nodular, blue limestones; highly fossiliferous.

SECTION 36

Measured along east-west county road in north-center sec. 10, T. 29 S., R. 10 E., Elk county, Kansas.

## Base of Burlingame limestone

Silver Lake shale

- 2.8 (1) Shale, clayey, grey above to greenish-grey below, contains several thin calcareous stringers.
- 1.7 (2) Limestone and shale, thin, light blue, fossiliferous limestones alternating with grey, clayey shales.
- 1.4 (3) Shale, grey, finely laminated.
- 0.9 (4) Limestone, light blue, hard above to buff, porous, "pseudoboxwork" below; with a few brown and buff limy pebbles in the upper part.
- 1.1 (5) Shale, grey, algal below, weathers reddish in part.

- 1.4 (6) Limestone, greenish-buff, silty; varies laterally from hard to a porous "boxwork".
- 2.9 (7) Shale, greenish-grey, clayey above to micaceous, silty below, finely laminated; contains a few buff, calcareous nodules in upper part.
- 28.9 (8) Shale, grey to blue above to yellowish-green below, streaked with orange, red, and black, jointed in part, silty to sandy throughout, gastropods common near top.
- Rulo limestone
- 0.6 (9) Limestone, shelly, dark grey, weathers to dark grey, sparingly fossiliferous.
- Cedar Vale shale
- 0.1 (10) Shale, grey, clayey, fossiliferous.
- 0.2 (11) Coal.
- 0.2 (12) Underclay, bluish-green, waxey.

### SECTION 37

Measured in road ditch of north-south county road in SW $\frac{1}{4}$  sec. 7, T. 29 S., R. 9 E., Elk county, Kansas.

- Elmont limestone
- 1.2 (1) Limestone, dark grey, dense, brittle, weathers light grey with some yellow splotches, fossiliferous.
- Harveyville shale
- 0.9 (2) Shale, grey to dark grey; with thin calcareous streaks above; becomes micaceous and silty below; fossils occur in pockets just below the overlying limestone.
- 2.2 (3) Shale, blue-grey to brownish, clayey, algal below.
- Reading limestone
- 4.0 (4) Limestone, grey to yellowish, hard, thin bedded, algal (Osagia).
- 3.2 (5) Shale, upper part bright yellow with irregular calcareous masses; lower part brown to greenish clay; sparingly fossiliferous.

- 1.6 (6) Limestone, massive, light grey, weathers to grey-buff, one bed; fusulinids and other fossils common.
- Auburn shale
- 4.6 (7) Shale, greenish-grey; clayey above to silty, micaceous, finely bedded below; contains calcareous plates near the top, pelecypods common.
- 0.8 (8) Shale, dark blue, micaceous, contains Linoproductus.
- 1.5 (9) Shale, buff, calcareous shale which laterally possesses a veinwork of resistant calcite which forms a "boxwork".
- 6.9 (10) Shale, grey, finely laminated; with occasional thin, calcareous, fossiliferous plates.
- 4.0 (11) Covered.
- 3.4 (12) Shale, blue-grey, clayey; with a few highly fossiliferous limestone stringers; contains a blue siltstone about a foot above the base.
- 0.7 (13) Limestone, light blue, hard, compact, weathers to blue-grey; contains large fenestellid bryozoans and many other fossils.
- 0.4 (14) Shale, brown, clayey; contains a persistent zone of well preserved Derbya.

### SECTION 38

Measured in road ditch along east-west county road in SE $\frac{1}{4}$  sec. 5, T. 31 S., R. 10 E., Elk county, Kansas.

Base of Burlingame limestone

Silver Lake shale

- 13.5 (1) Covered.
- 22.8 (2) Shale, yellow to reddish-brown, and grey, sandy, micaceous; upper part is hard, finely bedded; lower part contains nodular, grey sandstones and is prominently jointed.
- Rulo limestone
- 1.2 (3) Limestone, dark grey, dirty, weathers grey to brownish, shelly, algal, fossiliferous.

## Cedar Vale shale

- 0.8 (4) Shale, grey, calcareous, fossiliferous; with a few plant fragments in lower part.
- 0.1 (5) Coal, irregular, very smutty.

SECTION 39

Measured in road ditch of north-south county road in NE $\frac{1}{4}$  sec. 6, T. 31 S., R. 10 E., Elk county, Kansas.

## Wakarusa limestone

- 4.9 (1) Limestone, dark grey, hard, brittle, weathers grey to buff, irregular thin beds separated by thin shales; Ottonosia, Somphospongia?, and fusulinids common.

## Soldier Creek shale

- 3.4 (2) Shales, blue-grey, streaked with yellow, clayey.

## Burlingame limestone

- 3.3 (3) Limestone, hard, thin bedded, irregular, mottled, blue-grey above to grey below; weathers grey above to yellowish below; very fossiliferous.
- 2.2 (4) Shale, grey to dark grey, finely bedded; contains several thin silty limestone stringers; algal and fossiliferous.
- 0.3 (5) Limestone, thin, hard, dark blue, weathers dark grey; pelecypods and productid brachiopods common.
- 2.4 (6) Shale, purplish-green to reddish, algal.
- 1.2 (7) Limestone, earthy, veined, bright yellow weathering, "boxwork".
- 4.9 (8) Shale, green to red and purple; interbedded with buff, thin, nodular limestones.

SECTION 40

Measured in creek bank at north end of low water bridge,  
NW $\frac{1}{4}$  sec. 9, T. 30 S., R. 10 E., Elk county, Kansas.

## Howard limestone

## Aarde shale member

- 0.6 (1) Coal.
- 0.2 (2) Underclay, bluish-grey to yellow, mottled, waxy,
- 0.3 (3) Shale, yellow-brown, clayey; contains concretions.

## Bachelor Creek limestone member

- 4.0 (4) Limestone, light blue, hard, dense, massive, weathers buff, sparingly fossiliferous.

SECTION 41

Measured in road ditch of north-south county road in  
SE $\frac{1}{4}$  sec. 11, T. 30 S., R. 10 E., Elk county, Kansas.

## Howard limestone

## Aarde shale member

- 0.4 (1) Coal.
- 2.2 (2) Underclay, grey to yellowish, blocky, waxy; lower part is covered.

## Bachelor Creek limestone member

- 3.7 (3) Limestone, light bluish-grey, hard, massive, micaceous, sandy to silty, weathers grey to buff; upper bed is less silty and fossiliferous.

## Severy shale

- 3.5 (4) Shale, grey, sandy, micaceous; contains some hard, dark grey plates.
- 21.0 (5) Shale and siltstone, dark blue to grey, hard, micaceous siltstones alternating with grey to buff, platy, silty to sandy shale.
- 41.0 (6) Shale, finely bedded, grey; silty above to clayey below; jointed in part; partially covered.

- 2.0 (7) Shale, grey to red, clayey.  
 4.0 (8) Shale, grey to dark grey, clayey.

Top of Topeka limestone.

#### SECTION 42

Measured in creek bank just below the bridge and up to road level, SW $\frac{1}{4}$  sec. 11, T. 29 S., R. 10 E., Elk county, Kansas.

Howard limestone

Utopia limestone member

- 4.7 (1) Limestone, thin, irregular bedded, dark grey, dirty, weathers to orange and brown, sparingly fossiliferous; lower part not well exposed.

Church limestone member

- 2.1 (2) Limestone, massive, bluish-grey, weathers to rich brown.

Aarde shale member

- 3.5 (3) Shale, greenish-grey above to black below; finely bedded; with plant fragments common in the lower part.

- 0.3 (4) Coal.

- 1.3 (5) Shale, greenish-grey to yellowish, upper part appears to be an underclay.

Bachelor Creek limestone member

- 2.7 (6) Limestone, massive, hard, dense, bluish-grey, silty, slightly micaceous, weathers to dark grey.

#### SECTION 43

Measured in road cut of north-south county road in SW $\frac{1}{4}$  sec. 25, T. 29 S., R. 10 E., Elk county, Kansas.

Howard limestone

Church limestone member

- 2.3 (1) Limestone, dark blue, weathers rich orange-brown; contains Ottonosia above and small fusulinids below.

Aarde shale member

- 0.4 (2) Shale, grey to dark grey, clayey.

- 0.2 (3) Coal.

- 1.0 (4) Underclay, greenish-yellow and grey, waxy, shaly below.

Bachelor Creek limestone member

- 3.4 (5) Limestone, light to dark blue, blotchy, silty, micaceous, hard, weathers dark grey.

#### SECTION 44

Measured in road ditch and creek bottom in north-center sec. 16, T. 30 S., R. 10 E., Elk county, Kansas.

Base of Happy Hollow limestone

White Cloud shale

- 31.0 (1) Shale, grey to yellowish-grey above to bluish-green and grey below; clayey in lower part to sandy and silty above; jointing common.

- 0.9 (2) Limestone, shelly, grey to black, slightly silty; contains many black specimens of Ottonosia.

- 0.1 (3) Shale, grey to dark grey, calcareous.

- 0.4 (4) Limestone, dark grey, hard, fossiliferous.

- 7.0 (5) Shale, grey, clayey, finely bedded.

- 12.0 (6) Shale, covered.

Howard limestone

Utopia limestone member

- 4.8 (7) Limestone, dark blue-grey, weathers to rust-brown, thin, irregular plates, algal, fossiliferous.

~~Fl. position~~

Its position in reference to the  
River valley suggest correlation  
with the Wiggam terrace along  
Collymore at North River further  
north in Kansas (O'Connor 1952, p. 1)

## Winzeler shale member

- 1.6 (8) Shale, yellow-brown, clayey; partially covered.

## Church limestone member

- 255 (9) Limestone, massive, light blue, weathers to deep brown; contains Ottonosia.

## Aarde shale

- 0.4 (10) Shale, grey, clayey.  
 1.2 (11) Shale, black, fissile.  
 0.3 (12) Limestone, dark grey, hard, one bed, weathers to light grey; corals common.  
 0.5 (13) Shale, grey.  
 0.5 (14) Coal.  
 1.3 (15) Underclay, yellow to greenish-grey, waxy.

SECTION 45

Measured along east-west county road in south-center sec. 27, T. 28 S., R. 10 E., Elk county, Kansas.

## Wakarusa limestone

- 2.1 (1) Limestone, blue-grey, mottled, irregular to slabby bedded, weathers light buff to brown; Ottonosia and Triticites common.

## Soldier Creek shale

- 2.6 (2) Shale, blue-grey, clayey.

## Burlingame limestone

- 2.1 (3) Limestone, light blue to brownish, one massive bed, weathers to rich brown, algal top, fusulinids common.

## Silver Lake-Cedar Vale shale

- 2.4 (4) Shale, brown, calcareous; with a few thin limestone stringers.

- 5.6 (5) Shale, greenish-grey, silty to sandy; with several thin, fossiliferous limestones.
- 0.2 (6) Limestone, light blue to brown, mottled, fossiliferous.
- 5.2 (7) Shale, brown to grey with a few thin, bluish limestones.
- 1.1 (8) Coal, smutty; in two or three thin streaks separated by various colored clays.
- 23.0 (9) Shale, finely bedded; greenish-grey above to grey micaceous and sandy below.
- 8.0 (10) Covered.
- 3.6 (11) Sandstone, fine grained, thin bedded, light brown to rust brown weathering.
- 7.0 (12) Shale, grey, micaceous, sandy.
- 6.0 (13) Shale, grey to grey-brown, clayey.
- 6.0 (14) Covered.

Happy Hollow limestone

- 3.7 (15) Limestone, light grey to mottled, weathers pinkish-brown; irregular massive bedded below to thin bedded above; fossiliferous.
- White Cloud shale
- 20.0 (16) Shale, grey above to dark grey and bluish below, finely bedded; base not exposed.

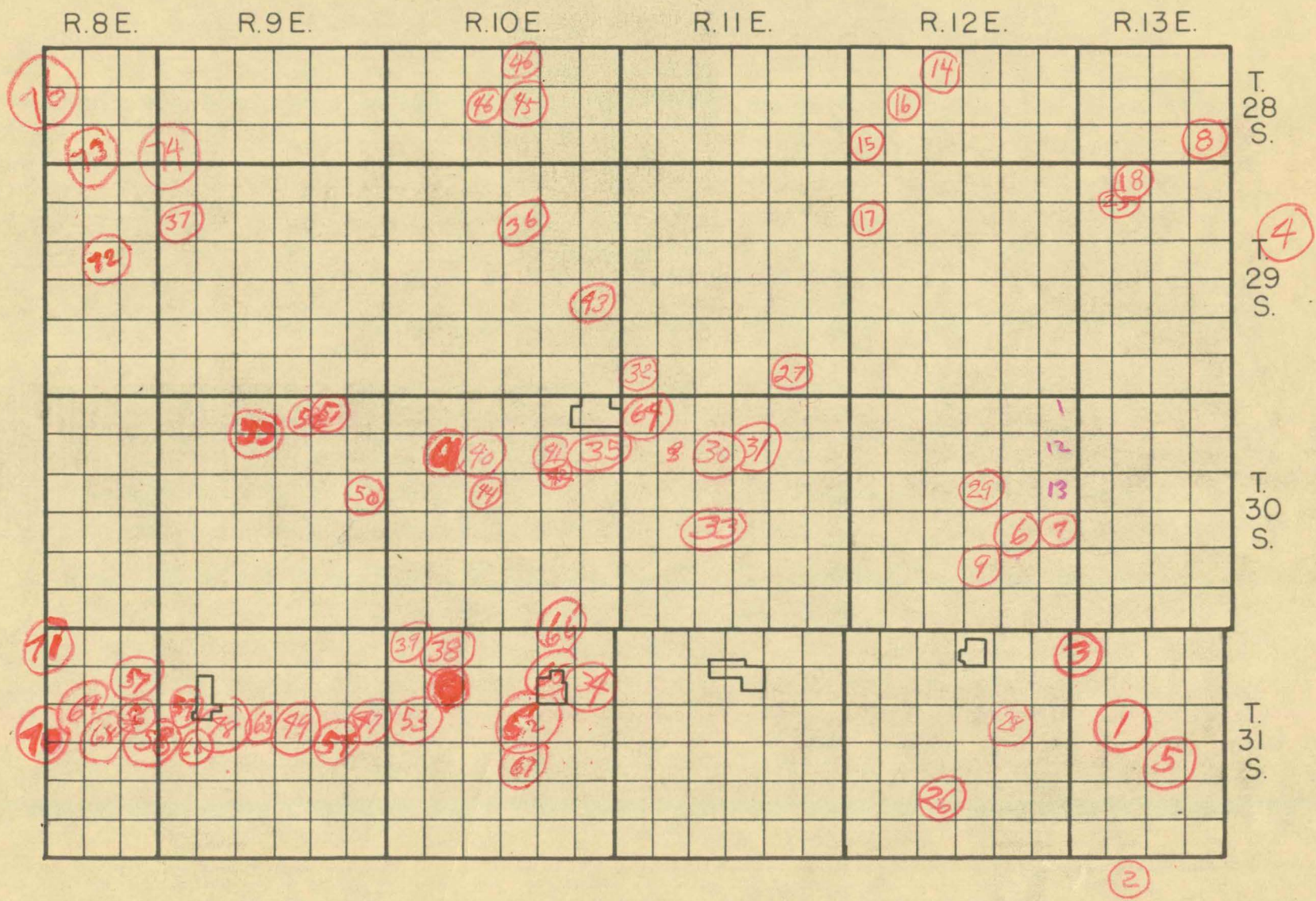
SECTION 46

Measured along north-south county road in NW $\frac{1}{4}$  sec. 22, T. 28 S., R. 10 E., Elk county, Kansas.

Reading limestone

- 1.0 (1) Limestone, light blue-grey, weathers grey with yellow and brown splotches, algal, fossiliferous.
- 1.0 (2) Limestone, rich yellow-brown to dark brown; not well exposed.
- 4.5 (3) Shale, covered.

ELK



- 1.7 (4) Limestone, blue-grey, hard, weathers to grey and buff, massive bedded, fossiliferous.
- Auburn shale
- 2.8 (5) Shale, blue-grey, clayey.
- 1.7 (6) Shale, brown to grey, platy, micaceous, silty to sandy.
- 0.5 (7) Limestone, blue, weathers grey-buff, soft, earthy; contains abundant pelecypods.
- 0.6 (8) Shale, grey, clayey; with a thin, blue, fossiliferous limestone in the middle.
- 2.3 (9) Shale, brown; contains numerous thin, buff limestone plates; algal.
- 9.0 (10) Shale, grey, clayey, finely bedded.
- 21.0 (11) Shale, grey, mostly covered.

389 Wakarusa limestone

- 2.0 (12) Limestone, blue-grey, slabby, weathers brown; contains Ottonosia and fusulinids.

Soldier Creek shale

- 3.5 (13) Shale, blue-grey, clayey.

Burlingame limestone

- 2.2 (14) Limestone, light grey, mottled with brown, weathers to yellow-brown; contains abundant Osagia and fusulinids.

SECTION 47

Measured along US Highway 160 in NE $\frac{1}{4}$  sec. 13, T. 31 S., R. 9 E., and NW $\frac{1}{4}$  sec. 18, T. 31 S., R. 10 E., Elk county, Kansas.

Elmont limestone

- 1.5 (1) Limestone, dark blue, platy, somewhat cross-bedded, highly crinoidal, weathers brown to dark buff.

## Harveyville shale

- 10.3 (2) Shale, grey to blue-grey; streaked above; yellowish, micaceous, and sandy below.

## Reading limestone

- 3.6 (3) Limestone, upper part dense, hard, blue, weathers with a light brown crust; lower part light buff to yellow, algal; fossiliferous throughout.

## Auburn shale

- 7.4 (4) Shale, brown above; to grey, finely bedded, micaceous, silty to sandy below.
- 1.9 (5) Limestone, thin, blue, dense, silty, fossiliferous; interbedded with a minor amount of grey, micaceous shale.
- 1.9 (6) Limestone, pinkish-brown, algal, silty, "pseudo-boxwork"; contains abundant productid brachiopods.
- 8.1 (7) Shale and limestone, alternating beds of brown shale and blue, dense, dirty, nodular limestones.
- 0.1 (8) Limestone, thin, brown-grey; coquina of brachiopod fragments.
- 1.6 (9) Shale, grey, finely laminated.
- 0.4 (10) Siltstone, blue, dense, nodular.
- 0.4 (11) Shale, grey-brown; with a veinwork of calcite.
- 0.6 (12) Siltstone, blue-grey, dense, hard; with a distinct set of vertical joints.
- 7.0 (13) Shale, grey; calcareous above to blue-grey and yellowish below; contains a persistent zone of Derbya about one foot below the top.
- 4.8 (14) Shale, red to purple; streaked with green and yellow.

## Wakarusa limestone

- 1.9 (15) Limestone, light blue-grey, dense, hard, weathers to rust-brown and yellow; contains abundant fusulinids and Ottonosia.
- 3.5 (16) Shale, grey to dark grey.

- 2.3 (17) Limestone, light blue, dense, hard, yellow-brown weathering; contains fusulinids and Ottonosia.

Soldier Creek shale

- 1.7 (18) Shale, grey, clayey.

- 1.4 (19) Limestone, light buff to orange-brown, algal, rotten, "pseudoboxwork".

- 0.9 (20) Shale, alternating buff and grey, calcareous, hard, algal.

Burlingame limestone

- 2.0 (21) Limestone, thin bedded, mottled, grey, weathers light grey to rust-brown; contains fusulinids and Osagia.

Silver Lake shale

- 2.1 (22) Shale, grey, platy, hard, algal; contains abundant pelecypods.

- 1.3 (23) Limestone and shale, alternating thin, blue, light grey, impure limestones and grey to greenish shale.

- 2.2 (24) Limestone and shale, brown, rotten, "boxwork" limestones interbedded with grey to buff shales.

- 2.0 (25) Shale, green, clayey, algal.

- 0.6 (26) Limestone, dark grey, dirty, hard, algal, coarsely crystalline, mottled; contains a few siltstone pebbles and abundant Osagia.

- 2.5 (27) Shale, grey, streaked with blue-green.

#### SECTION 48

Measured along east-west county road, center of the south line of sec. 17, T. 31, S., R. 9 E., Elk county, Kansas.

Elmont limestone

- 1.9 (1) Limestone, dark grey, thin bedded, slightly cross-bedded, crinoidal.

Harveyville shale

- 5.8 (2) Shale, grey-blue, clayey; contains small nodules.

- 0.4 (3) Limestone, thin, nodular, silty, yellow to orange, "boxwork".
- 1.5 (4) Shale, grey to greenish, fossiliferous.
- 0.2 (5) Limestone, blue-green, veined, somewhat silty, fossiliferous.
- 0.2 (6) Shale, grey, clayey.
- 0.4 (7) Limestone, dense, blue-green, irregular bedded, weathers buff.
- 0.2 (8) Shale, grey-brown.
- Reading limestone
- 1.6 (9) Limestone, dark-blue, hard, dense, massive, vertically jointed, weathers to yellow-buff; contains abundant fusulinids.

#### SECTION 49

Measured in roadcuts of east-west and north-south county roads in SW $\frac{1}{4}$  sec. 15, T. 31 S., R. 9 E., Elk county, Kansas.

#### Jim Creek limestone

- 0.9 (1) Limestone, dark blue, dense, massive, weathers to light grey; contains abundant large fusulinids.

#### Friedrich shale

- 660 (2) Shale, grey, sandy; almost all covered.
- 3.9 (3) Sandstone, massive, irregular bedded, brownish-grey, speckled with brown, micaceous.
- 18.0 (4) Shale, sandy, grey; micaceous above to bluish-grey, blocky below; streaked with yellow; upper part is partially covered.

#### Grandhaven limestone

- 1.0 (5) Limestone, dark grey to bluish, shelly, weathers to dark brown, fossiliferous.
- 1.1 (6) Shale, brown, streaked with orange and blue, fossiliferous.

- 0.2 (7) Coal.
- 2.3 (8) Shale, grey, partially covered.
- 0.4 (9) Limestone, dark blue to dirty grey, shelly, fossiliferous, weathers to rust-brown.
- Dry shale
- 6.6 (10) Shale, grey to brown, calcareous; with a thin coal streak about 1.5 feet below the top; contains abundant Myalina.
- Dover limestone
- 1.8 (11) Limestone, dense, dark blue, weathers to light brown, sandy to silty above, sparingly fossiliferous.
- 17.0 (12) Shale, brown to bluish-grey, calcareous; contains a few nodules; almost all covered.
- 0.9 (13) Limestone, dense, dark blue-grey, massive; contains abundant Ottonosia and slender Triticites.

#### SECTION 50

Measured along east-west county road, north line of sec. 24, T. 30 S., R. 9 E., from  $\frac{1}{4}$  to  $\frac{1}{2}$  mile west of section corner, Elk county, Kansas.

#### Grandhaven limestone

- 0.5 (1) Limestone, dense, hard, fine texture, weathers rust-brown, unfossiliferous.
- 9.5 (2) Shale, covered.
- 0.5 (3) Limestone, light blue to grey, one massive bed, weathers to bright buff-orange.
- Dry shale
- 6.6 (4) Shale, grey to brown; mostly covered.
- Dover limestone
- 1.9 (5) Limestone, dense, light blue to brown, weathers brown, two massive beds, no fossils seen.
- 11.4 (6) Shale, grey to brown above, greenish below; partially covered.

- 0.8 (7) Limestone, dark grey, weathers to light buff, massive but breaks down to thin slabs; contains Ottonosia and slender fusulinids.
- 8.0 (8) Shale, brown to grey, streaked with blue-green.
- 1.6 (9) Limestone, one massive bed, light blue, weathers blue to light buff; contains abundant Chonetes and other fossils.
- Willard-Langdon shale
- 0.5 (10) Shale, brown, streaked with blue-grey and yellow.
- 1.8 (11) Shale, grey to almost black, calcareous, hard; contains Myalina.
- 0.7 (12) Coal.

#### SECTION 51

Measured in stream bank just above bridge in NW $\frac{1}{4}$  sec. 2, T. 30 S., R. 9 E., Elk county, Kansas.

#### Reading limestone

- 2.3 (1) Limestone, massive, blue-grey, vertically jointed, weathers buff; contains abundant fusulinids in middle and lower parts.
- 2.6 (2) Shale, blue-grey above to bluish-black below.
- 0.9 (3) Limestone, light grey, algal, weathers to grey and white.
- 0.5 (4) Shale, greenish-grey, clayey, blocky.
- 3.7 (5) Limestone, blue-grey, nodular; thin beds above separated below from a very massive, buff to dark grey weathering bed by a thin grey-brown, fossiliferous shale.

SECTION 52

Measured in roadcut along the southwest side of sec. 2, T. 30 S., R. 9 E., Elk county, Kansas.

## Dover limestone

- 0.8 (1) Limestone, blue-grey, one massive bed, weathers light buff; contains slender Triticites and Ottonosia.
- 7.3 (2) Shale, grey to brown, clayey.
- 0.3 (3) Shale, paper thin, calcareous; interbedded with brown shale; fossiliferous.
- 1.2 (4) Limestone, dense, dark blue-grey, weathers to buff-yellow, fossiliferous.

## Willard-Langdon shale

- 0.7 (5) Shale, brown; contains abundant Myalina.
- 1.4 (6) Shale, dark grey, calcareous, platy to nodular, abundantly fossiliferous.
- 0.2 (7) Coal.
- 0.5 (8) Limestone, dark grey, weathers light grey, argillaceous, slabby; contains abundant plant remains.
- 0.2 (9) Coal.
- 0.3 (10) Limestone, dark grey to purplish, weathers to dark buff, lenticular; contains plant remains; passes laterally into iron stained nodules and bluish-grey clay.
- 2.6 (11) Shale, bluish-grey, clayey, finely laminated, grey-brown below; contains a thin coal streak about .7 feet below the top.
- 1.4 (12) Limestone, soft, earthy, veined with calcite, "boxwork", orange-buff.
- 3.4 (13) Shale, greenish-grey, clayey; contains a few iron stained nodules in the upper part.

**Elmont limestone**

- 1.7 (14) Limestone, blue-grey, dirty, weathers buff with reddish areas, highly fossiliferous; contains abundant, long, slender Triticites.

**Harveyville shale**

- 2.7 (15) Shale, blue-grey, clayey.
- 4.6 (16) Shale and sandstone, blue-grey shale interbedded with grey, micaceous, sandy shale; contains a thin grey to buff, fine grained sandstone about a foot above the base which overlies a thin coaly streak.

Top of Reading limestone.

**SECTION 53**

Measured along north-south county road along the northwestern edge of sec. 19 and the southwestern edge of sec. 18, T. 31 S., R. 10 E., Elk county, Kansas.

**Elmont limestone**

- 5.1 (1) Limestone, grey to bluish-grey, weathers dark grey, thin bedded, slightly cross-bedded, crinoidal.

**Harveyville shale**

- 3.2 (2) Shale, grey, clayey, finely bedded; contains algal nodules in lower part.
- 2.0 (3) Shale, red and green, clayey.
- 6.4 (4) Shale, greenish-grey, mostly covered.

**Reading limestone**

- 2.5 (5) Limestone, dark blue, dense, hard, weathers dark grey to buff, vertically jointed, brittle; contains abundant Triticites.
- 0.5 (6) Shale, buff.
- 1.7 (7) Limestone, irregular bedded, buff to yellowish, algal, fossiliferous.

**Auburn shale**

- 5.0 (8) Shale, brown to grey, silty and micaceous below; upper part fossiliferous.

- 3.8 (9) Shale, grey, micaceous.
- 23.0 (10) Limestones and shales, this interval is only partially exposed and consists of thin, blue-grey, pelecypod bearing limestones and blue siltstones interbedded with shales.

Wakarusa limestone

- 4.3 (11) Limestone, dark grey to bluish, massive but irregular bedded above, thin bedded below, weathers to grey-buff; contains algae, fusulinids, and other fossils.

SECTION 54

Measured in road ditch along east-west county road along the southeastern edge of sec. 14, T. 31 S., R. 9 E., Elk county, Kansas.

Dover limestone

- 1.9 (1) Limestone, blue-grey, weathers yellowish-grey, thin irregular bedded below to rather massive above, algal; highly fossiliferous in the lower part.
- 10.5 (2) Shale, brown-grey above to bluish-grey below, clayey; highly fossiliferous about three feet above the base.
- 0.8 (3) Limestone, one massive bed, dirty, dark grey, weathers buff to dark grey; contains abundant Ottonosia and slender Triticites.
- 2.6 (4) Shale, grey, clayey; with streaks of brown and blue.
- 1.8 (5) Limestone, dark blue to grey, weathers bright orange, massive but usually breaks down into two or three beds, highly fossiliferous.

Willard-Langdon shale

- 0.5 (6) Shale, brown, fossiliferous.
- 0.6 (7) Limestone, grey, thin bedded; contains large Neospirifer and Myalina.
- 0.5 (8) Shale, grey; with occasional brown streaks; Myalina common.

- 0.3 (9) Coal.
- 0.5 (10) Underclay, bluish-grey, iron stained.
- 4.6 (11) Shale, greenish-grey, blocky to finely laminated; contains yellow streaks.
- Elmont limestone
- 3.7 (12) Limestone, grey to bluish, thin bedded, slabby, slightly cross-bedded, highly fossiliferous, crinoidal.

### SECTION 55

Measured in the NE $\frac{1}{4}$  sec. 9 and along the north-south county road along the southeastern edge of sec. 4, T. 30 S., R. 9 E., Elk county, Kansas.

Foraker limestone

Americus limestone member

- 1.4 (1) Limestone, bluish-grey, massive, weathers light grey, fusulinids and other fossils common.
- 3.7 (2) Shale, covered.
- 1.8 (3) Limestone, dark blue, massive above, limonite stained; with small tan and blue pebbles common in the lower part; fossiliferous.

Hamlin shale

Oaks shale member

- 6.0 (4) Shale, brown above to grey-yellow below, almost black at the base, algal near the top; with many small fossils in a hard, calcareous plate at the base.

Houchen Creek limestone member

- 2.4 (5) Limestone, thin bedded, very shaly, silty, buff to yellowish, calcite veins common, "boxwork".

Stine shale member

- 6.3 (6) Shale, grey to greenish, finely bedded, streaked with orange and yellow.
- 19.0 (7) Shale, purple, reddish, green and yellow; with a yellow, nodular siltstone just above the middle.

- 4.8 (8) Shale, yellow to orange, platy.
- 5.5 (9) Shale, greenish-grey, blocky, clayey.  
Five Point limestone
- 1.9 (10) Limestone, massive, grey-brown, yellow to orange weathering, fusulinids very abundant.  
West Branch shale
- 24.0 (11) Shale, green to yellowish, grey weathering above to dark grey and bluish below; contains a thin coal 14 feet below the top.
- 3.0 (12) Limestone, buff to yellowish, weathers yellow-brown; with numerous calcite veins.
- 10.9 (13) Shale, light grey to greenish, micaceous, silty, finely bedded above to dark grey below; contains a thin, dark grey nodular limestone about two feet above the base.  
Falls City limestone
- 3.2 (14) Limestone, dark bluish-grey, dirty, weathers to yellow-orange, nodular above to massive below, sparingly fossiliferous.  
Hawxby shale
- 6.4 (15) Shale, dark grey above to purple, green, and yellow below; with a thin, bluish-grey, nodular, algal limestone just above the middle.  
Aspinwall limestone
- 10.8 (16) Limestone, upper part thin bedded, brown, light yellow weathering; lower part consists of alternating beds of grey to buff shales and thin, blue, fossiliferous limestones.  
Towle shale
- 11.0 (17) Shale, dark grey above to yellow-brown below, algal; discolored zone about two feet above the base.  
Brownville limestone
- 1.7 (18) Limestone, grey, dense, massive above, weathers grey to yellow-brown, fusulinds and other fossils common.

## Pony Creek shale

- 17.5 (19) Shale, grey and brown above to blue-green and yellow below; with a thin coal 8.8 feet below the top.

## Caneyville limestone

## Grayhorse limestone member

- 1.5 (20) Limestone, thin bedded, platy to slabby, slightly cross-bedded, dark grey, weathers to light grey and buff, pelecypods common.

The interval from the base of the Grayhorse limestone to the top of the Nebraska City limestone is approximately 25 feet thick.

## Nebraska City limestone member

- 0.9 (21) Limestone, one massive bed, dark bluish-grey, weathers yellowish; fusulinds and razor clams are the most common fossils.

## French Creek shale

- 11.0 (22) Shale, yellow-grey, micaceous, silty, streaked with orange.
- 13.7 (23) Sandstone, dark grey to yellowish-brown, limonite stained, micaceous, fine grained, massive below to thin bedded above, cross-bedded below; sharp contact with shale below suggests channeling.
- 11.4 (24) Shale, bluish-black, micaceous, very finely bedded, hard; with orange streaks along bedding planes.

## Jim Creek limestone

- 0.8 (25) Limestone, one massive bed, dark blue, dirty, weathers grey to purplish, fossiliferous.

SECTION 56

Measured along US Highway 160 about one-fourth mile west of Santa-Fe Railroad crossing, NW $\frac{1}{4}$  sec. 13, T. 31 S., R. 8 E., Elk county, Kansas.

## Brownville limestone

- 2.0 (1) Limestone, very massive bed, light grey, weathers to a cream yellow, highly fossiliferous; with large crinoid stems, Chonetes, and Triticites common.

## Pony Creek shale

- 4.2 (2) Shale, greenish-grey, finely laminated; contains yellow streaks.
- 0.5 (3) Limestone, yellow, algal, weathers to creamy yellow.
- 3.0 (4) Shale, green to grey, clayey.

SECTION 57

Measured at eastern edge of stock pond 0.3 miles north and 0.1 mile east of Santa Fe Railroad crossing over US Highway 160, SW $\frac{1}{4}$  sec. 12, T. 31 S., R. 8 E., Elk county, Kansas.

## Caneyville limestone

- 0.5 (1) Limestone, dark grey, weathers to yellow and rust brown, fossiliferous, two thin beds, Triticites common.
- 3.4 (2) Shale, greenish-grey above to brown below, clayey.
- 1.0 (3) Limestone, dark blue, weathers buff; three thin, irregular beds; highly fossiliferous.
- 1.3 (4) Shale, dark grey, micaceous, irregularly laminated; contains a few calcareous nodules, Myalina common.
- 1.6 (5) Limestone, dense, dark blue, weathers to grey-buff, lenticular; contains some yellow siltstone pebbles in lower part; passes laterally into shales and siltstones.
- 4.6 (6) Shale, dark grey to bluish, sandy, micaceous, finely bedded; contains some woody streaks and hard siltstone nodules.

SECTION 58

Measured in ditch of US Highway 160 in NE $\frac{1}{4}$  sec. 13, T. 31 S., R. 8 E., Elk county, Kansas.

## Caneyville limestone

- 23.0 (1) Shale, grey, buff, and yellow, micaceous, silty to sandy, finely laminated; highly jointed in the upper part.

## Nebraska City limestone member

- 1.2 (2) Limestone, bluish-grey, hard, dense, weathers buff with purplish splotches, fossiliferous; with fusulinids and Aviculopinna common.

SECTION 59

Measured just west of the bridge across Caney Creek, NW $\frac{1}{4}$  sec. 18, T. 31 S., R. 9 E., Elk county, Kansas.

## Caneyville limestone

## Nebraska City limestone member

- 1.2 (1) Limestone, dark grey to brownish, three beds, weathers to yellow-brown, fusulinids common.

## French Creek shale

- 3.8 (2) Shale, grey to greenish, slightly micaceous, clayey.
- 4.0 (3) Shale, light yellow to buff, silty, finely laminated, micaceous.
- 9.8 (4) Sandstone, massive to fine bedded, fine grained, micaceous, dark grey, dirty; slightly cross-bedded in the middle; base is sharp and represents channeling.
- 16.0 (5) Shale, tan and bluish-green above to bluish-black, fissile, and grey below, micaceous and sandy.

## Jim Creek limestone

- 1.0 (6) Limestone, bluish-grey, hard, weathers to brown with purplish tinge; fusulinids, Myalina, and other fossils common.

## Friedrich shale

- 0.6 (7) Shale, grey to brown; Crurithyris common.
- 0.6 (8) Coal.

SECTION 60

Measured just below the Santa Fe Railroad bridge across Caney Creek, SE $\frac{1}{4}$  sec. 18, T. 31 S., R. 9 E., Elk county, Kansas.

## Dover limestone

- 0.4 (1) Limestone, dark blue, earthy, weathers dark grey, one bed; contains slender Triticites and Ottonosia.
- 3.0 (2) Shale, brownish clay above to dark-grey and bluish clay below, streaked with orange.
- 0.9 (3) Limestone, one massive bed, blue, weathers to buff, highly fossiliferous.

## Willard-Langdon shale

- 3.6 (4) Shale, grey, clayey above to calcareous below; upper part fossiliferous.
- 0.2 (5) Coal.

SECTION 61

Measured just west of the bridge across the Elk River in north-center sec. 8, T. 30 S., R. 10 E., Elk county, Kansas.

## Happy Hollow limestone

- 10.8 (1) Limestone, buff to grey, mottled, massive below to thin, irregular bedded above; highly algal in upper part; robust Triticites and Csagia common.

SECTION 62

Measured along north-south county road in the extreme southwestern corner of sec. 15, T. 31 S., R. 10 E., Elk county, Kansas.

## Howard limestone

## Utopia limestone member

- 7.4 (1) Limestone, thin, irregular beds of dense, dark grey, hard, dirty grey weathering; lower two or three beds are separated by grey shales; sparingly fossiliferous.

## Winzeler shale member

- 0.5 (2) Shale, grey; poorly exposed.

## Church limestone member

- 1.8 (3) Limestone, two massive beds, dark blue, hard, dense, weathers buff, fossiliferous; Triticites rare.

## Aarde shale member

- 1.5 (4) Shale, blue-grey, clayey, fossiliferous.  
 0.7 (5) Limestone, blue-grey; contains Chonetes.  
 0.3 (6) Shale, grey, clayey.  
 0.2 (7) Coal.  
 3.0 (8) Shale, upper few inches are a waxy, blue-grey underclay; lower part grey, mottled clay; partially covered.

Upper part of the Bachelor Creek limestone member.

SECTION 63

Measured along US Highway 160, center of the north line of sec. 16, T. 31 S., R. 9 E., Elk county, Kansas.

## Dover limestone

- 16.0 (1) Shale, grey, streaked with blue and yellow, clayey; middle part is fossiliferous.  
 0.6 (2) Limestone, grey, weathers brown-grey, one bed; contains slender Triticites and Ottonosia.  
 5.5 (3) Shale, grey below to brown above, streaked with blue-green and yellow, clayey.  
 0.9 (4) Limestone, massive, light blue, weathers buff to bluish, fossiliferous.

SECTION 64

Measured along county road in SE $\frac{1}{4}$  sec. 6, T. 30 S., R. 11 E., Elk county, Kansas.

## Topeka limestone

## Coal Creek member

- 8.7 (1) Limestone, brown to grey, buff weathering, irregular to wavy bedded; beds average about 6 inches in thickness; brown shale along bedding planes; highly fossiliferous.

Holt-Jones Point shale

- 2.4 (2) Shale, blue-grey, clayey; Rhombopora common.
- 3.6 (3) Limestone and shale, soft, argillaceous, brown to buff, highly fossiliferous, thin limestones interbedded with highly fossiliferous grey shales.
- 3.2 (4) Shale, blue-grey, somewhat fissile, highly fossiliferous; with a few thin, buff weathering limestone plates.
- 11.0 (5) Shale, covered.
- 1.0 (6) Limestone, dark blue, dense, single bed, algal.
- 2.0 (7) Limestone, irregular bedded, light grey, weathers buff, mottled, algal.
- 3.0 (8) Shale, yellow to grey, clayey, mostly covered.

Curson limestone member ?

- 1.0 (9) Limestone, grey, mottled, massive; contains large Neospirifer and large Triticites.
- 12.0 (10) Shale, covered. (This interval represents the Hartford limestone member of the Topeka limestone and the Calhoun shale.)

Deer Creek limestone

Ervine Creek limestone member

- 10.0 (11) Limestone, blue-grey, coarsely crystalline, hard, weathers grey to white, irregular to wavy bedded; minor amounts of yellow-brown clay along the bedding planes; Syringopora common.

SECTION 65

Composite section measured in sec. 11, T. 31 S., R. 10 E., Elk county, Kansas.

## Topeka limestone

## Coal Creek limestone member

- 4.8 (1) Limestone, dark grey, weathers to grey-buff, irregular to wavy bedded, highly fossiliferous.
- 0.5 (2) Shale, yellow-grey, calcareous, sparingly fossiliferous.
- 0.8 (3) Limestone, blue-grey, mottled, thin, irregular beds, weathers to rich yellow, very fossiliferous.

## Holt shale member

- 3.6 (4) Shale, grey-yellow, clayey, highly fossiliferous.
- 13.6 (5) Shale, grey to bluish; with occasional thin, coquinoïd limestone plates; all very highly fossiliferous.
- 0.8 (6) Limestone, dirty, grey to greenish, thin, irregular plates, weathers brown, sparingly fossiliferous.
- 4.3 (7) Shale, green to grey, clayey.

## Du Bois limestone member ?

- 0.7 (8) Limestone, dark blue, dense, hard, vertically jointed; contains Lingula and numerous ostracods.

## Sheldon limestone member ?

- 2.9 (9) Limestone, irregular bedded, weathers mottled, grey to brown; separated from above bed of Lingula limestone by a very thin brown shale.

SECTION 66

Measured along east-west county road in the center of the south line of sec. 2, T. 31 S., R. 10 E., Elk county, Kansas.

## Topeka limestone

## Du Bois limestone member ?

- 0.7 (1) Limestone, dark grey, dirty, weathers grey with a cream yellow crust, hard, massive, vertically jointed; tends to split into three beds upon weathering; contains Lingula, ostracods, and small gastropods.

## Turner Creek shale member ?

- 0.4 (2) Shale, blue-grey, clayey.

## Sheldon limestone member ?

- 0.9 (3) Limestone, grey-buff, mottled, weathers cream yellow, three irregular beds, somewhat nodular, fossiliferous in lower part.

## Jones Point shale member ?

- 2.6 (4) Shale, buff to grey, calcareous; partially covered.

## Curzon limestone member

- 1.1 (5) Limestone, massive, dark blue to grey, weathers dark grey, very fossiliferous; contains large Triticites.

## Hartford limestone member

- 4.1 (6) Limestone and shale, buff to grey, micaceous, mottled, very sandy, lenticular; interbedded with sandy shale.

## Calhoun shale

- 1.4 (7) Shale, grey, clayey to silty, unfossiliferous.

Top of Deer Creek limestone.

SECTION 67

Measured along creek bank just south of bridge about one-fourth mile west of Kansas Highway 99, NW $\frac{1}{4}$  sec. 27, T. 31 S., R. 10 E., Elk county, Kansas.

## Topeka limestone

## Holt shale member ?

- 2.7 (1) Limestone and shale, thin, brown to buff, fusulinid bearing limestones interbedded with grey, fossiliferous shale.
- 3.5 (2) Shale, blue-grey; contains a few very thin calcareous plates; highly fossiliferous.
- 1.7 (3) Shale, blue-grey, clayey, fossiliferous.
- 1.3 (4) Shale, blue-grey above to bluish-black below; contains calcareous plates near top and a woody to coaly streak at the bottom.

## Du Bois limestone member ?

- 1.0 (5) Limestone, blue, dense, vertically jointed, weathers into thin slabs; contains Lingula and ostracods.

SECTION 68

Measured along US Highway 160 from top of hill down toward the Santa Fe Railroad crossing, west-center sec. 13, T. 31 S., R. 8 E., Elk county, Kansas.

## Foraker limestone.

## Hughes Creek shale member

- 5.2 (1) Limestone and chert, interbedded blue and grey chert and blue, dense, light grey weathering limestone; abundant fusulinids.
- 5.0 (2) Covered.
- 2.5 (3) Limestone and shale, light brown to grey, coquinoid limestones interbedded with brown shales; fossiliferous throughout.
- 2.4 (4) Shale, brown to buff, calcareous, finely bedded.

- 2.2 (5) Limestone, light blue to grey, thin bedded, highly cherty; both limestone and chert nodules are fossiliferous.
- 2.0 (6) Limestone, one massive bed, blue-grey, dense; contains abundant fusulinds.
- 1.0 (7) Shale, yellow to brown, calcareous; contains abundant fusulinids.
- 1.5 (8) Limestone, blue, hard, weathers yellowish-grey, small blue chert nodules, abundant fusulinids.
- 2.5 (9) Shale, grey to yellowish; contains a few thin limestone stringers; highly fossiliferous.
- 1.5 (10) Limestone and shale, two thin, grey to bluish, hard, dense, buff weathering limestones separated by a thin, grey-brown shale; sparingly fossiliferous.
- 7.2 (11) Shale, bluish to blue-black, finely bedded, platy; with several blue, nodular, limestone stringers; brachiopods common.

Americus limestone member

- 3.6 (12) Limestone, grey-blue, dense, weathers buff to dark grey, silty below, fossiliferous.
- 4.6 (13) Shale, dark blue to almost black, appears almost coaly, weathers light blue; contains a few thin limestone stringers.
- 2.2 (14) Limestone, bluish-grey, massive below, irregular, thin bedded above; contains many small pebbles in the lower part; fossiliferous.

Hamlin shale

Oaks shale member

- 2.7 (15) Shale, grey to yellowish.

Houchen Creek limestone member

- 0.6 (16) Limestone, dark grey, weathers white to buff; with network of calcite veins; "boxwork".

Stine shale member

- 9.0 (17) Covered.

- 1.2 (18) Siltstone, white to grey, irregularly bedded; interbedded with grey shale.
- 1.0 (19) Shale, purple, green and grey, clayey.
- 1.0 (20) Siltstone, dirty, dark grey, veined with calcite, "boxwork".
- 5.0 (21) Shale, varicolored, clayey.
- 1.7 (22) Limestone, yellow, weathers brownish, veined with calcite, "boxwork".
- 3.3 (23) Shale, green; clayey shale above to platy, yellow, silty shale below.
- 4.4 (24) Shale, grey to greenish, clayey.

Five Point limestone

- 1.0 (25) Limestone, one massive bed, dark grey, weathers to grey-buff, fossiliferous; fusulinids common.

West Branch shale

- 3.0 (26) Covered.
- 12.5 (27) Shale, greenish-blue above to grey below; micaceous in part; contains a very thin coaly streak, about 8.0 feet, below the top.
- 2.0 (28) Covered.

Falls City limestone

- 1.8 (29) Limestone, grey to yellowish, vuggy, weathers light brown; some calcite veins present.

Hawxby shale

- 3.0 (30) Sandstone, greenish-grey, micaceous, massive, limonite stains common.
- 5.0 (31) Shale, grey below to greenish and sandy above, streaked with orange, micaceous.

Aspinwall limestone

- 0.7 (32) Limestone, grey, dirty, slabby, weathers to buff-grey, fossiliferous.
- 0.6 (33) Shale, grey.

- 0.8 (34) Limestone, one massive bed, dark brown to chocolate, weathers to cream yellow, brachiopods common.

Towle shale

- 21.0 (35) Shale, dark grey to greenish, clayey; almost all covered.

Top of the Brownville limestone.

### SECTION 69

Measured along US Highway 160 at the junction of the old and new routes, east-center sec. 14, T. 31 S., R. 8 E., Elk county, Kansas.

Red Eagle limestone

Glenrock limestone member

- 6.0 (1) Limestone, irregular bedded, bluish-grey to buff, weathers yellowish grey to white, thin bedded; fossiliferous in the lower part. This exposure represents only the lower part of the Glenrock limestone.

Johnson shale

- 5.8 (2) Limestone and shale, thin, blue, dense, nodular, fossiliferous limestones interbedded with brown, grey, and blue fossiliferous shales.
- 1.9 (3) Limestone, yellow, algal, soft, silty, many calcite veins; "boxwork".
- 4.6 (4) Shale, grey to yellow, clayey; contains many small white algal bodies in the upper part.
- 8.0 (5) Shale, covered.

Foraker limestone

Long Creek limestone member

- 0.9 (6) Limestone, dense, heavy, grey to tan, weathers white to yellow, algal; contains a few small pebbles in lower part.

SECTION 70

Measured along US Highway 160, just west of the Elk county line in SE $\frac{1}{4}$  sec. 16, T. 31 S., R. 8 E., Cowley county, Kansas.

## Crouse limestone

- 5.6 (1) Limestone, thin, irregular bedded; lower part nodular; Ottonosia common; slightly cherty above.

## Easley Creek shale

- 13.3 (2) Shale, brownish above to red below; small white algal knobs common in the upper part of the red portion.

- 43.0 (3) Covered interval.

## Beattie limestone

## Florena shale member

- 11.8 (4) Shale, brown above to grey below, calcareous, very highly fossiliferous; contains several thin, nodular limestones in the upper part.

## Cottonwood limestone member

- 6.0 (5) Limestone and shale, thin, bluish, nodular, fossiliferous limestones interbedded with grey, calcareous shale.

## Eskridge shale

- 7.4 (6) Shale, clayey, grey to brownish above to red below; contains small, white algal bodies.

- 1.0 (7) Limestone, dense, grey to bluish, hard, fine grained, algal.

- 11.9 (8) Shale, red, clayey; mostly covered.

## Grenola limestone

## Neva limestone member

- 15.0 (9) Limestone, massive above to thin bedded below; Paraschwagerina and other fusulinids common; light grey, weathers grey to buff; not well exposed.

- 13.0 (10) Covered.

## Sallyards limestone member

- 3.5 (11) Limestone, dense, bluish-grey, massive, weathers to blue-grey spotted with yellow.

Roca shale

- 14.8 (12) Shale, grey to brownish above to red below, clayey.

Top of Red Eagle limestone.

SECTION 71

Measured along the Santa Fe Railroad in sec. 4, T. 31 S., R. 8 E., Cowley county and sec. 3, T. 31 S., R. 8 E., Elk county, Kansas.

## Beattie limestone

## Morrill limestone member

- 3.2 (1) Limestone, light buff, thin, irregular bedded, chalky, weathers to light grey and white.
- 1.8 (2) Limestone, one massive bed, light buff to bluish, weathers white to grey, pitted, cherty, sparingly fossiliferous.
- 2.0 (3) Limestone, thin, buff, irregular to nodular limestones interbedded with buff, calcareous shales; echinoid spines and Schwagerina common.

## Florena shale member

- 14.0 (4) Shale, grey to buff, highly fossiliferous; contains several thin, nodular limestones in the upper part.

## Cottonwood limestone member

- 4.8 (5) Limestone and shale, blue, dense, thin, slabby limestones interbedded with blue-grey and buff shales; highly fossiliferous.

## Eskridge shale

- 8.0 (6) Shale, grey above to red below, clayey.
- 1.2 (7) Limestone, dense, heavy, purple to greenish, algal; contains a few pelecypods; resistant.

- 7.6 (8) Shale, red to purple above to greenish below, clayey, algal.
- 0.5 (9) Limestone, dense, greenish-grey, weathers light yellow to grey, algal.
- 2.9 (10) Shale, greenish-grey and red, algal.

Grenola limestone

Neva limestone member

- 1.7 (11) Limestone, massive, light grey, weathers dark grey, fossiliferous.
- 2.5 (12) Limestone, nodular, thin bedded, fossiliferous; interbedded with grey, calcareous, fossiliferous shale.
- 1.4 (13) Limestone, light grey, massive; contains large fusulinids.
- 3.3 (14) Limestone, thin bedded, grey, weathers grey-buff, fossiliferous.
- 6.4 (15) Limestone, light buff to grey, massive to thin bedded, somewhat irregular, weathers buff, fusulinids common.
- 5.4 (16) Limestone and shale, interbedded grey to buff, nodular limestones and grey shales; fusulinids common.

20.7  
Salem Point shale member

- 5.1 (17) Shale, grey above to brown below; contains a persistent yellow-brown "boxwork" limestone in the middle; fossiliferous.
- 2.8 (18) Limestone and shale, interbedded, platy, buff, silty, thin, pelecypod bearing limestones and grey shales.

Burr limestone member

- 3.9 (19) Limestone, two very massive beds of dark grey, dark weathering limestones separated by a thin grey shale; ostracods and small gastropods common in upper part of upper bed.

Legion shale member

- 5.0 (20) Shale, grey to buff, finely bedded; with a few thin limestone stringers; sparingly fossiliferous.

## Sallyards limestone member

- 4.0 (21) Limestone, dark grey, platy to irregular bedded, coarsely crystalline; pelecypods common.

## Roca shale

- 14.7 (22) Shale, clayey, red; with numerous algal knobs in the upper part; top grey; base green.

## Red Eagle limestone

## Howe limestone member

- 2.5 (23) Limestone, buff, chalky appearance, sugary, massive bedded; contains many small foraminifera and gastropods; soft.

## Glenrock limestone member

- 16.6 (24) Limestone, grey, coarsely crystalline, weathers grey to buff, massive to thin, irregular bedded; lower part somewhat nodular; jointed.

SECTION 72

Measured along east-west county road in the center of sec. 14, T. 29 S., R. 8 E., Elk county, Kansas.

## Wreford limestone

- 6.0 (1) Limestone, grey, fine grained, brittle, thin irregular bedded, cherty; interbedded with thin beds of chert; sparingly fossiliferous.
- 24 38.0 (2) Covered.

## Funston limestone

- 4.6 (3) Shale, grey to buff, fossiliferous; interbedded with thin, nodular, grey limestones.
- 20 1.9 (4) Limestone, grey to light blue, massive above, porous; lower part darker blue and thin bedded; parts are almost coquina of small gastropods and pelecypods.

## Blue Rapids shale

- 19 5.0 (5) Shale, brown above to green below, clayey.

6.5 (6) Shale, red, clayey, algal; contains a thin, nodular, buff, limestone stringer in upper part.

8.5 (7) Shale, bluish-grey; with a thin, buff "boxwork" limestone and a greenish-grey, silty limestone in the middle.

20.0 Crouse limestone

8.8 (8) Limestone, blue-grey, dense, massive above to thin, nodular below; lower part is more shaly and contains numerous specimens of Ottonosia.

Easy Creek shale

8.0 (9) Shale, brown above to red below; small algal knobs common.

Bader limestone

Middleburg limestone member

4.2 (10) Limestone and shale, grey to greenish, dense, hard, light buff to white weathering limestones interbedded with greenish-grey shales; pelecypods common in the lower part.

Hooser shale member

4.7 (11) Shale, buff to yellow, finely laminated; contains corneous brachiopods.

2.7 (12) Limestone, greenish to blue-green above to blue, purer below, nodular, thin bedded, sparingly fossiliferous; interbedded with buff shales.

4.2 (13) Shale, brown above to red and green below, clayey, algal.

Eiss limestone member

6.3 (14) Limestone and shale, bluish-grey, light grey, weathering, pitted, massive above to nodular below; interbedded with green and red shales; sparingly fossiliferous.

4.5 (15) Shale, light grey, fossiliferous; interbedded with thin, blue limestones.

20  
2.4  
22.7

## Stearns shale

- 5.0 (16) Shale, grey, clayey, fossiliferous.
- 2.7 (17) Limestone, dark grey to bluish, nodular, fossiliferous; interbedded with grey and bluish-grey shale.
- 6.9 (18) Shale, grey to brown above to red below; algal in the lower part.

## Beattie limestone

## Morrill limestone member

- 9.0 (19) Limestone, bluish-grey, weathers to grey-buff, more massive above, pitted, algal; echinoid spines and Schwagerina common.

## Florena shale member

- 9.1 (20) Shale, grey above to bluish below, highly fossiliferous.

## Cottonwood limestone member

- 4.9 (21) Limestone and shale, thin, blue-grey, light grey weathering limestones interbedded with grey shale, fossiliferous.

## Eskridge shale

- 3.7 (22) Shale, grey to brown, clayey.
- 0.8 (23) Limestone, greenish, dense, hard, massive, algal.

SECTION 73

Measured along county road from the top of the high scarp eastward, SW $\frac{1}{4}$  sec. 35, T. 28 S., R. 8 E., Elk county, Kansas.

## Wreford limestone

- 4.0 (1) Limestone, light grey, thin, irregular bedded, cherty; interbedded with thin beds of tan and blue chert.
- 7.0 (2) Limestone, light grey, buff weathering, nodular, very irregular bedded; with occasional blue chert nodules; shaly below; fossiliferous in the lower part.

## Speiser shale

- 8.0 (3) Shale, grey, calcareous; with several thin grey limestone plates in upper part; contains abundant large specimens of Derbya, Juresania, and Composita.
- 11.9 (4) Shale, red to brown above to red, green and white below, algal.

## Funston limestone

- 2.1 (5) Limestone, green to grey, hard, weathers to white and buff; massive above to more finely bedded, blue, and purer below.
- 2.5 (6) Shale, red to purple, clayey, algal.
- 2.8 (7) Limestone, grey-green, dense, weathers buff; interbedded with thin shales; pelecypods common.
- 2.9 (8) Limestone and shale, thin, nodular, buff limestones interbedded with buff to grey shale.
- 1.2 (9) Shale, buff.
- 1.4 (10) Limestone, blue, thin bedded, dense, weathers dark grey to buff, sparingly fossiliferous.

SECTION 74

Measured along county road west of the bridge over the Elk River in SW $\frac{1}{4}$  sec. 31, T. 28 S., R. 9 E., Elk county, Kansas.

## Foraker limestone

## Hughes Creek shale member

Upper part of member not exposed.

- 6.8 (1) Shale, grey to brown; mostly covered.

## Americus limestone member

- 1.6 (2) Limestone, blue, massive, weathers grey, cherty; contains many fusulinids.
- 4.4 (3) Shale, bluish to brown above to yellow below; calcareous plates in lower part.

- 1.4 (4) Limestone, bluish-grey; two massive beds; lower bed more impure with dense, grey pebbles; upper bed contains numerous fusulinds.

Hamlin shale

Oaks shale member

- 6.9 (5) Shale, light brown above to yellow and blue grey below; contains a white to yellowish, algal, dense, nodular limestone about 1.5 feet below the top.
- 0.6 (6) Limestone, hard, dark grey, weathers grey to white.
- 0.5 (7) Shale, grey to greenish-yellow, platy.

Houchen Creek limestone member

- 5.5 (8) Limestone, massive, shaly, soft, buff to orange, calcite veins, "boxwork".

#### SECTION 75

Measured in road cut along US Highway 166, about four miles south and one-half mile west of Dexter, Cowley county, Kansas.

Wreford limestone

Only the lower part of the formation is exposed.

- 0.7 (1) Chert, massive, irregular bed; grey to tan, weathers grey to red; contains a few fossils.
- 0.3 (2) Shale, white to grey, algal.
- 4.0 (3) Limestone, massive, white to grey, weathers light grey; contains abundant grey chert nodules; sparingly fossiliferous.
- 1.4 (4) Shale, buff to grey, platy, calcareous.
- 2.7 (5) Limestone, massive, tends to split into three beds, light grey, weathers grey; contains a few large brachiopods.

Speiser shale

- 3.8 (6) Limestone and shale, thin, nodular, blue-grey limestones interbedded with brown and grey shale; large Derbya, Aviculopinna, Septimyalina, and Juresania are common.

- 19.8 (7) Shale, buff to greenish-grey in the upper few feet to red below; micaceous and sandy with a few lenticular sandstones in the middle; clayey below.
- 2.5 (8) Limestone, very thin, platy, dense, greenish-grey; interbedded with light grey, algal shale.

### SECTION 76

Measured along private ranch road in NW $\frac{1}{4}$  sec. 27, T. 28 S., R. 3 E., Elk county, Kansas.

#### Wreford limestone

Only the lower part of the formation is exposed.

- 7.0 (1) Limestone, light grey, thin bedded, cherty; interbedded with massive, blue, tan weathering, bedded chert; poorly exposed.

#### Speiser shale

- 19.0 (2) Shale, grey to light grey; with several thin, silty, buff limestones in the upper part; Derbya, Juresania, Composita, and Septimyalina common in upper part.

- 10.7 (3) Shale, red, clayey.

#### Funston limestone

- 4.1 (4) Limestone, thin, platy bedded, grey to white, dense; more massive below.
- 5.5 (5) Shale, grey; with two red zones in the middle.
- 2.4 (6) Limestone, blue-green, algal, mottled, dense.

#### Blue Rapids shale

- 2.3 (7) Shale, covered.
- 0.9 (8) Limestone, massive, mottled, silty; contains a few chert nodules.
- 3.7 (9) Shale, blue-grey, clayey; Juresania common.
- 0.5 (10) Limestone, like bed 8 but without chert.
- 4.6 (11) Shale, light grey; contains numerous hard, calcareous plates.

- 4.8 (12) Limestone, dense, blue-grey, massive, weathers to thin plates; not well exposed.
- 8.5 (13) Shale, brown to grey, algal; partially covered.  
Top of the Crouse limestone.

### SECTION 77

Measured along Kansas Highway 96, about 13 miles west of the junctions of Kansas Highways 96 and 99, Greenwood county, Kansas.

Red Eagle limestone

Glenrock limestone member

Only the lower part of the member is exposed.

- 2.0 (1) Limestone, light grey to buff, upper part more massive; echinoid spines and fusulinids are common.
- 0.5 (2) Shale, grey, algal.
- 0.9 (3) Limestone, buff, silty, soft.

Johnson shale

- 22.0 (4) Shale, brown to grey, lower part dark grey, sparingly fossiliferous; partially covered.

Foraker limestone

Long Creek limestone member

- 1.5 (5) Limestone, impure, mottled, grey-brown, weathers buff, irregular to crinkly bedded.
- 1.7 (6) Shale, brown above to dark grey, platy below.
- 1.2 (7) Limestone, massive, dark grey to bluish; veneer of Osagia; fusulinids common.

Hughes Creek shale member

- 6.0 (8) Shale, grey, clayey to platy, fossiliferous; fusulinids often occurring in odd-shaped, rod-like concretionary bodies.

- 12.3 (9) Limestone, light grey, very massive bedded; chert nodules common throughout; fossiliferous, with fusulinids being especially abundant in the lower part.
- 5.0 (10) Shale, brown above to dark grey, calcareous below, highly fossiliferous; three or four thin, fossiliferous, calcareous plates in the middle.
- 1.3 (11) Limestone, dense, massive, blue-grey, sparingly cherty, fossiliferous.
- 2.7 (12) Shale, blue to grey, clayey, abundant bryozoans.
- 1.4 (13) Limestone, grey, massive, fossiliferous; middle part almost a solid bed of blue chert.
- 1.1 (14) Shale, buff to brown; slender fusulinids common.
- 2.7 (15) Limestone, massive, grey; blue chert nodules and fusulinids common.
- 4.2 (16) Shale, blue-grey, clayey; lower part calcareous.

Americus limestone member

- 1.8 (17) Limestone, blue-grey; contains a bed of blue chert in the middle; brachiopods common above; fusulinids common below.
- 0.4 (18) Shale, brown, clayey.
- 2.0 (19) Limestone, massive, blue-grey, abundant small chert nodules throughout, fossiliferous.
- 4.7 (20) Shale, brown, clayey above to bluish, bladed below.
- 2.3 (21) Limestone, dark grey, jointed, sparingly fossiliferous; surface covered with calcite deposited from ground water.

Hamlin shale

Oaks shale member

- 1.5 (22) Shale, light grey, clayey, blocky; with plant remains.
- 0.2 (23) Coal.
- 3.5 (24) Shale, grey to brown, clayey; contains a zone of calcite veins near the top which resemble a "boxwork".

- 0.8 (25) Limestone, buff, silty, soft, limonite spots common; calcite veins present.

SECTION 78

Measured along Kansas Highway 96, about 15 miles west of the junction of Kansas Highways 96 and 99, Greenwood county, Kansas.

Beattie limestone

Morrill limestone member

- 4.5 (1) Limestone, upper part nodular, greenish-grey; lower part dark grey; fossiliferous throughout; small chert nodules common in the middle; echinoid spines and Schwagerina common.

Florena shale member

- 5.8 (2) Shale, brown above to grey below, clayey, fossiliferous.

Cottonwood limestone member

- 4.9 (3) Limestone, dark grey to buff, weathers grey, thin bedded above but massive below; some buff shale along the bedding planes; fossiliferous.

Eskridge shale

- 9.5 (4) Shale, grey to yellowish, clayey, algal.
- 1.0 (5) Limestone, three thin beds; dark grey, hard, dense, yellow stained, sparingly fossiliferous, grey to white weathering.
- 8.2 (6) Shale, greenish-grey in upper few feet to red below, algal.
- 0.8 (7) Limestone, hard, grey-green, dense, heavy, algal.
- 3.2 (8) Shale, grey-green, clayey; algal knobs common.
- 0.3 (9) Limestone, same as bed 7.
- 5.1 (10) Shale, grey-green above to green below, algal; contains two thin, hard, calcareous plates in the middle.

## Grenola limestone

## Neva limestone member

- 2.6 (11) Limestone, very massive, grey; dense and algal above; lower part purer and sparingly fossiliferous; weathers dark grey.
- 1.6 (12) Limestone, buff to yellow, silty, massive, weathers buff to white; echinoid spines and plates common.
- 1.3 (13) Limestone, dark grey to greenish, irregular thin beds; very shaly in part; sparingly fossiliferous.
- 2.1 (14) Shale, grey to brown, clayey.
- 2.2 (15) Limestone, blue, massive; but breaks down into thin plates; soft; abundant Paraschwagerina.
- 2.8 (16) Shale, dark grey, dirty; with occasional hard plates, very abundant fusulinids.
- 2.9 (17) Limestone, three beds of gray to buff limestone separated by thin, buff shales; fusulinids very abundant in lower bed.
- 0.9 (18) Shale, grey, clayey; with abundant fusulinids.
- 2.7 (19) Limestone, dark grey, thin bedded, nodular; with many shale breaks; fusulinids very abundant.

## Salem Point shale member

- 1.9 (20) Shale, grey-buff; badly covered.
- 1.0 (21) Limestone, buff, veined with calcite; "boxwork".
- 2.6 (22) Shale, covered but contains several thin pelecypod bearing, limy plates in the middle.

## Burr limestone member

- 2.4 (23) Limestone, massive, grey to blue, mottled, weathers to thin beds; upper part more buff and silty; middle massive bed contains abundant ostracods, small gastropods, and Osagia.

SECTION 79

Measured along Kansas Highway 96, about 10.5 miles west of the junction of Kansas Highways 96 and 99, Greenwood county, Kansas.

## Foraker limestone

## Americus limestone member

- 2.1 (1) Limestone, dark blue, dense, massive; with abundant blue chert nodules; vertically jointed; fusulinids very common.
- 0.5 (2) Shale, grey to brown, calcareous; fusulinids abundant.
- 2.4 (3) Limestone, like bed 1.
- 1.0 (4) Shale, grey to brown, clayey.
- 3.6 (5) Shale, black to grey, fissile, streaked.
- 1.2 (6) Limestone, light grey to bluish, somewhat lenticular, weathers grey to buff, dense, slightly silty.
- 0.5 (7) Shale, very calcareous, thin, platy, hard; contains streaks of pebble conglomerate; disc shaped algal bodies are present in the upper part.

## Hamlin shale

## Oaks shale member

- 0.9 (8) Shale, dark grey, weathers grey to bluish, somewhat fissile.
- 1.2 (9) Limestone, light grey to almost white, very irregular; concretionary in appearance.
- 1.5 (10) Shale, light grey, finely laminated; with hard plates.
- 1.9 (11) Limestone, light buff, silty, irregular base, iron stained, irregular bedded, calcite veins.
- 2.3 (12) Shale, dark grey with black streaks above; grey, platy and slightly veined with calcite below.

## Houchen Creek limestone member

- 3.4 (13) Limestone, massive, buff, weathers to rich cream yellow, soft, silty; extensive network of calcite veins; "boxwork".

## Stine shale member

- 6.3 (14) Shale, greenish-grey, clayey; with occasional hard, green, micaceous plates.
- 7.4 (15) Shale, greenish-blue to red, clayey; partially covered.
- 8.0 (16) Shale, dark grey to black, finely bedded to fissile.
- 2.4 (17) Shale, grey, blocky.

SECTION 80

Measured just east of the junction of Kansas Highways 15 and 38, north of Dexter, Cowley county, Kansas.

## Wreford limestone

- 3.9 (1) Limestone, light grey, soft, massive in the middle, weathers light grey to almost white; contains numerous grey and tan chert nodules; sparingly fossiliferous.
- 0.7 (2) Shale, grey-brown, dirty, calcareous, platy.
- 5.4 (3) Limestone, light brown to grey; very massive bed which weathers to thin irregular plates; silty; no chert.
- 2.5 (4) Shale, upper part fissile black to dark grey; lower part silty, buff, calcareous.
- 6.0 (5) Limestone, very massive, light grey, soft, algal, sparingly fossiliferous; with a thin blue chert bed just above the base.
- 4.2 (6) Limestone, grey to brown, nodular, weathers to irregular thin plates; contains abundant blue chert nodules; with two thin beds of chert in the middle.
- 0.8 (7) Chert, massive, blue; with irregular top.
- 5.0 (8) Limestone, massive, light brown to grey, sugary texture, abundant blue chert nodules; lower few inches thin bedded and somewhat shaly.

- 3.7 (9) Limestone, blue, massive, weathers brown, a few chert nodules present; shaly zone about 1 foot above the base.

Speiser shale

- 7.0 (10) Limestone and shale, thin, blue limestones interbedded with bluish-grey shale; Juresania, Derbya, and pelecypods common.

### SECTION 81

Measured at the junction of Kansas Highways 15 and 38, north of Dexter, Cowley county, Kansas.

Barneston limestone

Florence limestone member

- 7.8 (1) Limestone, light grey to buff, sugary texture, weathers to dark grey; tan and grey chert nodules abundant; numerous specimens of Pseudoschwagerina and Schwagerina present in the chert.
- 0.8 (2) Shale, grey, nodular, calcareous.
- 1.0 (3) Limestone, light buff to grey, soft, weathers shaly, fossiliferous, small chert nodules present.

Matfield shale

- 1.0 (4) Shale, grey, calcareous.
- 1.2 (5) Limestone, thin bedded, nodular, grey, fossiliferous.
- 1.2 (6) Shale, grey, clayey, fossiliferous.
- 1.8 (7) Limestone, blue, dense; five thin beds, highly fossiliferous.
- 6.8 (8) Shale, dark blue to grey, blocky above to clayey below.
- 14.1 (9) Shale, red, clayey, lower part covered.
- 1.8 (10) Limestone, light green, dense, algal.

SECTION 82

Measured along north-south county road and along stream bed, NW $\frac{1}{4}$  sec. 27, T. 29 S., R. 9 E., Elk county, Kansas.

## Caneyville limestone

## Grayhorse limestone member

- 1.1 (1) Limestone, dark grey, weathers grey to buff, massive but weathers slabby, sandy above; contains many small rounded bodies resembling oolites; Myalina fairly common; cross-bedding suggested.
- 17.0 (2) Shale, blue-grey to buff and grey; clayey above to silty below; fossiliferous in the lower part.

## Nebraska City limestone member

- 0.8 (3) Limestone, massive, sandy, yellow, weathers with a hard crust over the top.

## French Creek shale

- 2.0 (4) Shale, buff to grey, clayey.
- 0.2 (5) Coal.
- 40.0 (6) Sandstone and shale, alternating beds of yellow to grey, sandy to silty shale and massive to thin bedded, reddish to yellow, fine grained sandstone; poorly exposed in the lower part.

## Jim Creek limestone

- 0.8 (7) Limestone, dark blue, dirty, weathers dark grey to purplish; one massive bed; fusulinids and razor clams present.

SECTION 83

Measured along the north and west sides of sec. 11, T. 29 S., R. 9 E., Elk county, Kansas. This section was originally measured by R. C. Moore (1934) and rechecked by the writer in 1949.

## Jim Creek limestone

- 1.0 (1) Limestone, grey, massive, dark grey to purplish weathering; fusulinids rare.

## Friedrich shale

- 6.0 (2) Shale, grey to buff, sandy to silty, partially covered.
- 10.0 (3) Sandstone, massive to thin bedded, grey to buff, fine grained.
- 10.5 (4) Shale, grey to buff, sandy to silty, partially covered.
- 0.4 (5) Limestone, grey, impure, sandy; contains pelecypods.
- 6.7 (6) Shale, grey, silty to sandy.
- 3.0 (7) Sandstone, fine grained, buff to brown.
- 2.0 (8) Shale, grey.

## Grandhaven limestone

- 1.2 (9) Limestone, grey, weathers brown, massive, algal, fossiliferous.
- 11.0 (10) Shale, grey, mostly covered.
- 0.5 (11) Limestone, brown, hard, fine grained; brachiopods common.
- 1.0 (12) Shale, grey to brown, clayey.
- 0.4 (13) Limestone, like bed 11 but contains Crurithyris.

## Dry shale

- 6.0 (14) Shale, grey, silty; contains a thin coal just above the middle; partially covered.

## Dover limestone

- 1.3 (15) Limestone, light grey to bluish, weathers brown, fossiliferous.
- 12.0 (16) Shale, grey, clayey, partially covered.
- 0.9 (17) Limestone, blue-grey, one massive bed, weathers dark grey; contains Ottonosia and slender Triticites.
- 6.0 (18) Shale, grey.

1.2 (19) Limestone, blue-grey, weathers with yellow-brown crust; Chonetes common.

Willard-Langdon shale

2.6 (20) Shale, grey, calcareous; Myalina common.

0.2 (21) Coal.

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